$4 GASOLINE AND FUEL ECONOMY: AUTO INDUSTRY AT A CROSSROADS

HEARING

BEFORE THE

SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

JUNE 26, 2008

Serial No. 110–42

SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING

EDWARD J. MARKEY, Massachusetts, *Chairman*

EARL BLUMENAUER, Oregon
JAY INSLEE, Washington
JOHN B. LARSON, Connecticut
HILDA L. SOLIS, California
STEPHANIE HERSETH SANDLIN,
  South Dakota
EMANUEL CLEAVER, Missouri
JOHN J. HALL, New York
JERRY McNERNEY, California

F. JAMES SENSENBRENNER, JR.,
  Wisconsin, *Ranking Member*
JOHN B. SHADEGG, Arizona
GREG WALDEN, Oregon
CANDICE S. MILLER, Michigan
JOHN SULLIVAN, Oklahoma
MARSHA BLACKBURN, Tennessee

———

PROFESSIONAL STAFF

GERARD J. WALDRON, *Staff Director*
ALIYA BRODSKY, *Chief Clerk*
THOMAS WEIMER, *Minority Staff Director*

C O N T E N T S

$4 GASOLINE AND FUEL ECONOMY: AUTO INDUSTRY AT A CROSSROADS

THURSDAY, JUNE 26, 2008

House of Representatives,
Select Committee on Energy Independence
and Global Warming,
Washington, DC.

The committee met, pursuant to call, at 1:41 p.m. in room 210, Cannon House Office Building, Hon. Edward J. Markey (chairman of the committee) presiding.

Present: Representatives Markey, Inslee, Hall, Blackburn and Miller.

Staff present: Michal Freedhoff.

The CHAIRMAN. This hearing of The Select Committee on Energy Independence and Global Warming is called to order, and we thank everyone for being here.

Every day the news is filled with the stories of how $4-a-gallon gasoline hurts working people in this country. Every day we hear of some new societal impact, some new economic problem, some new forecast of even higher prices yet to come. The skyrocketing price of gas at the pump hits consumers all over the country, and high oil prices also send a shock wave through our economy that hurts businesses and threatens to inflate prices. Most experts do not believe that these prices will come down anytime soon.

We are here today to discuss solutions to this latest energy crisis. Because 70 percent of oil goes into transportation, any solutions to the oil crisis must focus on the transportation sector.

The Bush administration argues that we can drill our way out of this crisis. This is wrong. Forty-five percent of the world's oil is located in Iraq, Iran and Saudi Arabia, and almost two-thirds of known oil reserves are in the Middle East. The United States is home to less than 3 percent of the world's oil reserves, but we consume 25 percent of the world's oil. Sixty percent of the oil that we use every day comes from overseas at an annual cost of hundreds of billions of dollars, much of which ends up in the hands of countries hostile to our interests.

Even if we open the Arctic National Wildlife Refuge and the Atlantic and Pacific coastlines to drilling today, the Energy Department reports that the first drops of oil would not hit consumers' gas tanks for 10 years. Peak production would not occur until 2030, and even then there would be no significant impact on prices at the pump.

America's strength lies not in the size of its oil reserves, but in our superior technological might. Our biggest single step we have

taken to curb our oil dependence is to raise the fuel economy standards of our automotive fleet. When CAFE was first passed in the mid-1970s in response to the first oil crisis, imported oil fell as a percentage of total consumption in the United States from 47 percent in 1977 to 27 percent in 1985. And last December, after my efforts in 2001, 2003, 2005 and 2006 were blocked, Congress passed the first mandated increase in fuel economy standards since 1975, requiring that the fleet of cars and light trucks average at least 35 miles per gallon by 2020. This will save at least 2.5 million barrels of oil per day by the year 2030, when our entire fleet will have turned over. It will save consumers billions of dollars in gasoline they will not have to buy.

Today the Department of Transportation, charged with implementing the energy bill, will discuss its proposal to increase the fleet fuel economy average to 31.6 miles per gallon by 2015. A major flaw in its analysis is that it uses outdated Energy Information Agency assumptions about gas prices that simply defy reality. At a time when gasoline prices are soaring well above $4 per gallon, almost $1 more than when we passed the energy bill just in December, NHTSA and the Energy Information Agency, that is the Department of Transportation and the Department of Energy, mid-range forecast for gasoline prices that range from $2.42 a gallon in 2016 to $2.51 a gallon in 2030.

When compared to today's prices at the pump, these numbers are nothing short of absurd, especially absurd in terms of what we should be planning for as a country technologically in terms of the vehicles which we drive. Buried at the back of its very long technical analysis, NHTSA documents the results of using EIA's high-price gasoline projection of 3.14 in 2016 to 3.74 a gallon in 2030 and found that technology is available to cost-effectively achieve a much higher fleetwide fuel economy of nearly 35 miles per gallon by 2015.

On June 11th, Guy Caruso, Administrator of the Energy Information Agency, told this committee that he agreed that NHTSA should use EIA's high-gas-price scenario in setting its final fuel economy standards. I agree and have been joined by dozens of my colleagues, sending a letter encouraging the Department of Transportation to do so. I look forward to hearing the Department's views on this and other aspects of its proposal.

We are also fortunate today to have with us some participants in the next generation of automotive technology development. Making cars and light trucks use less oil is enormously important, but ultimately to address our energy security and global warming challenges, we will need to develop vehicles that use no oil at all. Our second panel of witnesses will show us one way of getting to that better place.

I thank you all for coming here today, and now I turn and recognize the Ranking Member of the select committee, the gentleman from Wisconsin Mr. Sensenbrenner.

[The information follows:]

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Opening Statement for Edward J. Markey (D-MA)
"$4 Gasoline and Fuel Economy: Auto Industry at a Crossroads"
Select Committee on Energy Independence and Global Warming
June 26, 2008

This hearing is called to order.

Every day, the news is filled with the stories of how $4 a gallon gasoline hurts working people in this country. Every day we hear of some new societal impact, some new economic problem, some new forecast of even higher prices yet to come.

The skyrocketing price of gas at the pump hits consumers all over the country, and high oil prices also send a shock wave through our economy that hurts businesses and threatens to inflate prices. Most experts do not believe that these prices will come down any time soon.

We are here today to discuss solutions to this latest energy crisis. Because seventy percent of oil goes into transportation, any solutions to the oil crisis must focus on the transportation sector.

The Bush Administration argues that we can drill our way out of this crisis. They are wrong.

Forty-five percent of the world's oil is located in Iraq, Iran and Saudi Arabia – and almost two-thirds of known oil reserves are in the Middle East. The United States is home to less than 3% of the world's oil reserves – but consumes 25% of the world's oil.

60% of the oil we use each day comes from overseas, at an annual cost of hundreds of billions of dollars, much of which ends up in the hands of countries hostile to our interests.

Even if we opened the Arctic National Wildlife Refuge and the Atlantic and Pacific coastlines to drilling today, the Energy Department reports that the first drops of oil would not hit consumers' gas tanks for 10 years, peak production would not occur until 2030, and even then, there would be no significant impact on prices at the pump.

America's strength lies not in the size of our oil reserves, but in our superior technological might. The biggest single step we have taken to curb our oil dependence is to raise the fuel economy standards of our automotive fleet. When CAFE was first passed in the mid-1970s in response to the first oil crisis, imported oil fell as a percentage of total consumption in the U.S. from 47 percent in 1977 to 27 percent in 1985.

And last December, after my efforts in 2001, 2003, 2005 and 2006 were blocked, Congress passed the first mandated increase in fuel economy standards since 1975, requiring that the fleet of cars and light trucks average *at least* 35 miles per gallon by 2020. This will save us at least 2.5 million barrels of oil per day by 2030, and will save consumers *billions of dollars* in gasoline they will not have to buy.

Today the Department of Transportation, charged with implanting the Energy Bill, will discuss its proposal to increase the fleet fuel economy average to 31.6 miles per gallon by 2015. A major flaw in its analysis is that it uses outdated EIA

assumptions about gas prices that simply defy reality. At a time when gasoline prices are soaring well above $4 per gallon – almost a dollar more than when we passed the Energy Bill - NHTSA used EIA's 2008 mid-range forecast for gasoline prices that range from $2.42/gallon in 2016 to $2.51/gallon in 2030. When compared to today's price at the pump, these numbers are nothing short of absurd.

Buried at the back of its very long technical analysis, NHTSA documents the results of using EIA's high-price gasoline projection of $3.14/gallon in 2016 to $3.74/gallon in 2030 – and found that technology is available to cost-effectively achieve a much higher fleet wide fuel economy of nearly 35 mpg in 2015.

On June 11, Guy Caruso, Administrator of EIA, told this Committee that he agreed NHTSA should use EIA's *high* gas price scenario in setting its final fuel economy standards. I agree – and have been joined by dozens of my colleagues today in sending a letter encouraging the Department of Transportation to do so. I look forward to hearing the Department's views on this and other aspects of its proposal.

We are also fortunate today to have with us some participants in the next generation of automotive technology development. Making cars and light trucks use less oil is enormously important – but ultimately, to address both our energy security and global warming challenges, we will need to develop vehicles that use *no oil at all.* Our second panel of witnesses will show us one way of getting to that "Better Place."

I thank you all for coming, and look forward to hearing from our witnesses.

Mr. SENSENBRENNER. Thank you very much, Mr. Chairman. Your opening comments have inspired me so much, that rather than reading off the prepared statement that the staff has prepared for me to say, I am going to ask unanimous consent to put in it the record, and I will respond to my friend, the Chairman, extemporaneously.

The CHAIRMAN. Without objection.

Mr. SENSENBRENNER. The topic of this hearing, $4 gasoline and fuel economy, I think is symptomatic of why we have a problem in this country. We have $4-a-gallon gasoline today because we have deliberately not exploited our domestic resources. And while I am the first to say that we can't drill our way out of high gas prices, locking up all of our domestic resources and not wanting to drill practically anywhere where it is economically feasible has contributed to the high gas prices.

And while it will probably take 10 to 20 years for us to fully benefit from drilling in the Outer Continental Shelf and other places, and we started that 10 or 20 years ago, maybe we wouldn't be about in the pickle that we are in today and our constituents and consumers are having to suffer the cost of the high gas prices.

Now, overlaying all of this is the increase in the CAFE standards that the Chairman is very proud of. Listening to what he said today, when CAFE was first passed in 1975, we saw a huge decrease in the percentage of imported oil. Well, what has happened is that we passed CAFE; the percentage of imported oil has gone up, and meantime the Majority party two or three times has passed legislation that actually repeals the domestic production tax credit for developing domestic resources, which means it is cheaper for oil companies to buy more oil overseas.

Now, the result of all of this is starting to show up in lost jobs and lost good-paying jobs. The major employer in Jamesville, Wisconsin, is General Motors. They make SUVs there. They are highly skilled, highly paid members of the United Auto Workers that will be losing their jobs between now and 2010 because GM has decided that the market is not going to support having a full-fledged production facility for SUV vehicles which are made in Jamesville, Wisconsin. All of these people are going to lose their jobs, and they are going to lose their jobs because of the short-sightedness of the people who say we can't drill, we ought to increase taxes on domestic production of oil, we ought to raise CAFE standards so that these types of vehicles cannot meet them, and effectively are legislating themselves out of the market. This is the type of attitude where people go around saying Congress knows best, and we know what is good for you, rather than you know what is good for yourself in deciding how you are going to spend your dollars.

Now, I guess I am particularly disturbed, given what has happened in Wisconsin. We have big GM plant closing and a lot of UAW members being thrown out of work. With all due respect to my colleague from Nashville Mrs. Blackburn, that we invite somebody from Nissan here to talk about this. Nissan is a Japanese company, and it seems to me if we want to keep production in the United States, and we want those profits to be patriated in the United States rather than being sent to a foreign country, we ought to be working with General Motors and Chrysler and with Ford to

developing solutions rather than providing a forum for a representative of a Japanese company.

Now, there are all kinds of solutions that are on the table. Of one of the solutions that we have been discussing in this committee is cap and tax, and that is what it is, because it will be a tax on fossil fuel energy production, whether it is electricity, whether it is gasoline or whether it is natural gas.

There have been several economic studies that the Lieberman-Warner and the Markey bills, which impose a cap-and-tax regime, will increase the cost of gasoline by 150 percent, plus or minus. That is a $10-a-gallon cost for gas, and that is assuming that there is no inflation that will take place over the period of time that the study runs.

If we all think our constituents are having a bad time at $4-a-gallon gas, imagine the consequences of $10-a-gallon gas, because raising the price of gas is a regressive way of raising money, whether it is through cap and tax or whether it is through market economics.

So the solution that is being proposed on the other side is unacceptable. It is one that will really dislocate the American economy, and particularly poor people who have to commute to go to and from work. These are bad solutions. And no wonder the United Auto Workers and the United Mine Workers have come out against both the Lieberman-Warner bill and the Markey bill, which will effectively put their businesses and their workers, who are mostly Democratic voters I might add, out of jobs and out of business.

So let us start using market economics rather than having hearings complaining about $4 gas, because what is being proposed on the other side is going to raise that 150 percent.

I yield back.

Mr. INSLEE [presiding]. The new Chair will recognize himself for 5 minutes.

I think the discussion we are having is obviously healthy with the pickle we are in, and I think there are two fundamental different routes that we are discussing. One is a route where we remain addicted exclusively to oil for our transportation purposes, and we do not use the scientific technological advances for efficiency in making them efficient. That is a status quo route, and it is one largely advocated by many of my colleagues across the aisle.

The alternative route is to be one that looks to give Americans alternatives to oil so that we can once and for all break the addiction to oil that we suffer from and the monopoly we have from the oil and gas industry when we pull up to the pump. And while we are doing that, we use the new scientific technologies to make our cars that do run on oil, which they are going to do for decades because that is the dominant fuel force and will be for a decade or two—that we use cars that are more efficient.

That is the fundamental two tracks that we were on. I want to suggest the second track is the preferred one for two reasons. One, if you look at what can actually deliver for the American people, we know one thing cannot deliver, and we know one thing that can deliver. We know one thing that cannot deliver, which is relying exclusively on domestic drilling. The reason we know that is that the dinosaurs, for reasons that escape all of us, decided to go die

under somebody else's sand. The oil is not here. There are more dinosaur theme parks as a percentage of theme parks in the world than there are oil reserves in our domestic country relative to world oil reserves.

Now, this isn't a theory or a hypothesis or Democratic Communist thought, it is a simple fact of geology. We have 25 percent of the world's usage, and we have 3 percent or less of all the reserves. If you drill—this is according to George Bush's administration. If you drill in Yellowstone, Mount Rainier and the South Lawn of the White House, you will not increase world oil reserves by more than 1 percent, and it will take you a decade to do it. That route is doomed to failure to have any significant restraint on oil prices, any significant increase in our oil independence or any reduction of global warming gases.

There is another route that is capable of success. The first is to do the obvious things, which are to manufacture cars that use existing oil drivetrains. They are more efficient. I talked to Jimmy Carter a couple years ago about this, and he pointed out something that I thought was kind of interesting. Talk about lost opportunities, if we had simply continued the rate of increase of gas mileage we were having from 1976 to 1982, if we simply had continued the path we were on, we would be free of Saudi Arabia oil today.

Now, if we would have drilled in Mount Rainier National Park and the South Lawn of the White House, we would still be addicted to Saudi Arabia oil today. But if we had simply had CAFE standards during that period of time, we would have been free from Saudi Arabia oil today. That is number one.

The second, and more importantly—and we will hear some testimony from Shai Agassi and others here today about the possibilities and, I believe, probabilities that within the next decade or two Americans will be freed from the addiction to oil with a new technologies. Anybody want to know this and question me go up to Watertown, Massachusetts, and talk to the A 123 Battery Company, that I did, that is going to provide the battery for the Chevrolet Volt. If anybody doesn't think Chevrolet is serious about that, read the article in the Atlantic Monthly. If anybody doesn't think there is advanced biofuels that are possible on this, go talk to the venture capitalists who just put $50 million in the Sapphire Energy Company to produce gasoline, ATSM-certified gasoline, from algae without feeding it any sugar whatsoever, simply using photosynthesis.

So we simply suggest on this side that when President Bush said 2 years ago in a stunning statement for a Texas oilman, he said, we are addicted to oil, it was good for him to say that. It was not so hot when last week he came out and said, and, my fellow citizens, since we are addicted to oil, let us get more addicted. Let us go back and ask the pusher for just one more needle, and that is going to solve our problem.

We think bolder on this side of this aisle. We think a bolder vision that ought to break this monopoly and give Americans a choice. When we do that, prices are going to come down, and we are going to be more secure and have a chance to beat global warming. That is the future we ought to have.

I yield back.

Mrs. Miller.

Mrs. MILLER. Thank you. Mr. Chairman, I am delighted to be at this hearing as we talk about how we implement the fuel economy standards or examine the recently proposed CAFE standards proposed by NHTSA. I certainly look forward to hearing from our panel. In fact, I principally sought a seat on this committee because I wanted to be a very strong advocate for the domestic auto industry, obviously, in full disclosure, being from Michigan. I think we should take a moment to consider the entire history of this cornerstone industry and really what it has meant for our Nation as well.

In fact, during World War II southeast Michigan was known as the arsenal of democracy because we had the manufacturing capability that literally built the armaments that led the world to peace, I believe, keep our Nation free. There were 2 years during that time when the domestic autos didn't even build cars because they were so busy building airplanes, jeeps, tanks. We were fully engaged in the war effort, protecting freedom, liberty and democracy. In fact, the domestic auto industry, I believe, absolutely helped to create—in fact, did create—the middle class in States like mine in Michigan and others as well.

And then after 9/11, let us not forget the domestic autos immediately offered zero-interest financing, which kept plants running, and people kept buying cars, and our citizens were employed so that our national economy did not implode as the terrorists had hoped.

And yet in spite of this very proud history of the domestic auto industry, it seems sometimes to us in Michigan and other areas that hosted domestic autos that many in this Congress seem to be focused on bankrupting the domestic auto industry and losing American jobs.

Now, of course, Congress has passed and the President has signed what amounts to an $85 billion mandate on the domestic autos; that is, $85 billion now that is mandated in this industry, in an industry that is absolutely literally struggling to survive right now. This is money that has to be spent by the Big 3 over the next decade just to achieve the mandate that has been set forth in the law.

And as has been mentioned already, the CAFE standards were set in place in 1973. They have not only devastated the American auto manufacturer, but they have done nothing—most importantly, they have done nothing to decrease our Nation's dependence on foreign oil. When they were first established, the CAFE standards, the U.S. relied on—about 30 percent of our oil was imported from foreign sources, and now that number is closer to 60 percent. So I am not sure that anyone could really say with a straight face that Congress has helped here.

And for the past 30 years, critics of the domestic auto industry have put forth CAFE as the simple solution to limit America's demand for foreign sources of oil. I think all CAFE has really done is put on the brakes on innovation, because we agree that we have to get off of oil. But we should be, I think, as a government and a Nation incentivizing the domestic auto industry rather than mandates that cost literally hundreds of billions of dollars to comply with. I think we should be encouraging them to invest in new tech-

nology, such as the lithium ion battery and other biodiesels, rather than mandating expenditures on very old and antiquated technology, and I think it is stifling American innovation.

And as has been mentioned, we will be hearing from a Japanese company. I think it is of note that the Japanese Government spends a lot of money on incentivizing their companies not only for their automobiles, but for their electronics, for everything with lithium ion batteries and R&D strategies. Instead we expect are our industry to shoulder all of that on itself while we continue to mandate, as I say, for very old technology.

Again, I thank the Chairman for calling the hearing. I certainly look forward to hearing from all the witnesses.

I yield back the balance of my time. Thank you.

Mr. INSLEE. Thank you.

Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman.

I regret that my colleague from Michigan feels that some of us on this side of the aisle are out to get the American domestic auto industry. Myself, I drive a Mercury Mariner hybrid and my wife drives a Chevrolet. I could have gotten better mileage had I gone for a Prius. It would have been a little bit of a waiting time involved. In fact, I understand from the literature before us that the average time a Prius spends on the lot is 17 hours right now. They sell as quick as they can make them.

Some of the problem here is, unfortunately, that the CEOs and executives of the auto industries didn't talk to their workers. I know that by talking to the workers myself. And had they done so, they might have known not to concentrate so much on big, heavy vehicles where the profit margin was maybe a little bit bigger, and advertise such ridiculous things as driving an SUV up to the top of a mountain and playing Frisbee across to another mountaintop, and then showing that this four-wheeler could do that and advertising power.

To this day, to this day, power and speed. When I have watched TV and see the advertising that is going on, it is starting to change, but I think that you can't judge the recent CAFE standard increase that was signed into law that we passed and was signed into law just last December—and it is not supposed to fully take effect until 2020—you certainly can't blame that for the gas prices of today. I think what you can blame is the lack of doing anything like that for the last 32 years.

Sometimes government needs to act to try to help the national interest when market forces or corporate interests don't do so, when they diverge from the natural interests. I think the same goes with oil. The Ranking Member was talking about the need to open up land for drilling. Well, we have got 68 million acres of land, mostly public land, that is open on national lands, onshore and offshore, leased already by the oil companies, environmental studies done, ready for a drill bit to go into the ground, and they are not doing it. Well, why? At the same time asking us to open up more land and open up the Arctic preserve and so on. I would prefer to see those 68 million acres drilled on, but I suspect the reason that they are not being drilled on is because the oil is worth more left in the ground. So once again it may be necessary for the

government to do something like they use it or lose it proposal, which I think we will be discussing later this week, to change the interest and to incentivize the oil companies to actually pump oil out of lands they have already acquired the rights to.

I will enter my written statement into the record and yield back.

Mr. INSLEE. Thank you.

Mrs. Blackburn.

Mrs. BLACKBURN. Thank you, Mr. Chairman.

What a feisty discussion we are having through our opening statements today. I want to thank you for the hearing. I want to welcome all of our witnesses. We are delighted that you are here, and we are looking forward to hearing from you as we work on the issue of gas prices and the auto industry.

And I want to particularly introduce a member of the second panel, Mr. Thormann, who is from Nissan North America and is one of my constituents, and is one of our very proud Tennessee companies. We are delighted that he is here.

We also know—and I hope he is going to talk a little bit today about the innovation that is being done on electric cars and good work that is being done by American engineers who are located in my district who are finding answers to all of these questions that obviously past Congresses have felt were insurmountable. You can go back to the Jimmy Carter era and go back to 1977 and look at what started happening with the EPA. You can look in the 1990s when Clinton vetoed drilling in ANWR, and Vice President Gore decided that the EPA needed to have even more ability to restrict American supply and focus on those items from the past.

Today let us put our attention on what American innovators are doing to solve this problem and some of the work that is taking place with electric vehicles. And I hope that my colleagues will join me and say if we are going to do this, if this is going to be an option, then it behooves Congress to take a serious look with how we improve the electric power grid in this Nation. Are we going to consider nuclear, which works well in my area? What are we going to see happen in other areas?

This is not a time for bickering, it is a time for action. We are going to have a panel before us who can help address this. I hope that we will welcome them, that we will listen attentively, and that we will put our focus on solving this problem. And I yield back.

Mr. INSLEE. Thank you.

We will start with our witnesses. Tyler Duvall is Assistant Secretary for Transportation Policy and acting Under Secretary for Policy at the United States Department of Transportation. He has been working in the development of transportation policy, has held the title for the past 2 years. He is a business and finance associate for 4 years at Hogan & Hartson, and he has a B.A. in economics, Washington and Lee University; J.D. from the University of Virginia.

Mr. Duvall, thank you for joining us.

STATEMENT OF TYLER DUVALL, ASSISTANT SECRETARY FOR POLICY, DEPARTMENT OF TRANSPORTATION; ACCOMPANIED BY STEVE KRATZKE, NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Mr. DUVALL. Thank you, Mr. Chairman, members of committee. I appreciate the opportunity to appear before you to discuss the Department's proposal to substantially increase fuel economy standards.

To my right is Steve Kratzke, who is one of the leading experts on fuel economy in the United States, a technical expert and available for in-the-weeds questioning.

A key component of the President's 2010 proposal was a significant increase in fuel economy standards for cars and light trucks. By increasing standards beginning in model year 2010 for cars and in model year 2012 for light trucks, the President's aggressive proposal was projected to save up to 8.5 billion gallons of gasoline in 2017 alone and reduce consumption by 5 percent.

Through the leadership of many of you on this committee, Congress opened the way last December to further increases in those standards, including in the car standards, when it enacted the Energy Information and Security Act. That legislation provided the framework for the first meaningful increases in fuel economy standards in decades.

The proposed standards would increase fuel economy 4.5 percent per year over the 5-year period ending in 2015. This rate substantially exceeds not only the 3.3 percent needed on average to meet the 35-mile-per-gallon minimum established by Congress last year, but also the 4 percent per year increase called for in the President's 2010 proposal. We estimate achieving these levels of fuel economy would require nearly $50 billion of investments in fuel-saving technologies through 2015.

These standards are tough, but achievable and necessary. All told, the proposal will save nearly 55 billion gallons of fuel and reduction in carbon dioxide emissions estimated at 521 million metric tons over the life of the affected vehicles.

In addition to the rulemaking, the Department delivered to EPA about an hour ago a Draft Environmental Impact Statement. We expect that that statement will be published by EPA on July 3rd. I have a copy here for the record and available for public comment. In the meantime, it will be on our Web site. And, Mr. Chairman, the copy of the EIS, as I said, will be submitted for the record right now.

[The information follows:]

Draft Environmental Impact Statement
Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015

June 2008

★★★★★
NHTSA
www.nhtsa.gov

Deputy Administrator

1200 New Jersey Avenue SE.
Washington, DC 20590

JUN 2 4 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

★★★★★
NHTSA
www.nhtsa.gov

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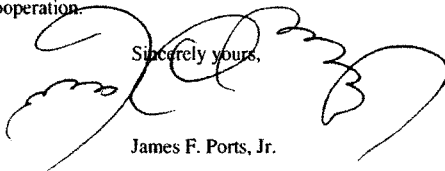
DOT Library, W12-300
1200 New Jersey Avenue, SE
West Building
Washington, DC 20590

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.

1 # SUMMARY

2 ## FOREWORD

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

12 ## BACKGROUND

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

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

24 ## PURPOSE AND NEED FOR THE PROPOSED ACTION

25   EISA sets forth extensive requirements for the proposed rulemaking and these requirements form
26 the purpose of and need for the proposed standards. These requirements also serve as the basis for
27 establishing a range of alternatives to be considered in this DEIS. Specifically, EPCA requires the
28 Secretary of Transportation to establish average fuel economy standards for each model year at least 18
29 months before the beginning of that model year and to set them at "the maximum feasible average fuel
30 economy level that the Secretary decides the manufacturers can achieve in that model year." When setting
31 "maximum feasible" fuel economy standards, the Secretary is required to "consider technological
32 feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel
33 economy, and the need of the United States to conserve energy." NHTSA construes the statutory factors
34 as including environmental issues and permitting the consideration of other relevant societal issues such
35 as safety. The purpose of this DEIS, is to analyze the potential environmental impacts of the proposed
36 action and its alternatives.

37   EPCA further directs the Secretary, after consultation with the Secretary of Energy and the
38 Administrator of the Environmental Protection Agency (EPA), to establish separate average fuel economy
39 standards for passenger cars and for light trucks manufactured in each model year beginning with MY
40 2011, "to achieve a combined fuel economy average for MY 2020 of at least 35 miles per gallon for the

---

[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.

1 total fleet of passenger and non-passenger automobiles manufactured for sale in the United States for that
2 model year." In doing so, the Secretary of Transportation is to adopt "annual fuel economy standard
3 increases," but in any single rulemaking, standards may be established for not more than five model
4 years. This DEIS covers the initial 5-year rulemaking and also considers the cumulative impacts of
5 reaching the 35 miles per gallon (mpg) total fleet requirement during the second 5-year period, MY 2015-
6 2020.

7 **ALTERNATIVES**

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

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

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

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

1

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

2

3 **POTENTIAL ENVIRONMENTAL CONSEQUENCES**
4
5   The DEIS describes potential environmental impacts to a variety of resources. The impact areas
6 that warrant the most detailed analysis are energy resources, air quality, and climate – as well as resources
7 that may be impacted by changes in climate. Tables S-2 through S-14 and Figures S-1 through S-6 below
8 summarize the direct, indirect, and cumulative effects of the CAFE alternatives on energy, air quality, and
9 climate. In regard to global climate change issues, NHTSA recognizes the national interest in global
10 climate change issues, particularly as they relate to the country's use of automobiles and light trucks.
11 "Global climate change" refers to long-term fluctuations in global surface temperatures, precipitation, sea
12 levels, cloud cover, ocean temperatures and currents, and other climatic conditions. Scientific research
13 has shown that in the past century, the earth's surface temperature has risen by an average of about 1.3
14 degrees Fahrenheit (°F) (0.74 °Celsius [C]) and sea levels have risen 6.7 inches (0.17 meters).

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

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

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

---

[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.

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

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

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

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

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

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

---

[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.

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

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

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

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

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

1 among the CAFE alternatives, but rather provides a qualitative review of the benefits of reducing GHG
2 emissions and the magnitude of the risks involved in climate change.[7]

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

21 **Direct and Indirect Effects**

22 **Energy**

23   Table S-2 shows the impact on fuel consumption for passenger cars and light trucks from 2020
24 through 2060[8], a period in which an increasing volume of the fleet will be MY 2011-2015 vehicles. The
25 table shows total fuel consumption (both gasoline and diesel) under the No Action Alternative and the six
26 action alternative scenarios. Fuel consumption under the No Action Alternative is 256.9 billion gallons in
27 2060. Consumption falls under to 228.5 billion gallons under the Optimized Alternative and would fall to
28 208.1 billion gallons under the Technology Exhaustion Alternative.

---

[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.

1

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

2

3 **Air Quality**

4   Table S-3 summarizes the total national criteria and air toxic pollutant emissions in 2035 for the
5 seven alternatives, presented in left-to-right order of increasing fuel economy requirements. The No
6 Action Alternative has the highest emissions of all the alternatives for all air pollutants except acrolein,
7 which increases with the action alternatives because upstream emissions data were not available
8 (emissions for acrolein reflect only increases due to the rebound effect). Localized increases in criteria
9 and toxic air pollutant emissions could occur in some non-attainment areas as a result of implementation
10 of the CAFE standards under the alternatives. These localized increases represent a slight decline in the
11 rate of reductions being achieved by implementation of Clean Air Act standards. Under the No Action
12 alternative, CO_2 emissions and energy consumption would continue to increase; thus the proposed
13 standard has a beneficial effect that would not need mitigation. The Federal Highway Administration
14 (FHWA) has funds dedicated to the reduction of air pollutants in nonattainment areas providing state and
15 local authorities the ability to mitigate for the localized increases in criteria and toxic air pollutants in
16 nonattainment areas that would be observed under the proposed standard. Further, EPA has authority to
17 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

---

[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.

---

[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 (°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 (°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

---

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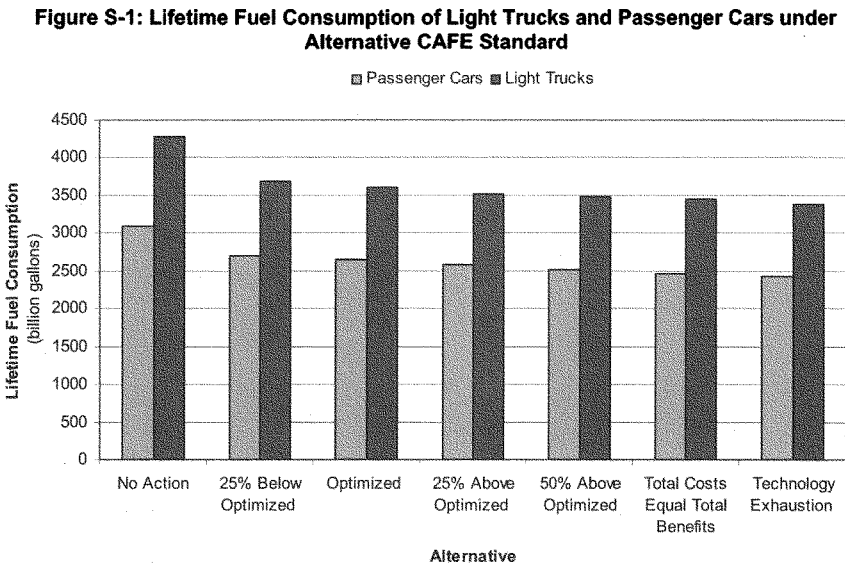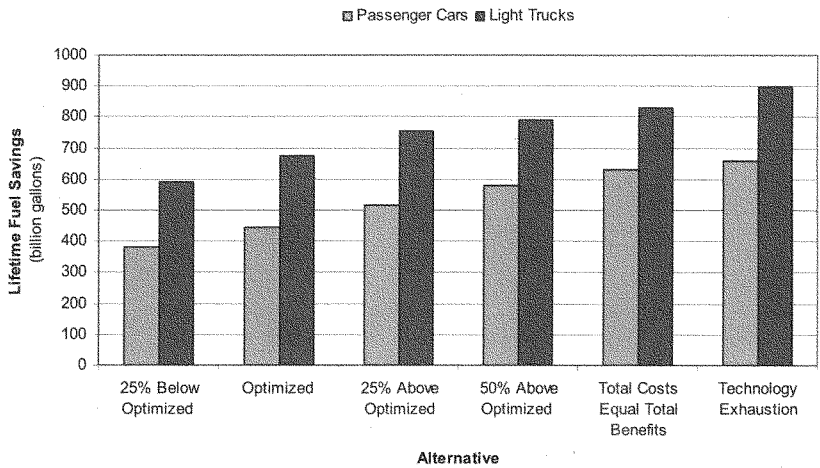
Figure S-1: Lifetime Fuel Consumption of Light Trucks and Passenger Cars under Alternative CAFE Standard

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 (°C)		
	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

---

[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
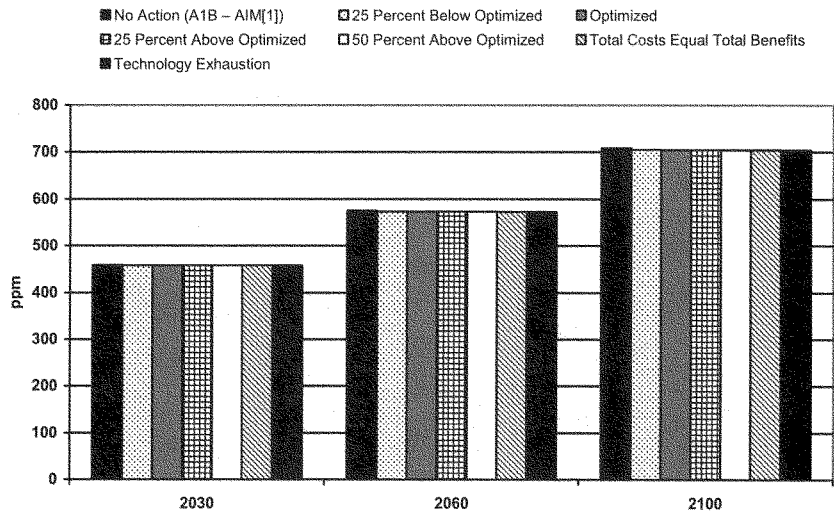
■ No Action (A1B – AIM[1])   ▨ 25 Percent Below Optimized   ▩ Optimized
▤ 25 Percent Above Optimized   ▢ 50 Percent Above Optimized   ▨ Total Costs Equal Total Benefits
■ Technology Exhaustion

Figure S-4: Increase in Global Mean Surface Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020
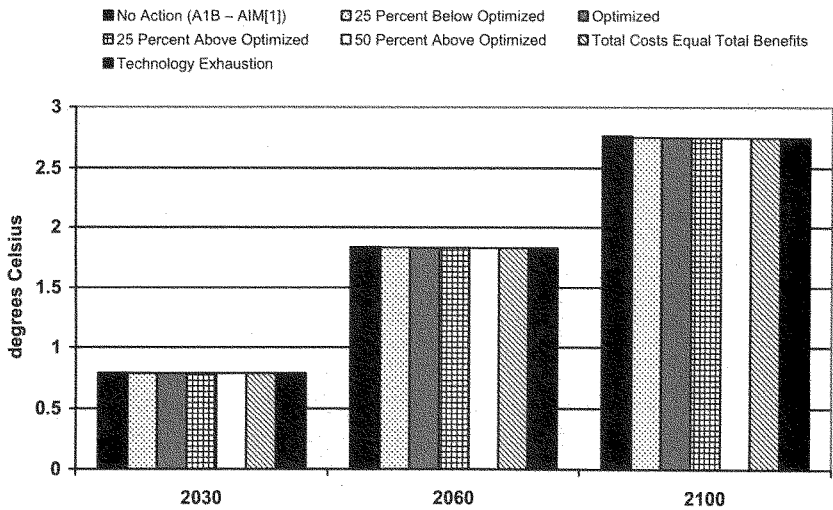
■ No Action (A1B – AIM[1])   ▨ 25 Percent Below Optimized   ▩ Optimized
▤ 25 Percent Above Optimized   ▢ 50 Percent Above Optimized   ▨ Total Costs Equal Total Benefits
■ Technology Exhaustion

Figure S-5: Reduction in the Growth of CO2 Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020
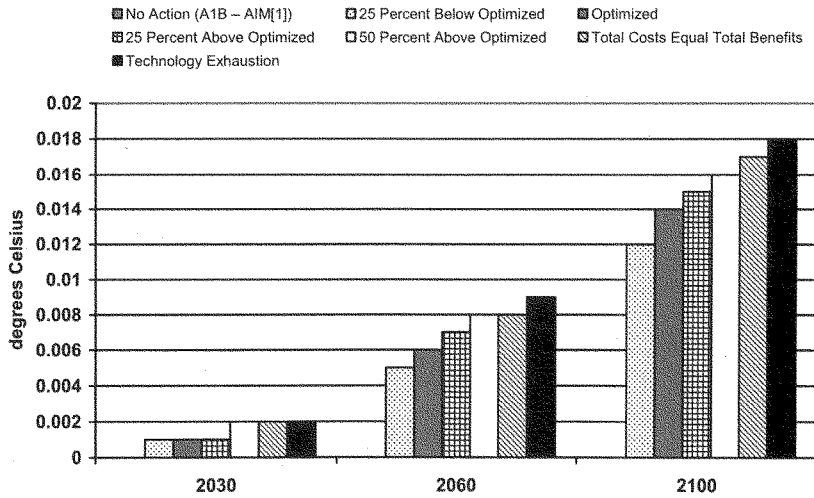
No Action (A1B – AIM[1])   25 Percent Below Optimized   Optimized
25 Percent Above Optimized   50 Percent Above Optimized   Total Costs Equal Total Benefits
Technology Exhaustion
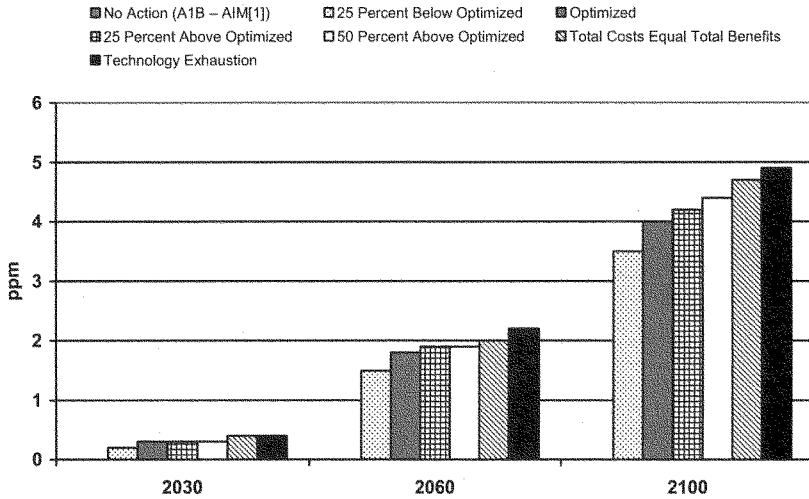
Figure S-6: Reduction in the Growth of Global Mean Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020

No Action (A1B – AIM[1])   25 Percent Below Optimized   Optimized
25 Percent Above Optimized   50 Percent Above Optimized   Total Costs Equal Total Benefits
Technology Exhaustion

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 (°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 (°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 °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	2.640	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.

---

[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.

Table of Contents

45

List of Appendices

The appendices to this Draft Environmental Impact Statement (DEIS) have been provided electronically on the accompanying CD.

Appendix A   Sources Identified in Scoping Comments
Appendix B   Modeling Data
                B-1   Air Emissions Modeling Data
                B-2   Climate Modeling Data
Appendix C   Cost Benefit Analysis Excerpt from the Preliminary Regulatory Impact Analysis

46

List of Tables

48

49

List of Figures

50

List of Acronyms and Abbreviations

µg/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$_2$O	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
WGI	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 Niño-Southern Oscillation	The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and 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.

1 Chapter 1 Purpose and Need for the Proposed Action

2 1.1 INTRODUCTION

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

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

16 Under the National Environmental Policy Act[6] (NEPA), an environmental impact analysis must
17 be performed if a federal agency implements a proposed action, provides funding for an action, or issues a
18 permit for that action. Specifically, NEPA directs that "to the fullest extent possible," federal agencies
19 proposing "major federal actions significantly affecting the quality of the human environment" must
20 prepare "a detailed statement" on the environmental impacts of the proposed action (including
21 alternatives to the proposed action). NHTSA submits this Draft Environmental Impact Statement (DEIS)
22 to inform its evaluation of the potential environmental impacts of adopting CAFE standards for MY
23 2011-2015.

24 1.2 NEPA PROCESS

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

---

[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).

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

5   1.3   PURPOSE AND NEED STATEMENT

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

10   As recently amended, EPCA sets forth extensive requirements concerning the rulemaking to
11   establish the MY 2011-2015 CAFE standards. These requirements form the purpose of and need for the
12   proposed standards (action). These requirements are also the basis for establishing a range of alternatives
13   to be considered in this NEPA analysis. Specifically, EPCA requires the Secretary of Transportation to
14   establish average fuel economy standards for each MY at least 18 months before the beginning of that
15   model year and to set them at "the maximum feasible average fuel economy level that the Secretary
16   decides the manufacturers can achieve in that model year." When setting "maximum feasible" fuel
17   economy standards, the Secretary is required to "consider technological feasibility, economic
18   practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the
19   need of the United States to conserve energy."[8] As explained in the NPRM:

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

23   •   "Economic practicability" means whether a standard is one "within the financial capability of
24   the industry, but not so stringent as to" lead to adverse economic consequences, such as a
25   significant job losses or unreasonable elimination of consumer choice.

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

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

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

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

---

[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.

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

9. ### 1.3.1 Notice of Intent and Scoping

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

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

20. ▪ 78 contacts at Federal agencies having jurisdiction by law or special expertise with respect to
21. the environmental impacts involved or authorized to develop and enforce environmental
22. standards, including other modes within DOT;

23. ▪ the Governors of every State and United States territory to share with the appropriate
24. agencies and offices within their administrations, and with the local jurisdictions within their
25. States;

26. ▪ 23 organizations representing state and local governments;

27. ▪ 14 Native American tribal organizations and academic centers that had issued reports on
28. climate change and tribal communities; and

29. ▪ 92 contacts at other stakeholder organizations that NHTSA reasonably expected to be
30. interested in the NEPA analysis for the MY 2011-2015 CAFE standards, including auto
31. industry organizations, environmental organizations, and other organizations that had
32. expressed interest in prior CAFE rules.

---

[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).

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

13   **1.3.1.1 Supplemental Notice of Public Scoping**

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

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

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

21   ...consider the direct, indirect and cumulative environmental impacts of the proposed
22   standards and those of reasonable alternatives. Among other potential impacts, NHTSA
23   will consider direct and indirect impacts related to fuel and energy use, emissions,
24   including Carbon Dioxide (CO_2) and their effects on temperature and climate change, air
25   quality, natural resources, and the human environment. NHTSA also will consider the
26   cumulative impacts of the proposed standards for MY 2011-2015 automobiles together
27   with estimated impacts of NHTSA's implementation of the CAFE program through MY
28   2010 and NHTSA's future CAFE rulemaking for MY 2016-2020, as prescribed by
29   EPCA, as amended by EISA...[19]

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

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

---

[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.

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

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

5   ▪   46 Governors from whom NHTSA had not received a lead State NEPA contact in response to
6   the agency's initial letters;

7   ▪   24 State and local government NEPA contacts that had responded to the agency's initial
8   letters;

9   ▪   11 Administrators or other officials at other DOT agencies and offices;

10   ▪   62 NEPA contacts at other Federal agencies; and

11   ▪   42 other stakeholders that asked to remain or be included on NHTSA's NEPA mailing list.

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

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

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

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

---

[21] *Id.* at 22917.

1   **1.3.2   Summary of Scoping Comments and NHTSA's Responses**

2   NHTSA received 1,748 comment letters in response to its two scoping notices (as of June 17,
3   2008). All but 11 of these letters were a form letter similar in content and sent by individuals. The non-
4   form letters were provided by federal and state agencies, automobile trade associations, environmental
5   advocacy groups, and two individuals.

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

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

18   **1.3.2.1 Federal Agencies**

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

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

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

---

[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).

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

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

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

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

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

41   Finally, the CDC recommended that NHTSA's NEPA analyses of potential health impacts of the
42 proposed CAFE standards and alternatives should be done in collaboration with public health officials.
43 NHTSA discussed the CDC scoping comments with CDC officials by telephone on June 12, 2008.
44 NHTSA appreciates the suggestion and the effort CDC took to submit scoping comments. After a
45 thorough discussion, NHTSA believes it reached a high degree of understanding and assured CDC that
46 health impacts would be included in various ways in the DEIS. NHTSA feels confident that the

1 consultants retained to assist in the analysis and development of the DEIS, along with its own staff, have
2 the requisite knowledge and skills to effectively incorporate health issues into the document.

3 **1.3.2.2 States**

4   A number of comments representing the interests of States were received, including comments
5 from the New York State Department of Transportation (Docket No. NHTSA-2008-0060-0012),
6 Washington State Department of Transportation (Docket No. NHTSA-2008-0060-0177), and the
7 Minnesota Pollution Control Agency (Docket No. NHTSA-2008-0060-0011). A single, combined
8 comment letter was also received from the Attorneys General of the State of California, Connecticut, New
9 Jersey, New Mexico, Oregon, and Rhode Island, the Commonwealth of Pennsylvania Department of
10 Environmental Protection, and the New York City Corporation Counsel (Docket No. NHTSA-2008-0060-
11 0007.1).

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

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

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

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

43   The Minnesota Pollution Control Agency also recommended the use of the published marginal
44 cost estimates found in the economics literature for the next emitted ton of CO_2 in order to provide a basis

1   for assessing the cumulative environmental impacts of releases as monetized damages that may contribute
2   to a larger global problem. Detailed estimates of economic benefits and costs of establishing alternative
3   CAFE standards are presented in the PRIA.[24] As that document explains, consistent with its treatment of
4   pollutants such as nitrogen oxides, NHTSA's analysis applies an estimate representing damage costs, not
5   marginal avoidance costs. As Chapter VIII of that document describes, these estimates utilize the value
6   recommended in a survey of nearly 100 published estimates of the Social Cost of Carbon as a basis for
7   assessing the monetized benefits of the reductions in CO_2 emissions projected to result from alternative
8   CAFE standards.

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

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

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

25   The Attorneys General also referenced what they state to be significant new studies and research
26   on the health-related effects, both direct and indirect, of global warming, and requested that NHTSA take
27   these into account. These reviews and studies were reviewed and incorporated as appropriate in Chapters
28   3 and 4.

29   The Attorneys General letter also requested that NHTSA describe and discuss the potential
30   "tipping points" associated with global warming "that could create unstoppable, large-scale, disastrous
31   impacts for the planet." The term "tipping point" refers to a situation where the climate system reaches a
32   point at which is there is a strong and amplifying positive feedback from only a moderate additional
33   change in driver, such as CO_2 or temperature increase. These tipping points could potentially result in
34   abrupt climate change defined in Alley et al. (2002) (cited in Meehl, et al., 2007) to "occur when the
35   climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined
36   by the climate system itself and faster than the cause."

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

---

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

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

6 Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has
7 relied on CEQ's regulations regarding incomplete or unavailable information (see 40 C.F.R. §
8 1502.22(b)). In this case, the DEIS acknowledges that information on tipping points or abrupt climate
9 change is incomplete, and the state of the science does not allow for a characterization of how the CAFE
10 alternatives influence these risks, other than to say that the greater the emission reductions, the lower the
11 risk of abrupt climate change.

12 ### 1.3.2.3 Automobile Trade Associations

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

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

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

35 NHTSA's approach to analyzing the rate of vehicle fleet turnover is set forth in the NPRM. *See*
36 73 Fed. Reg. 24352, 24406-24407 (May 2, 2008).

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

---

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

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

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

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

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

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

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

---

[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").

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

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

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

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

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

37   **1.3.2.4 Environmental Advocacy Groups**

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

---

[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.

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

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

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

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

---

[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.

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

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

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

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

18   **1.3.2.5 Individuals**

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

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

---

[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.

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

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

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

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

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

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

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

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

8   **1.3.2.6 Other Comments**

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

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

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

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

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

---

[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]

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

7   The AAM also suggested that NHTSA consider an alternative tied to the "least capable
8   manufacturer" approach that was applied prior to the advent of Reformed CAFE. NHTSA does not adopt
9   this approach for the following reasons. NHTSA's earlier "Unreformed CAFE" standards specified a
10   "one size fits all" (uniform) level of CAFE that applied to each manufacturer and that was set with
11   particular regard to the lowest projected level of CAFE among the manufacturers that have a significant
12   share of the market. The manufacturer with the lowest projected CAFE level is typically known as the
13   "least capable" manufacturer. However, NHTSA's 2006 CAFE standards for light trucks adopted a
14   different "Reformed CAFE" approach. 71 Fed. Reg. 17566 (Apr. 6, 2006). EISA recently codified that
15   approach, requiring that all CAFE standards be based on one or more vehicle attributes. 49 U.S.C. §
16   32902(b)(3)(A); see 73 Fed. Reg. 24352, 24354-24355 (May 2, 2008) (discussing NHTSA's proposal to
17   base CAFE standards on the attribute of vehicle size, as defined by vehicle footprint).

18   As NHTSA explained when proposing Reformed CAFE standards for MY 2008-2011 light
19   trucks, "[u]nder Reformed CAFE, it is unnecessary to set standards with particular regard to the
20   capabilities of a single manufacturer in order to ensure that the standards are technologically feasible and
21   economically practicable for all manufacturers with a significant share of the market. This is true both
22   fleet wide and within any individual category of vehicles." See 70 Fed. Reg. 51414, 51432 (Aug. 30,
23   2005). Specifically:

24   There is no need under Reformed CAFE to set the standards with particular regard to the
25   capabilities of the "least capable" manufacturer. Indeed, it would often be difficult to
26   identify which manufacturer should be deemed the "least capable" manufacturer under
27   Reformed CAFE. The "least capable" manufacturer approach was simply a way of
28   implementing the guidance in the conference report [part of EPCA's legislative history][42]
29   in the specific context of Unreformed CAFE....

30   ...The very structure of Reformed CAFE standards makes it unnecessary to continue to
31   use that particular approach in order to be responsive to guidance in the conference
32   report. Instead of specifying a common level of CAFE, a Reformed CAFE standard
33   specifies a variable level of CAFE that varies based on the production mix of each
34   manufacturer. By basing the level required for an individual manufacturer on that
35   manufacturer's own mix, a Reformed CAFE standard in effect recognizes and
36   accommodates differences in production mix between full- and part-line manufacturers,

---

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).

1   and between manufacturers that concentrate on small vehicles and those that concentrate
2   on large ones.

3   There is an additional reason for ceasing to use the "least capable" manufacturer
4   approach. There would be relatively limited added fuel savings under Reformed CAFE if
5   we continued to use the "least capable" manufacturer approach even though there ceased
6   to be a need to use it...." (70 Fed. Reg. at 51433).

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

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

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

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

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

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

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

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

---

[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).

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

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

9　**1.3.3　Next Steps in the NEPA Process and CAFE Rulemaking**

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

11　　　■　provide a 45-day public comment period where interested parties can submit written
12　　　　comments on this document (Summer 2008); and

13　　　■　hold a public hearing in Washington, D.C. where interested parties can present oral testimony
14　　　　in early August 2008.

15　　　　　The Final Environmental Impact Statement (FEIS) is expected to be released later this year. The
16　FEIS will address comments received on the DEIS and identify the Preferred Alternative. No sooner than
17　30 days after the availability of the FEIS is announced in the Federal Register by EPA and prior to, or in
18　conjunction with, the release of a final CAFE rulemaking, NHTSA will execute a Record of Decision
19　(ROD). The ROD will state and explain NHTSA's decision.

1 # Chapter 2 The Proposed Action and Alternatives

2 ## 2.1   INTRODUCTION

3   The National Environmental Policy Act[1] (NEPA) requires an agency to compare the
4 environmental impacts of its proposed action and alternatives. An agency must rigorously explore and
5 objectively evaluate all reasonable alternatives, including a No Action Alternative. For any alternative an
6 agency eliminates from detailed study, the agency must "briefly discuss the reasons for their having been
7 eliminated."[2] The purpose of and need for the agency's action provides the foundation for determining
8 the range of reasonable alternatives to be considered in its NEPA analysis.[3]

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

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

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

23 ## 2.2   BENEFIT-COST ANALYSIS

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

---

[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).

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

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

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

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

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

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

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

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

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

---

[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.

1   **2.3   ALTERNATIVES**

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

19   NHTSA has examined five alternatives that fall between the extremes of the No Action
20   Alternative and the Technology Exhaustion Alternative mpg standards. The preferred alternative
21   establishes optimized mpg standards that yield the greatest net benefits of any feasible alternative. As
22   mpg standards are increased beyond this optimized level, manufacturers are increasingly forced to apply
23   technologies that entail higher incremental costs than benefits, thereby reducing total net benefits.
24   Another specific alternative examined is the total costs (TC) equal total benefits (TB) level (Total Costs
25   Equal Total Benefits Alternative), at which manufacturers are forced to apply technologies until total
26   costs equal total benefits, yielding zero net benefits. The Total Costs Equal Total Benefits Alternative
27   sets the second most stringent set of mpg standards examined, after the Technology Exhaustion
28   Alternative (which yields negative net benefits). The other three alternatives illustrate how costs,
29   benefits, and net benefits vary across other possible CAFE standards between the No Action and the Total
30   Costs Equal Total Benefits Alternatives. As shown in Table 2.3-1, the 50 Percent Above Optimized
31   Alternative would impose a 2015 mpg standard half-way between the Optimized and Total Costs Equal
32   Total Benefits Alternatives. The 25 Percent Above Optimized Alternative would impose a 2015 mpg
33   standard halfway between the Optimized and 50 Percent Above Optimized Alternatives, and the 25
34   Percent Below Optimized Alternative would impose a 2015 standard that falls below the Optimized
35   Alternative by the same absolute amount by which the 25 Percent Above Optimized Alternative exceeds
36   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

37

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

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

19   **2.3.1   Alternative 1: No Action**

20   This is the alternative of maintaining CAFE standards at the MY 2010 levels of 27.5 mpg and
21   23.5 mpg for passenger cars and light trucks, respectively.[9] NEPA requires agencies to consider a No
22   Action Alternative in their NEPA analyses,[10] although the recent amendments to EPCA direct NHTSA to
23   set new CAFE standards and do not permit the agency to take no action on fuel economy. In the NPRM,
24   NHTSA refers to the No Action Alternative as the no increase or baseline alternative.

25   **2.3.2   Alternative 2: 25 Percent Below Optimized**

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

---

[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).

1   For passenger cars, the average required fuel economy in mpg for the industry would range from
2 29.6 mpg in MY 2011 to 33.9 mpg in MY 2015. For light trucks, the average required fuel economy for
3 the industry would range from 24.9 mpg in MY 2011 to 27.5 mpg in MY 2015. The combined industry-
4 wide average fuel economy for all passenger cars and light trucks would range from 27.1 mpg in MY
5 2011 to 30.2 mpg in MY 2015, if each manufacturer exactly met its obligations under these standards.
6 The annual average increase in mpg during the period from MY 2011-2015 would be approximately 3.6
7 percent.

8 **2.3.3   Alternative 3: Optimized**

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

24   For passenger cars, the average required fuel economy in mpg for the industry would range from
25 31.2 mpg in MY 2011 to 35.7 mpg in MY 2015. For light trucks, the average required fuel economy for
26 the industry would range from 25.0 mpg in MY 2011 to 28.6 mpg in MY 2015. The combined industry-
27 wide average fuel economy for all passenger cars and light trucks would range from 27.8 mpg in MY
28 2011 to 31.6 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the standards
29 proposed in the NPRM.[15]

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

---

[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.

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

2.3.4   Alternative 4: 25 Percent Above Optimized

5   This alternative reflects standards that take the mpg levels to the Optimized Alternative level plus
6   25 percent of the difference between the Optimized and the Total Costs Equal Total Benefits Alternative
7   mpg levels.

8   For passenger cars, the average fuel required economy in mpg for the industry would range from
9   32.8 mpg in MY 2011 to 37.5 mpg in MY 2015. For light trucks, the average required fuel economy for
10 the industry would range from 25.1 mpg in MY 2011 to 29.8 mpg in MY 2015. The combined industry-
11 wide average fuel economy for all passenger cars and light trucks would range from 28.5 mpg in MY
12 2011 to 33.0 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the
13 standards. The annual average mpg increase during the period from MY 2011-2015 would be
14 approximately 5.4 percent.

2.3.5   Alternative 5: 50 Percent Above Optimized

16   This alternative reflects standards that take the mpg levels to the Optimized Alternative level plus
17 50 percent of the difference between the Optimized and the Total Costs Equal Total Benefits Alternative
18 mpg levels.

19   For passenger cars, the average required fuel economy in mpg for the industry would range from
20 34.3 mpg in MY 2011 to 39.5 mpg in MY 2015. For light trucks, the average required fuel economy for
21 the industry would range from 25.3 mpg in MY 2011 to 30.9 mpg in MY 2015. The combined industry-
22 wide average fuel economy for all passenger cars and light trucks would range from 29.2 mpg in MY
23 2011 to 34.5 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the
24 standards. The annual average mpg increase during the period from MY 2011-2015 would be
25 approximately 6.4 percent.

2.3.6   Alternative 6: Total Costs Equal Total Benefits

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

29   For passenger cars, the average required fuel economy in mpg for the industry would range from
30 37.5 mpg in MY 2011 to 43.3 mpg in MY 2015. For light trucks, the average required fuel economy for
31 the industry would range from 25.6 mpg in MY 2011 to 33.1 mpg in MY 2015. The combined industry-
32 wide average fuel economy for all passenger cars and light trucks would range from 27.8 mpg in MY
33 2011 to 37.3 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the
34 standards. The annual average mpg increase during the period from MY 2011-2015 would be
35 approximately 8.0 percent.

---

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

1   **2.3.7   Alternative 7: Technology Exhaustion**

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

9   For passenger cars, the average required fuel economy in mpg for the industry would range from
10   38.6 mpg in MY 2011 to 52.6 mpg in MY 2015. For light trucks, the average required fuel economy for
11   the industry would range from 25.9 mpg in MY 2011 to 34.7 mpg in MY 2015. The combined industry-
12   wide average fuel economy for all passenger cars and light trucks would range from 31.1 mpg in MY
13   2011 to 41.4 mpg in MY 2015, again, if each manufacturer exactly met its obligations under the
14   standards. The annual average mpg increase during the period from MY 2011-2015 would be
15   approximately 10.3 percent.

16   **2.4   ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL**

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

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

30   ▪ **Least Capable Manufacturer Approach.** NHTSA's earlier Unreformed CAFE standards
31   specified a "one size fits all" (uniform) level of CAFE that applied to each manufacturer and
32   that was set with particular regard to the lowest projected level of CAFE among the
33   manufacturers that have a significant share of the market. The major manufacturer with the
34   lowest projected CAFE level is typically known as the "least capable" manufacturer.
35   However, NHTSA's 2006 CAFE standards for light trucks adopted a different Reformed
36   CAFE approach (71 *Federal Register* [FR] 17566, April 6, 2006). EISA recently codified
37   that approach, requiring that all CAFE standards be based on one or more vehicle attributes
38   (49 United States Code [U.S.C.] § 32902(b)(3)(A); 73 FR 24352, 24354-24355, May 2, 2008)
39   (discussing NHTSA's proposal to base CAFE standards on the attribute of vehicle size, as
40   defined by vehicle footprint).

41   As NHTSA explained when proposing Reformed CAFE standards for MY 2008-2011 light
42   trucks, "[u]nder Reformed CAFE, it is unnecessary to set standards with particular regard to
43   the capabilities of a single manufacturer in order to ensure that the standards are
44   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

---

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

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

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

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

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

2.5 COMPARISON OF ALTERNATIVES

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

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

38   Tables 2.5-1 through 2.5-11 and Figures 2.5-1 through 2.5-6 summarize the direct, indirect, and
39 cumulative effects of the CAFE alternatives on energy, air quality, and climate. No quantifiable,
40 alternative-specific effects were identified for the other resources discussed in Chapters 3 and 4. Please
41 refer to the text in Chapters 3 and 4 for qualitative discussions of the potential direct and indirect effects
42 of the alternatives on these other resources. Similarly, although the alternatives have the potential to
43 substantially decrease GHG emissions, they do not prevent climate change from occurring, but only result
44 in small reductions in the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea

1   level. As discussed below, NHTSA's presumption is that these reductions in climate effects will be
2   reflected in reduced impacts on affected resources. The resources addressed in Chapter 4 of the DEIS
3   include freshwater resources, terrestrial ecosystems, coastal ecosystems, land use, and human heath.
4   However, the magnitudes of the changes in these climate effects that the alternatives produce – a few
5   parts per million (ppm) of CO_2, a hundredth of a degree celsius (C) difference in temperature, a small
6   percentage-wise change in the rate of precipitation increase, and 1 or 2 millimeters (mm) of sea level –
7   are too small to address quantitatively in terms of their impacts on resources. Given the enormous
8   resource values at stake, these distinctions may be important – very small percentages of huge numbers
9   can still yield significant results – but they are too small for current quantitative techniques to resolve.
10   Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but
11   rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the
12   risks involved in climate change. Thus, there are no differences to report in this comparison of the
13   alternatives.

14   **2.5.1   Direct and Indirect Effects**

15   **2.5.1.1 Energy**

16   Table 2.5-1 shows the impact on fuel consumption for passenger cars and light trucks from 2020
17   through 2050, a period in which an increasing volume of the fleet will be model year (MY) 2011-2015
18   passenger cars. The table shows total fuel consumption (both gasoline and diesel) under No Action
19   Alternative and the six other alternative scenarios. Fuel consumption under the No Action Alternative is
20   256.9 billion gallons in 2060. Consumption falls to 228.5 billion gallons under the Optimized Alternative
21   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

22

1   **2.5.1.2 Air Quality**

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

16 **2.5.1.3 Climate: GHG emissions**

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

23 **2.5.1.4 Climate: CO_2 Concentration and Global Mean Surface Temperature**

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

30 **2.5.1.5 Climate: Global Mean Rainfall and Global Mean Surface Temperature**

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

35

---

[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

1
2

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 ($^\circ$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

3

---

[20] The A1B-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 (°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 (°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

1   **2.5.1.6 Climate: Impact on Sea Level Rise**

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

7
8   **2.5.2   Cumulative Effects**

9   **2.5.2.1 Energy**

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

Figure 2.5-1 Lifetime Fuel Consumption of Passenger Cars and Light Trucks under
Alternative CAFE Standards
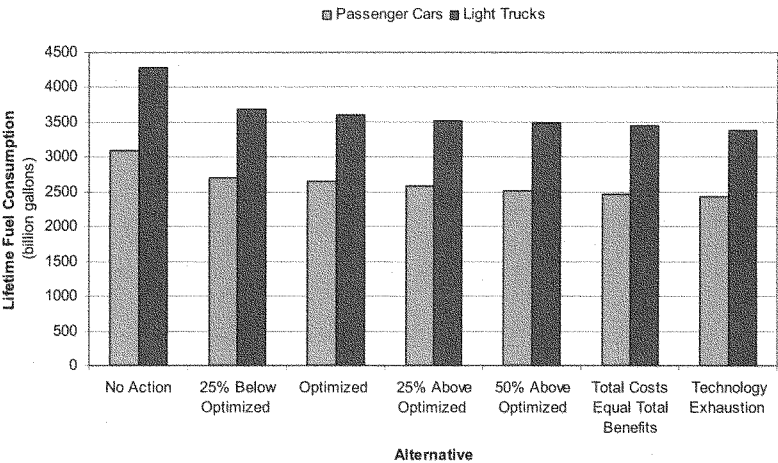
Figure 2.5-2 Savings in Lifetime Fuel Consumption by Passenger Cars and Light Trucks
under Alternative CAFE Standards

1 **2.5.2.2 Air Quality**

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

15 **2.5.2.3 Climate: Cumulative GHG Emissions**

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

22 **2.5.2.4 Climate: CO_2 Concentration and Global Mean Surface Temperature**

23   The mid-range results of MAGICC model simulations for the No Action Alternative and the six
24 alternative CAFE levels, in terms of CO2 concentrations and increase in global mean surface temperature
25 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
26 2.5-4 show, the impact on the growth in CO2 concentrations and temperature is just a fraction of the total
27 growth in CO2 concentrations and global mean surface temperature. However, the relative impact of the
28 CAFE alternatives is illustrated by the reduction in growth of both CO2 concentrations and temperature in
29 the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized
30 Alternative, as shown in Figures 2.5-5 to 2.5-6.

31   As shown in the table and figures, there is a fairly narrow band of estimated CO2 concentrations
32 as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. As
33 CO2 concentrations are the key driver of all the other climate effects, this narrow range implies that the
34 differences among alternatives are difficult to distinguish. The MAGICC simulations of mean global
35 surface air temperature increases are also shown below in Table 2.5-9. For all alternatives, the
36 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
37 among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No
38 Action Alternative, ranges from 0.012°C to 0.018°C. These estimates include considerable uncertainty
39 due to a number of factors of which the climate sensitivity is the most important. The IPCC AR4
40 estimates a range of the climate sensitivity from 2.5 to 4.0 degrees C with a mid-point of 3.0 degrees C
41 which directly relates to the uncertainty in the estimated global mean surface temperature.

42

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

1

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 (°C)		
	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

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

2

Figure 2.5-3 CO2 Concentrations for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020
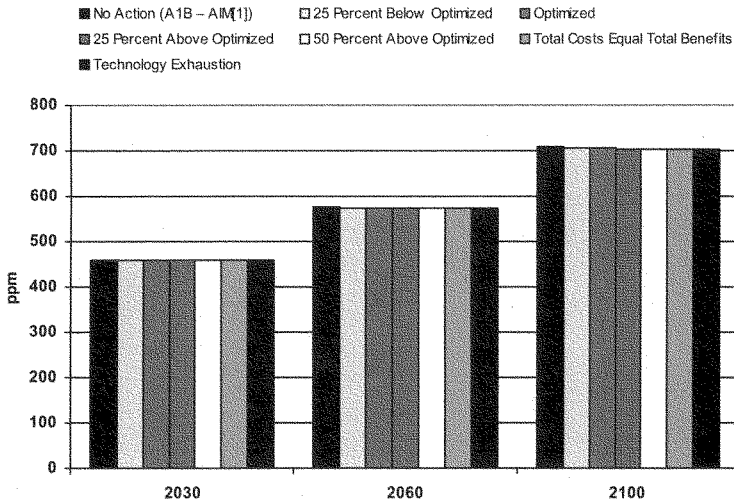
Figure 2.5-4 Increase in Global Mean Surface Temperature for the A1B Scenario and MY 2011-2015 Standard and Potential MY 2016-2020

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

3
4 **Figure 2.5-6 Reduction in the Growth of Global Mean Temperature for the A1B Scenario**
5 **MY 2011-2015 Standard and Potential MY 2016-2020**
6

7

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

15   **2.5.2.5 Climate: Global Mean Rainfall and Global Mean Surface Temperature**

16   The CAFE alternatives reduce temperature increases slightly with respect to the No Action
17   Alternative, thus they also reduce predicted increases in precipitation slightly, as shown in Table 2.5-10.
18   As shown in the table and figures, there is a fairly narrow band of estimated precipitation increase
19   reductions as of 2100, from 4.29 percent to 4.32 percent, and there is very little difference between the
20   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

1

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
3 ## 2.5.2.6 Climate: Impact on Sea Level Rise

4   The impact on sea level rise from the alternatives is near the threshold of the MAGICC model's
5 reporting capabilities: the alternatives reduce sea level rise by 0.1 to 0.2 cm (Table 2.5-11). Although the
6 model does not report enough significant figures to distinguish between the effects of the alternatives, it is
7 clear that the more stringent the alternative (i.e., the lower the emissions), the lower the temperature (as
8 shown above); and the lower the temperature, the lower the sea level. Thus, the more stringent
9 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

1

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

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;

1 ### 3.1.1 Direct and Indirect Effects

2   The Council on Environmental Quality (CEQ) regulations state that an EIS "shall succinctly
3 describe" the environment to be affected by the alternatives under consideration and to provide data and
4 analyses "commensurate with the importance of the impact[s]" (40 Code of Federal Regulations [CFR] §
5 1502.15 and § 1502.16). Chapter 3 provides the analysis to determine and compare the significance of
6 the direct and indirect effects of the proposed action and alternatives. Under NEPA, direct effects "are
7 caused by the action and occur at the same time and place" (40 CFR §1508.8). CEQ regulations define
8 indirect effects as those that "are caused by the action and are later in time or farther removed in distance,
9 but are still reasonably foreseeable. Indirect effects may include ... effects on air and water and other
10 natural systems, including ecosystems" (40 CFR §1508.8). Sections 3.2, 3.3, and 3.4 provide a
11 quantitative analysis for the direct and indirect effects of the proposed action on energy, air, and climate,
12 respectively. Impacts to other resource areas typically found in an environmental impact statement, and
13 the areas required by DOT order 5610 such as biological resources, water resources, noise, land use,
14 environmental justice, etc., are described qualitatively in Section 3.5 because sufficient data was not
15 available in the literature for a quantitative analysis, and because many of these effects are not localized.
16 In this DEIS such qualitative analysis is sufficient for NEPA purposes.[1]

17 ### 3.1.2 Areas not Affected

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

26 ### 3.1.3 Approach to Science Uncertainty and Incomplete Information

27 ### 3.1.3.1 CEQ Regulations

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

---

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

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

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

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

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

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

22   **3.1.3.2 Uncertainty with the IPCC Framework**

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

29   The DEIS uses the IPCC uncertainty language (always noted in italics) throughout Chapters 3 and
30   4, when discussing qualitative environmental impacts on certain resources. The reader should refer to the
31   documents referenced above to gain a full understanding of the meaning of those uncertainty terms, as
32   they may be separate from the meaning of language describing uncertainty in the DEIS as required by the
33   CEQ regulations discussed above.

---

[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);

---

[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]

---

[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).

1 **3.2   ENERGY**

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

7 **3.2.1 Affected Environment**

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

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

21   Most United States gasoline and diesel is produced domestically.[13] In 2007, 4 percent of finished
22 motor gasoline and 6 percent of on-road diesel was imported. However, increasing volumes of crude oil
23 are imported for processing in United States refineries as indigenous production is declining steadily. By
24 2006, petroleum imports equaled 60 percent of total liquids supplied and by 2007 crude oil imports had
25 surpassed 10,000 barrels per day[14].

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

---

[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.

	Actual a/				Forecasted b/				
TABLE 3.2-1									
Energy Consumption By Sector									
Sector (Quadrillion Btu)	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

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/table1.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

1
2   According to EIA net imports, in part due to the changes in CAFE standards and biofuels, will
3 fall to 51 percent in 2022 and then rise again to 54 percent in 2030. The impact on the industry and the
4 environment in which it works will be felt largely by overseas producers. The actual impact on overseas
5 producers and whether or not there is a decline in production, and a concomitant decline in emissions,
6 will depend on the demand patterns in the developing nations.

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

1 **3.2.2 Methodology**

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

10 **3.2.3 Consequences**

11   Table 3.2-2 shows the impact on fuel consumption for passenger cars from 2020 through 2060, a
12 period in which an increasing volume of the fleet will be MY 2011-2015 cars which shows the increasing
13 impact of the CAFE alternatives over time. The table shows total fuel consumption for passenger cars,
14 both gasoline and diesel, under No Action Alternative and the six alternative CAFE standards. By 2060,
15 when the entire fleet is likely to be composed of MY 2011 or later, cars fuel consumption reaches 131.5
16 billion gallons under the No Action Alternative. Consumption falls under all the alternatives from 127.7
17 billion gallons under the Optimized Alternative to 114.8 billion gallons in the Technology Exhaustion
18 Alternative. As a comparison in 2007 the United States consumed 9.3 million barrels per day.
19 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
a/ Uncertainties in the growth of VMT and number of vehicles in operation make forecasts past 2060 uncertain.							

20
21   Table 3.2-3 shows similar results for the light trucks/SUVs for the same time period and with the
22 same alternative scenarios. As with the previous table fuel consumption is combined diesel and gasoline.
23 Fuel consumption under the No Action Alternative is 144.7 billion gallons in 2050. Consumption falls

1 under the alternative CAFE standards to 127.4 under the Optimized Alternative to 117.2 billion gallons
2 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

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

3

1 **3.3   AIR QUALITY**

2 **3.3.1   Affected Environment**

3 **3.3.1.1 Relevant Pollutants and Standards**

4   The proposed standards and the alternatives would affect air pollution, which has potential effects
5 on public health and welfare, and in turn, air quality. The primary Federal legislation that addresses air
6 quality is the Clean Air Act (CAA). Under the authority of the CAA and amendments, the U.S.
7 Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards
8 (NAAQS) for six criteria pollutants, relatively commonplace pollutants that can accumulate in the
9 atmosphere as a result of normal levels of human activity. The air quality analysis assesses the impacts of
10 the alternatives with respect to criteria pollutants and Hazardous Air Pollutants (HAPs, also known as
11 toxic air pollutants or air toxics) as defined under Section 112(b) of the CAA.

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

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

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

33   Table 3.3-1 shows the primary and secondary air quality standards established by the NAAQS for
34 each criteria pollutant. Primary standards are set at levels that are intended to protect against adverse
35 effects on human health, while secondary standards are intended to protect against adverse effects on
36 public welfare, such as damage to agricultural crops or vegetation, and damage to buildings or other
37 property. Because each criteria pollutant has different potential effects on human health and public
38 welfare, the NAAQS specify different permissible levels for each pollutant. The NAAQS for some
39 pollutants include standards for both short-term and long-term average levels. Short-term standards,

---

[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.)

1 which typically specify higher levels of a pollutant, are intended to protect against acute health effects
2 from short-term exposure to high levels, while long-term standards are established to protect against
3 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 (10 mg/m3)	8-hour b/	None	
	35 ppm (40 mg/m3)	1 hour b/		
Lead	1.5 µg/m3	Quarterly Average	Same as Primary	
Nitrogen Dioxide	0.053 ppm (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 (2008 std.)	8-hour f/	Same as Primary	
	0.08 ppm (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 (1300 µg/m3)	3-hour b/
	0.14 ppm	24-hour b/		

a/ Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m3), and micrograms per cubic meter of air (µg/m3).
b/ Not to be exceeded more than once per year.
c/ 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.

4

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

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

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

24   The relevant air toxics for this analysis are referred to by EPA and Federal Highway
25   Administration (FHWA) as the priority Mobile Source Air Toxics (MSAT). The priority MSATs are
26   acetaldehyde, acrolein, benzene, 1,3-butadiene, diesel particulate matter (DPM), and formaldehyde (EPA,
27   2008).[16] DPM is a component of exhaust from diesel-fueled vehicles and falls almost entirely within the
28   PM2.5 particle size class.

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

32
33   **3.3.1.2 Health Effects of Criteria Pollutants**

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

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

---

[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

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

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

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

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

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

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

1   **3.3.1.3 Health Effects of Mobile Source Air Toxics**

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

4   ▪   Acetaldehyde is a probable human carcinogen based on increased incidence of nasal tumors
5   in rats and throat tumors in hamsters after inhalation exposure. Acetaldehyde is also a potent
6   respiratory irritant.

7   ▪   Acrolein, an aldehyde, is a respiratory irritant. Its potential carcinogenic effects are
8   uncertain.

9   ▪   Benzene, an aromatic hydrocarbon, is a known human carcinogen (causing leukemia) by all
10   routes of exposure. Benzene also affects the immune system.

11   ▪   1,3-Butadiene, a hydrocarbon, is characterized as carcinogenic to humans by inhalation. It
12   also damages the reproductive system.

13   ▪   Diesel particulate matter is a component, along with diesel exhaust organic gases, of diesel
14   exhaust. The particles are very fine with most particles smaller than 1 micron, and their small
15   size allows inhaled DPM to reach the lung. Particles typically have a carbon core coated by
16   condensed organic compounds, which include mutagens and carcinogens. Diesel exhaust is
17   likely to be carcinogenic to humans by inhalation from environmental exposure.

18   ▪   Formaldehyde is a probable human carcinogen based on evidence in humans and in rats,
19   mice, hamsters, and monkeys. Formaldehyde also is a respiratory and eye irritant.

20   **3.3.1.4 Clean Air Act and Conformity Regulations**

21   **3.3.1.4.1 Vehicle Emissions Standards**

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

---

[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.

1 **Figure 3.3-1 Vehicle Miles Traveled (VMT) vs. Vehicle Emissions**
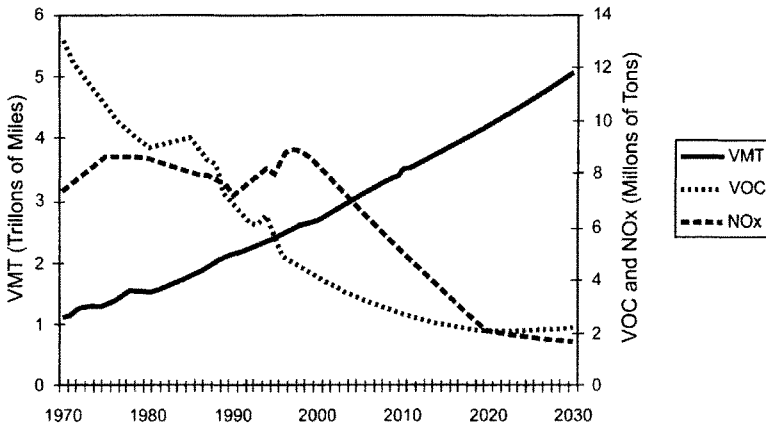
2
3
4   From 1970 to 1999, aggregate emissions traditionally associated with vehicles significantly
5 decreased (with the exception of NOx) even as vehicle miles traveled have increased by approximately
6 149 percent. NOx emissions increased between 1970 and 1999 by 16 percent, due mainly to emissions
7 from light-duty trucks and heavy-duty vehicles. However, as future trends show, vehicle travel is having
8 a smaller and smaller impact on emissions as a result of stricter engine and fuel standards, even with
9 additional growth in VMT.[18]

10   EPA is addressing air toxics through its MSAT rules (EPA, 2008). These rules limit the benzene
11 content of gasoline beginning in 2011. They also limit exhaust emissions of hydrocarbons (many VOCs
12 and MSATs are hydrocarbons) from passenger car and light trucks when they are operated at cold
13 temperatures. The cold temperature standard will be phased in from 2010 to 2015. The MSAT rules also
14 adopt nationally the California evaporative emissions standards. EPA projects that these controls will
15 substantially reduce emissions of benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein.

16   **3.3.1.4.2 Conformity Regulations**

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

---

[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.

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

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

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

18   The General Conformity Rules contain several exemptions applicable to "Federal actions," which
19 the conformity regulations define as: "any activity engaged in by a department, agency, or instrumentality
20 of the Federal Government, or any activity that a department, agency or instrumentality of the Federal
21 Government supports in any way, provides financial assistance for, licenses, permits, or approves, other
22 than activities [subject to transportation conformity]." 40 CFR 51.852. "Rulemaking and policy
23 development and issuance" are exempted at 40 CFR 51.853(c)(2)(iii). Since NHTSA's proposed CAFE
24 standards involve a rulemaking process, NHTSA believes that its action is exempt from general
25 conformity. Also, emissions for which a Federal agency does not have a "continuing program
26 responsibility" are not considered "indirect emissions" subject to general conformity under 40 CFR
27 51.852. "Emissions that a Federal agency has a continuing program responsibility for means emissions
28 that are specifically caused by an agency carrying out its authorities, and does not include emissions that
29 occur due to subsequent activities, unless such activities are required by the Federal agency." 40 CFR
30 51.852. Emissions that occur as a result of the CAFE standards are not caused by NHTSA carrying out
31 its statutory authorities and clearly occur due to subsequent activities, including vehicle manufacturers'
32 production of passenger car and light truck fleets and consumer purchases and driving behavior. Thus,
33 changes in any emissions that result from NHTSA's new CAFE standards are not those for which the
34 agency has a "continuing program responsibility" and NHTSA believes that a general conformity
35 determination is not required. NHTSA is evaluating the potential impacts of air emissions for the
36 purposes of NEPA.

37 **3.3.2 Consequences**

38 **3.3.2.1 Methodology**

39   **3.3.2.1.1 Overview**

40   The air quality impacts of the action alternatives were analyzed by calculating the emissions from
41 passenger car and light trucks that would occur under each alternative, and assessing the changes in
42 emissions relative to the No Action Alternative. The analysis assumes that assessing emissions is a valid
43 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 air 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.

---

[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.

1   **3.3.2.1.2 Timeframes for Analysis**

2   Ground-level concentrations of criteria and toxic air pollutants generally respond quickly to
3   changes in emission rates. The longest averaging period for the NAAQS is 1 year. (The ozone and PM2.5
4   NAAQS use annual averages over a 3-year period to account for meteorological variations). The air
5   quality analysis considers the emissions that would occur over annual periods, consistent with the
6   NAAQS. Calendar years were selected that are meaningful for the timing of likely effects of the
7   proposed alternatives.

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

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

26   ▪   2015 – Required attainment date for most PM2.5 nonattainment areas; first year of complete
27   implementation of the proposed MY 2011-2015 CAFE standards; year of highest overall
28   emissions from passenger cars and light trucks following complete implementation.

29   ▪   2020 – Latest required attainment date for 8-hour ozone nonattainment areas (2020 is latest
30   full year, as last attainment date is June 2021 for South Coast Air Basin, CA); by this point a
31   large proportion of passenger car and light truck VMT would be driven by vehicles that meet
32   the MY 2011-2015 standards; first year of complete implementation of potential MY 2016-
33   2020 CAFE standards (Section 4.3);

34   ▪   2025 – By this point a large proportion of passenger car and light truck VMT would be driven
35   by vehicles that meet the potential MY 2016-2020 standards;

36   ▪   2035 – By 2035, almost all passenger cars and light trucks in operation would meet at least
37   the MY 2011-2015 standards and the impact of the standards would start to come only from
38   VMT growth rather than further tightening of the standards. The impacts of the CAFE and
39   EPA standards on a year-by-year basis by 2035 will change little from model year turnover,
40   and most changes in emissions from year to year will come from the rebound effect. Year
41   2035 represents a reasonable limit to the ability to forecast important variables such as
42   survival rates and mileage accrual rates of vehicles in the fleet, future EPA emissions
43   standards, emission control technologies and the emission rates from vehicles. NHTSA

1   believes the year 2035 is a practical maximum for impacts of criteria and toxic air pollutants
2   to be considered reasonably foreseeable rather than speculative.

3   ▪   2100 – Used for climate change effects but not criteria and toxic air pollutants; NHTSA
4   believes that given the current state-of-the-science the year 2100 is a practical maximum for
5   impacts of climate change to be considered reasonably foreseeable rather than speculative.

6   **3.3.2.1.3   Treatment of Incomplete or Unavailable Information**

7   As noted above, the estimates of emissions rely on models and forecasts that contain numerous
8 assumptions and data that are uncertain. Examples of areas in which information is incomplete or
9 unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and
10 design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and
11 economic factors. Where information in the analysis included in the DEIS is incomplete or unavailable,
12 the agency has relied on CEQ's regulations regarding incomplete or unavailable information. *See* 40 CFR
13 § 1502.22(b). NHTSA has used the best available models and supporting data. The models used for the
14 DEIS were subjected to scientific review and have received the approval of the agencies that sponsored
15 their development. NHTSA believes that the assumptions that the DEIS makes regarding uncertain
16 conditions reflect the best available information and are valid and sufficient for this analysis.

17   **3.3.2.1.4   Allocation of Exhaust Emissions to Nonattainment Areas**

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

33   The geographical definitions of ozone and PM2.5 NAAs came from the current EPA Greenbook
34 list (EPA, 2008). For those NAAs that include portions of counties, we calculated the proportion of
35 county population that falls within the NAA boundary as a proxy for the proportion of county VMT that
36 occurs within the NAA boundary. Partial county boundaries were taken from geographic information
37 system files based on 2006 NAA definitions. In some cases partial counties within NAAs as currently
38 defined were not included in the 2006 NAAs. In those cases we did not add any part of the missing
39 counties' VMT to our NAA totals, on the basis that partial counties added to NAAs between 2006 and
40 2008 likely represent relatively small additions to total NAA VMT. Several urban areas are in

---

[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.

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

3   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	**O₃**	**PM2.5**	**O₃**	**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

l

		Classification a/		General Conformity Threshold b/	
Nonattainment/Maintenance Area		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

TABLE 3.3-2 (cont'd)				
Nonattainment Areas for Ozone and PM2.5				
	Classification a/		General Conformity Threshold b/	
Nonattainment/Maintenance Area	**O₃**	**PM2.5**	**O₃**	**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

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

1 crude oil is produced domestically. Once in the lower 48 states, almost all (92 percent) of crude oil is
2 transported to refineries by pipeline.

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

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

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

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

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

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

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

1   apportioned the national T&S&D emissions to NAAs based on their total share of national
2   fuel demand.

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

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

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

16 ### 3.3.2.2 Results of the Emissions Analysis

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

25 ### 3.3.2.3 Alternative 1: No Action

26 ### 3.3.2.3.1 Criteria Pollutants

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

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

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
TABLE 3.3-3							
Nationwide Criteria Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)							
Pollutant and Year	**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 (SOx)							
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)

■ Carbon Monoxide (CO) ■ Nitrogen Oxides (NOx) ◻ Particulate Matter (PM) ▨ Sulfur Oxides (SOx) ▨ Volatile Organic Compounds (VOC)

1
2

3
4
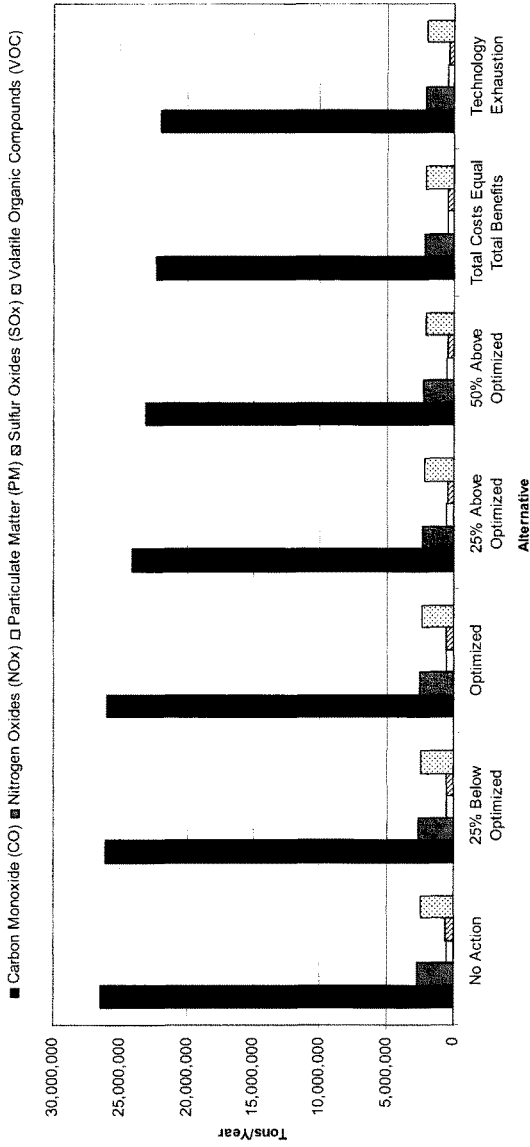
1   Table 3.3-4 presents the net change in nationwide emissions from passenger cars and light trucks
2 for the No Action Alternative for each of the criteria pollutants and analysis years. The other alternatives
3 (Alternatives 2 through 7) are presented in left-to-right order of increasing fuel economy requirements. In
4 Table 3.3-4 the nationwide emissions reductions become greater from left to right, reflecting the
5 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)							
	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
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 (SOx)							
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

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.

6
7   **3.3.2.3.2 Air Toxics**

8   With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in
9 future years. As with the criteria pollutants, current trends in the levels of air toxics emissions from

1   vehicles would continue, with emissions continuing to decline due to the EPA emission standards despite
2   a growth in total VMT. The EPA regulates air toxics from motor vehicles through vehicle emission
3   standards and fuel quality standards, as discussed in Section 3.3.1. The No Action Alternative
4   (Alternative 1) would not result in any other increase or decrease in toxic air pollutant emissions in
5   nonattainment and maintenance areas throughout the United States

6   Table 3.3-5 summarizes the total national emissions of air toxics from passenger cars and light
7   trucks with the No Action Alternative for each of the pollutants and analysis years. As with the criteria
8   pollutants, the No Action Alternative has the highest emissions of all the alternatives for all toxic air
9   pollutants except acrolein. Table 3.3-3 shows increases for acrolein with the action alternatives because
10 data on upstream emissions reductions were not available. The emissions for acrolein in Table 3.3-3
11 reflect only the increases due to the rebound effect. Because the upstream emissions reductions result
12 from the decline in the amount of fuel processed, it is reasonable that upstream acrolein emissions should
13 decrease as the other pollutants' upstream emissions do. Thus, the acrolein emissions given in Table
14 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

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
TABLE 3.3-5 (cont'd)							
Nationwide Toxic Air Pollutant Emissions from Passenger Cars and Light Trucks with Alternative CAFE Standards (tons/year)							
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

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)

■ Acetaldehyde ▨ Acrolein ▢ Benzene ▨ 1,3-Butadiene ▨ Diesel Particulate Matter (DPM) ▨ Formaldehyde

3-31

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

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 SOx 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

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

10   ### 3.3.2.5.2 Air Toxics

11   As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic
12   air pollutants with the Optimized Alternative compared to the 25 Percent Below Optimized Alternative
13   and the No Action Alternative. The Optimized Alternative would reduce air toxics emissions less than
14   would Alternatives 4 through 7 (Table 3.3-8). At the nationwide level emissions of toxic air pollutants
15   decrease because the reduction in upstream emissions more than offsets the increase in VMT and
16   emissions due to the rebound effect. However, as with the 25 Percent Below Optimized Alternative, the
17   reductions in upstream emissions are not uniformly distributed to individual NAAs. With the Optimized
18   Alternative many NAAs would experience net increases in emissions of one or more toxic air pollutants
19   in at least one of the analysis years (Appendix B-1). Also, data were not available to quantify upstream
20   emissions of acrolein, and so emissions of acrolein reflect only the increases due to the rebound effect.
21   However, the sizes of the emission increases are quite small, as shown in Appendix B-1, and emission
22   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.

1   ### 3.3.2.7 Alternative 5: 50 Percent Above Optimized

2   #### 3.3.2.7.1 Criteria Pollutants

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

13   #### 3.3.2.7.2 Air Toxics

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

28   ### 3.3.2.8 Alternative 6: Total Costs Equal Total Benefits

29   #### 3.3.2.8.1 Criteria Pollutants

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

40   #### 3.3.2.8.2 Air Toxics

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

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

13   **3.3.2.9 Alternative 7: Technology Exhaustion**

14   **3.3.2.9.1 Criteria Pollutants**

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

23   **3.3.2.9.2 Air Toxics**

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

1
2
3

[This page intentionally left blank]

1 **3.4   CLIMATE**

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

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

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

22 **3.4.1   Introduction - Greenhouse Gases and Climate Change**

23   There have been a series of intensive and extensive analyses conducted by the Intergovernmental
24 Panel on Climate Change (IPCC), the scientific body tasked by the United Nations to evaluate the risk of
25 human-induced climate change), the United States Climate Change Science Program (USCCSP), and
26 many other government, non-government organization (NGO), and industry-sponsored programs. Our
27 discussion relies heavily on the most recent, thoroughly peer-reviewed, and credible assessments of
28 global and United States climate change: the IPCC Fourth Assessment Report (AR4, *Climate Change*
29 *2007*), and reports by the USCCSP that include the *Scientific Assessment of the Effects of Global Change*
30 *on the United States* and Synthesis and Assessment Products. These sources and the studies they review
31 are frequently quoted throughout this DEIS. Since new evidence is continuously emerging on the subject
32 of climate change impacts, the discussions on climate impacts in this DEIS also draw on more recent
33 studies, where possible.

34 **3.4.1.1 What is Climate Change?**

35   Global climate change refers to long-term fluctuations in global surface temperatures,
36 precipitation, ice cover, sea levels, cloud cover, ocean temperatures and currents, and other climatic
37 conditions. Scientific research has shown that in the past century, Earth's surface temperature has risen
38 by an average of about 1.3 degrees Fahrenheit (°F) (0.74° C) (IPCC, 2007); sea levels have risen 6.7
39 inches (0.17 meters) (IPCC, 2007); and Arctic Sea ice has shrunk by 2.7 percent per decade with larger
40 decreases in summer of 7.4 percent as well as decreases in mountain glaciers and snow cover (IPCC,
41 2007) (Figure 3.4-1).

Figure 3.4-1 Changes in Temperature, Sea
Level, and Northern Hemisphere Snow Cover
(source: IPCC, 2007)
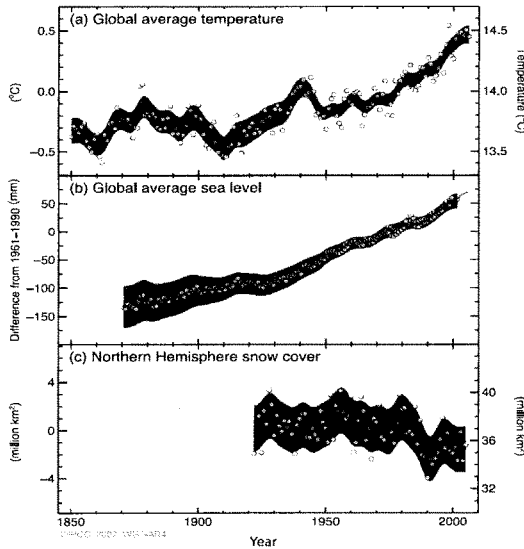
1
2
3 **3.4.1.2 What Causes Climate Change?**

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

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

---

[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.

1
2

Figure 3.4-2 The Greenhouse Effect (source: Le Treut et al., 2007)
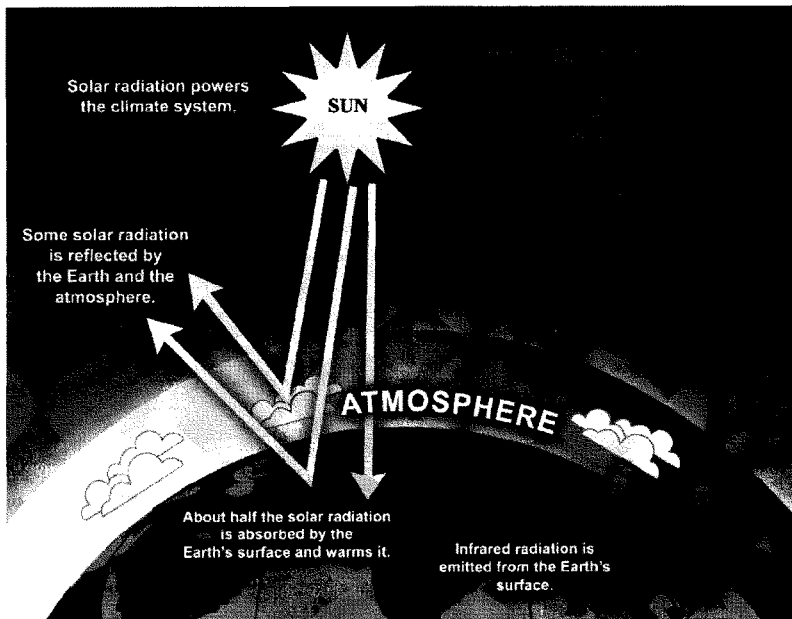
3
4   Most GHGs are naturally occurring, including CO_2, CH_4, N_2O, water vapor, and ozone. Human
5 activities such as the combustion of fossil fuel, the production of agricultural commodities, and the
6 harvesting of trees can contribute to increased concentrations of these gases in the atmosphere. In
7 addition, a number of very potent anthropogenic GHGs, including hydrofluorocarbons (HFCs),
8 perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), are created and emitted through industrial
9 processes.

10 **3.4.1.3 What are the Anthropogenic Sources of Greenhouse Gases?**

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

18   Contributions to the build-up of GHG in the atmosphere vary greatly from country to country,
19 and depend heavily on the level of industrial and economic activity. Emissions from the United States

1 accounted for approximately 15-20 percent of global GHG emissions in the year 2000 (CAIT, 2008).[22]
2 With about one-third of United States emissions due to the combustion of petroleum fuels in the
3 transportation sector (EPA, 2008), CO_2 emissions from the United States transportation sector alone
4 represent nearly 4 percent of all global GHG emissions (CAIT, 2008).

5 **3.4.1.4 Evidence of Climate Change**

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

12 **3.4.1.5 Future Climactic Trends and Expected Impacts**

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

17 Among other trends forecasted, the average global surface temperature is *likely* to rise 2.0° to
18 11.5° F (1.1 to 6.4° C) over the next century, accompanied by a *likely* sea level rise of approximately 0.6
19 to 1.9 feet (0.18 to 0.59 m) (IPCC, 2007). In addition to rising temperatures and sea levels, climate
20 change is expected to have many environmental, human health, and economic consequences.

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

23 **3.4.2 Affected Environment**

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

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

---

[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]

1 **3.4.2.1 Greenhouse Gas Emissions (Historic and Current)**

2   **3.4.2.1.1 United States Emissions**

3   GHG emissions for the United States in 2006 were estimated at 7,054 million metric tons of
4 carbon dioxide (MMTCO$_2$) equivalent[24] (EPA, 2008), and, as noted earlier, comprise about 15-20 percent
5 of total global emissions[25] (CAIT, 2008). Annual United States emissions, which have increased 15
6 percent since 1990 and typically increase each year, are heavily influenced by "general economic
7 conditions, energy prices, weather, and the availability of non-fossil alternatives" (EPA, 2008).

8   Carbon dioxide is by far the primary GHG emissions emitted in the United States, representing
9 nearly 85 percent of all United States GHG emissions in 2006 (EPA, 2008). The other gases include CH$_4$,
10 N$_2$O, and a variety of fluorinated gases, including, HFCs, PFCs, and SF$_6$. The fluorinated gases are
11 collectively referred to as high global warming potential (GWP) gases. Methane accounted for 8 percent
12 of the remaining GHGs on a GWP-weighted basis, followed by N$_2$O (5 percent), and the high-GWP gases
13 (2 percent) (EPA, 2008, ES4-6).

14   GHGs are emitted from a wide variety of sectors, including energy, industrial processes, waste,
15 agriculture, and forestry. The majority of United States emissions are from the energy sector, largely due
16 to CO$_2$ emissions from the combustion of fossil fuels, which alone account for 80 percent of total United
17 States emissions (EPA, 2008). These emissions are due to fuels consumed in the electric power (41
18 percent of fossil fuel emissions), transportation (33 percent), industry (15 percent), residential (6 percent),
19 and commercial (4 percent) sectors (EPA, 2008). However, when the United States CO$_2$ emissions are
20 apportioned by end use, transportation becomes the single leading source of United States emissions from
21 fossil fuels, at approximately one-third of total CO$_2$ emissions from fossil fuels (EPA, 2008).

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

29   **3.4.2.1.2 Global Emissions**

30   Although humans have always contributed to some level of GHG emissions to the atmosphere
31 through activities like farming and land clearing, significant contributions did not begin until the mid-
32 1700s, with the onset of the Industrial Revolution. People began burning coal, oil, and natural gas to light
33 their homes, to power trains and cars, and to run factories and industrial operations. Today the burning of
34 fossil fuels is still the predominant source of GHG emissions.

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.

1   In 2000, global GHG emissions were estimated at 44,347 MMTCO$_2$ equivalent, a 6 percent
2 increase since 1990[26] (CAIT, 2008). In general, global GHG emissions have increased regularly, though
3 annual increases vary according to a variety of factors (e.g., weather, energy prices, and economic
4 factors).

5   As in the United States, the primary GHGs emitted globally are CO$_2$, CH$_4$, N$_2$O, and the
6 fluorinated gases HFCs, PFCs, and SF$_6$. In 2000, CO$_2$ emissions comprised 79 percent of global
7 emissions on a GWP-weighted basis, followed by CH$_4$, (14 percent) and N$_2$O (7 percent). Collectively,
8 fluorinated gases represented 1 percent of global emissions (CAIT, 2008).

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

16   Emissions from transportation are primarily due to the combustion of petroleum to power
17 vehicles such as cars, trucks, trains, planes, and ships. In 2000, transportation represented 12 percent of
18 total emissions and 15 percent of CO$_2$ emissions; transportation emissions increased 11 percent since
19 1990 (CAIT, 2008).

20 **3.4.2.2 Climate Change Effects and Impacts (Historic and Current)**

21   **3.4.2.2.1 United States Climate Change Effects**

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

25   Observed Changes to the Climate

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

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

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

---

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

1   Observed Impacts from the Changing Climate

2   Streamflow decreased about 20 percent over the past century in the central Rocky Mountain
3   region, while in the East it increased 25 percent in the last 60 years. Annual peak streamflow (dominated
4   by snowmelt) in western mountains is presently occurring at least a week earlier than in the middle of the
5   20th century. Winter streamflow is increasing in seasonal snow-covered basins while the fraction of
6   annual precipitation falling as rain (rather than snow) increased in the last half century (USCCSP, 2008).
7   Spring and summer snow cover decreased in the West, and in mountainous regions of the western United
8   States, April snow water equivalent has declined 15 to 30 percent since 1950, particularly at lower
9   elevations and primarily due to warming (Field et al., 2007 as cited by USCCSP, 2008). However, total
10   United States snow-cover area increased in the November to January season from 1915–2004 (USCCSP,
11   2008).

12   Annual average Arctic sea ice extent decreased 2.7 ± 0.6 percent per decade from 1978–2005. In
13   2007, sea ice extent was approximately 23 percent below the previous all-time minimum observed in
14   2005. Average sea ice thickness in the central Arctic *very likely* decreased up to approximately 3 feet
15   from 1987–1997. These area and thickness reductions allow winds to generate stronger waves, which
16   have increased shoreline erosion along the Alaskan coast. Alaska has also experienced permafrost
17   thawing of up to 1.6 inches per year since 1992 (USCCSP, 2008).

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

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

28   **3.4.2.2.2 Global Climate Change Effects**

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

34   In their latest assessment of climate change, the IPCC states that "Warming of the climate system
35   is unequivocal, as is now evident from observations of increases in global average air and ocean
36   temperatures, widespread melting of snow and ice and rising global average sea level" (IPCC, 2007, p. 5).

37   Observed Changes to the Climate

38   Global temperatures have been increasing over the past century. The 100-year linear trend
39   (1906–2005) is 0.13 ± 0.03 °F per decade, while the corresponding 50-year linear trend of 0.23 ± 0.05 °F
40   per decade is nearly double (USCCSP, 2008). Average arctic temperatures increased at almost twice the
41   global average rate in the past 100 years. Permafrost top layer temperatures have generally increased
42   since the 1980s (about 5°F in the Arctic) while the maximum area covered by seasonal frozen ground has

1 decreased since 1900 by about 7 percent in the Northern Hemisphere, with a decrease in spring of up to
2 15 percent (IPCC, 2007).

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

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

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

16   Global average sea level rose at an average rate of 0.07 ± 0.02 inches per year over 1961–2003
17 with the rate increasing to about 0.12 ± 0.03 inches per year over 1993–2003. Total 20th-century rise is
18 estimated at 0.56 ± 0.16 feet (IPCC, 2007). However, since the IPCC Fourth Assessment Report, a recent
19 study improved the historical estimates of upper-ocean warming (300-meters and 700-meters) from 1950
20 to 2003 by correcting for expendable bathy-thermographs (XBT) instrument bias and found the improved
21 estimates demonstrate clear agreement with the decadal variability of the climate models that included
22 volcanic forcing (Domingues et. al., 2008). Further, this study estimated the globally averaged sea-level
23 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
24 1993 to 2003 consistent with the estimated trend of 0.091 inch per year from tide gauges after taking into
25 account thermal expansion in the upper-ocean and deep ocean, variations in the Antarctica and Greenland
26 ice sheets, glaciers and ice caps, and terrestrial storage.

27   ## Observed Impacts from the Changing Climate

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

32   Long-term trends in global precipitation amounts have been observed since 1900. Precipitation
33 has significantly increased in eastern parts of North and South America, northern Europe, and northern
34 and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa, and parts of
35 southern Asia. Spatial and temporal variability for precipitation is high, and data is limited for some
36 regions (IPCC, 2007).

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

41   Long-term trends in tropical cyclone activity have been reported, but there is no clear trend in the
42 number of tropical cyclones each year. There is observational evidence for an increase in intense tropical

1   cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface
2   temperatures. However, concerns over data quality and multi-decadal variability persist (IPCC, 2007).
3   The World Meteorological Organization (WMO) Sixth International Workshop on Tropical Cyclones in
4   2006 agreed that "no firm conclusion can be made" on anthropogenic influence on tropical cyclone
5   activity as, "there is evidence both for and against the existence of a detectable anthropogenic signal in
6   the tropical cyclone climate record" (WMO, 2006).

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

15   **3.4.3   Methodology**

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

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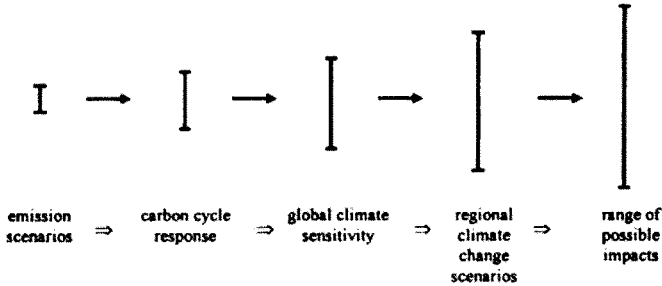19   2. Analyzing how the GHG emissions affect the climate system (climate effects).

20   Each element is discussed below.

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

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

33   Moss and Schneider (2000) characterize the "cascade of uncertainty" in climate change
34   simulations (see Figure 3.4-3). As indicated in the figure, the emission estimates used in this DEIS have
35   narrower bands of uncertainty than the global climate effects, which in turn have less uncertainty than the
36   regional climate change effects. The effects on climate are in turn less uncertain than the impacts of
37   climate changes on affected resources (e.g., terrestrial and coastal ecosystems, human health, and other
38   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."

| emission scenarios | ⇒ | carbon cycle response | ⇒ | global climate sensitivity | ⇒ | regional climate change scenarios | ⇒ | range of possible impacts |

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.

---

[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.

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

14   **3.4.3.2 Methodology for Estimating Climate Effects**

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

17   ▪ Changes in CO_2 concentrations
18   ▪ Changes in global mean surface temperature
19   ▪ Changes in regional temperature and precipitation
20   ▪ Changes in sea level

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

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

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

---

[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).

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

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

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

12 ### 3.4.3.2.1 MAGICC Version 4.1

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

14 ▪ MAGICC has been used in a number of peer reviewed literature to evaluate changes in global
15   mean surface temperature and sea level rise, including the IPCC Fourth Assessment for WG1
16   (IPCC, 2007) where it was used to scale the results from the atmospheric-ocean general
17   circulation models (AOGCMs)[32] to estimate the global mean surface temperature and the sea
18   level rise for SRES scenarios that the AOGCMs did not run.

19 ▪ MAGICC is publicly available and is already populated with the SRES scenarios.

20 ▪ MAGICC was designed for the type of analysis performed in this DEIS.

21 ▪ More complex AOGCMs are not designed for the type of sensitivity analysis performed here
22   and are best used to provide results for groups of scenarios with much greater differences in
23   emissions such as the B1 (low), A1B (medium), and A2 (high) scenarios.

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

26 ### 3.4.3.2.2 Scaling Approach

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

---

[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

1 emissions for the A1B (medium) scenario in 2020 are 46,339 MMTCO$_2$, and represent the No Action
2 Alternative. Global emissions for the optimized scenario are 103 MMTCO$_2$ less, or 46,236 MMTCO$_2$.

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

10   Where information in the analysis included in this DEIS is incomplete or unavailable, NHTSA
11 has relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR §
12 1502.22(b)). In this case, despite the inconsistencies between the IPCC assumptions on global trends
13 across all GHG-emitting sectors (and the drivers that affect them) and the particularities of the Volpe
14 model on the United States transportation sector, the approach used is valid for this analysis; these
15 inconsistencies affect all of the alternatives equally, and thus they do not hinder a comparison of the
16 alternatives in terms of their relative effects on climate.

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

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

27 ### 3.4.3.2.4 Tipping Points and Abrupt Climate Change

28   In a linear system, the response is proportional to the change in a driver. For climate, CO$_2$ and
29 temperature are two key drivers. However, the climate system is complex; there are many positive and
30 negative feedback mechanisms. Moreover, there may be thresholds in the response of the system. Below
31 the thresholds, the response may be small or zero, and above the thresholds, the response could be much
32 quicker than previously observed or expected. The term "tipping point" refers to a situation where the
33 climate system reaches a point at which there is a strong and amplifying positive feedback from only a
34 moderate addition change in driver, such as CO$_2$ or temperature increase. These tipping points can result
35 in abrupt climate change—defined in Alley at al (2002) (cited in Meehl, et al. 2007, p. 775) to "occur
36 when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate
37 determined by the climate system itself and faster than the cause."

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

1   has led some climate scientists including Hansen et al., (2007b) to conclude that a CO_2 level exceeding
2   about 450 ppm is "dangerous."[34]

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

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

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

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

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

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

---

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

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

3   **3.4.4   Consequences**

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

6   **3.4.4.1 Greenhouse Gas Emissions**

7   To estimate the emissions resulting from changes in passenger car and light truck CAFE
8   standards, NHTSA uses the Volpe model (see Section 3.1.4 for a discussion of the model). The change in
9   fuel use projected to result from each alternative CAFE standard determines the resulting impacts on total
10   and petroleum energy use, which in turn affects the amount of CO_2 emissions. Reducing fuel use also
11   lowers CO_2 emissions from the use of fossil carbon-based energy during crude oil extraction,
12   transportation, and refining, as well in the transportation, storage, and distribution of refined fuel. Because
13   CO_2 accounts for such a large fraction of total GHG emitted during fuel production and use – more than
14   95 percent, even after accounting for the higher global warming potentials of other GHGs – NHTSA's
15   consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the savings in fuel
16   use that accompany higher fuel economy.

17   GHG emissions were estimated for each alternative. In the discussion and table that follows,
18   emission reductions represent the differences in total annual emissions by all cars or light trucks in use
19   between their estimated future levels under the No Action Alternative, and with each alternative CAFE
20   standard in effect. Emission reductions resulting from the CAFE standard for MY 2011-2015 cars and
21   light trucks were estimated from 2010 to 2100. Reductions begin in the year 2010, the first year that MY
22   2011 vehicles are on the road. For each alternative, all vehicles after MY 2015 were assumed to meet the
23   MY 2015 CAFE standard. Emissions were estimated for all alternatives through 2100, and these
24   emissions were compared against the Notice of Proposed Rulemaking (NPRM) baseline (which assumes
25   all vehicles post MY 2010 meet the MY 2010 standard) to estimate emission reductions. The Volpe
26   model estimates emissions through the year 2060.[35] As a simplifying assumption, annual emission
27   reductions from 2061-2100 were held constant at 2060 levels.

28   Total emissions and emission reductions resulting from implementation of the seven alternatives
29   to new passenger cars and light trucks from 2010-2100 are shown below in Table 3.4-1 and Figure 3.4-4.
30   Emissions for the period range from 213,000 MMTCO$_2$ for the technology exhaustion alternative to
31   248,000 MMTCO$_2$ for the No Action Alternative. Compared to the No Action Alternative, projections of
32   emission reductions over the 2010 to 2100 timeframe due to the MY 2011-2015 CAFE standard ranged
33   from 18,333 to 35,378 MMTCO$_2$.[36] Compared against global emissions of 4,850,000 MMTCO$_2$ over this
34   period (projected by the A1B-medium scenario), this rulemaking is expected to reduce global CO_2
35   emissions by about 0.4 to 0.7 percent.

---

[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)

■ Total Emissions □ Emission Reduction Compared to No Action Alternative
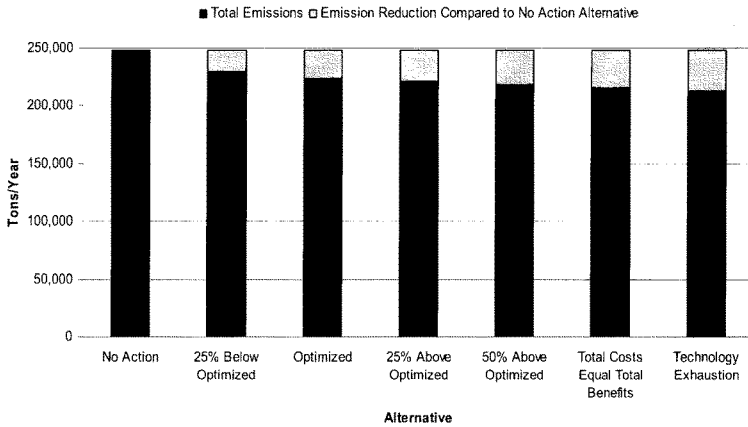
To gain a sense of the relative impact of these reductions, it can be helpful to compare them against emission projections from the transportation sector, as well as expected or stated goals from existing programs designed to reduce CO_2 emissions.

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)

GHG 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
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

160

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

11 　　In their *Annual Energy Outlook 2007*, EIA projects United States transportation CO_2 emissions to
12 increase from 2,037 MMTCO$_2$ in 2010 to 2,682 MMTCO$_2$ in 2030,[37] with total United States emissions
13 from transportation over this period at 49,287 MMTCO$_2$. Over this same timeframe, the emissions
14 reductions over the range of the proposed standards are projected to be 1,562 to 3,072 MMTCO$_2$, which
15 would yield a 5 to 10 percent reduction from the transportation sector. The environmental impact from
16 increasing fuel economy standards grows as new vehicles enter the fleet and older vehicles are retired.
17 For example, in 2030, projected emission reductions are 190 MMTCO$_2$, a 7 percent decrease from
18 projected United States transportation emissions of 2,682 MMTCO$_2$ in 2030. It is important to note that
19 the EIA did not take into account the expected effects of this rulemaking into their forecast (EIA, 2007),
20 thus allowing a comparison of the impact of this rulemaking to United States transportation emissions
21 under the No Action Alternative.

22 　　As another measure of the relative environmental impact of this rulemaking, these emission
23 reductions can be compared to existing programs designed to reduce GHG emissions in the United States.
24 In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate
25 Initiative (WCI) to develop regional strategies to address climate change. The WCI has a stated goal of
26 reducing 350 MMTCO$_2$ equivalent over the period from 2009-2020 (WCI, 2007). By comparison, this
27 rulemaking is expected to reduce CO_2 emissions by 379 to 762 MMTCO$_2$ over the same time period. In
28 the Northeast, nine Northeast and Mid-Atlantic states have formed the Regional Greenhouse Gas
29 Initiative (RGGI) to reduce CO_2 emissions from power plants in that region. Emission reductions from
30 2006-2024 are estimated at 268 MMTCO$_2$ (RGGI, 2006).[38] By comparison, NHTSA forecasts that this
31 rulemaking will reduce CO_2 emissions by 773 to 1,540 MMTCO$_2$ over this timeframe. It is, important to
32 note, however, that these projections are only estimates, and the scope of these climate programs differs
33 from this rulemaking in geography, sector, and purpose.

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

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

[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.

1   **3.4.4.2 Sensitivity Analysis**

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

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

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

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

32   **3.4.4.2.1 Range of Input Values in Sensitivity Analysis**

33   The sensitivity analysis examines a range of CO_2 values from $0 per metric ton to $14 per metric
34   ton CO_2 ($51.34 per metric ton carbon). The PRIA uses a reference value of $7.50 per metric ton CO_2
35   ($27.50 per metric ton carbon). Like the reference value, the alternative values for CO_2 are assumed to
36   increase at 2.4 percent annually beginning in 2011.

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

---

[39] PRIA Page IX-10

1   The sensitivity analysis examines the range of low to high price estimates for gasoline in the *AEO*
2   *2008 Early Release Forecast*[40]. For the "high-case" scenario the price of gasoline was $3.37 per gallon
3   (average price for MY 2011-2030); while for the "low-case" scenario the price of gasoline was $2.04 per
4   gallon (average price for MY 2011-2030.) The PRIA uses the reference price estimate for gasoline in the
5   *AEO 2008 Early Release Forecast*.[41]

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

8   Finally, the sensitivity analysis examines the effect of a discount rate of 3 percent, rather than the
9   7 percent reference value for the discount rate used in the PRIA. The sensitivity analysis did not include
10   the effect of discount rates higher than the 7 percent reference value.

11   ### 3.4.4.2.2 Sensitivity Analysis for CO_2 Reduction under Optimized Alternative

12   Table 3.4-3 shows that the range of estimated CO_2 reductions mirrors the findings from the PRIA
13   sensitivity analysis about how changes in economic assumptions affect the levels of optimized fuel
14   economy. As in the case of CAFE standards, Table 3.4-3 shows that variations in the value of CO_2, the
15   value of petroleum import externalities, and the rebound effect have relatively little impact on CO_2
16   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 (MMTCO₂) 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

17
18   NHTSA selected the various economic assumptions to be used in the Volpe model carefully, and
19   described those values and the process for selecting each of them in detail in Section 7 of Chapter V of
20   the NPRM, as well as in Chapter VIII of the PRIA. Please see those passages for detailed discussions of
21   the rationale for selecting each value. With regard to each of these economic inputs, NHTSA notes that:

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

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

---

[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

1　　externalities from petroleum consumption and imports.[42]　More recently, ORNL updated its
2　　estimates of the value of these externalities, using the analytic framework developed in its
3　　original 1997, and used them in a study for EPA in its Renewable Fuel Standard Rule of
4　　2007.　The updated ORNL study was subjected to a detailed peer review by experts selected
5　　by EPA.

6　　■　**Fuel Price:** NHTSA relied on the most recent fuel price projections from the EIA's *Annual*
7　　　　*Energy Outlook* (AEO) for this analysis.　Specifically, NHTSA used the AEO 2008 Early
8　　　　Release forecasts of inflation-adjusted (constant-dollar) retail gasoline and diesel fuel prices,
9　　　　which represent the EIA's most up-to-date estimate of the most likely course of future prices
10　　　　for petroleum products.[43]　Federal government agencies generally use EIA's projections in
11　　　　their assessments of future energy-related policies.

12　　■　**Rebound Effect:** In order to arrive at a preliminary estimate of the rebound effect for use in
13　　　　assessing the fuel savings, emissions reductions, and other impacts of alternative standards,
14　　　　NHTSA reviewed 22 studies of the rebound effect conducted from 1983 through 2005.　Then
15　　　　a detailed analysis of the 66 separate estimates of the long-run rebound effect was conducted
16　　　　and reported in these studies.

17　　■　**Discount Rate:** The White House Office of Management and Budget (OMB) provides
18　　　　detailed guidance for federal agencies in conducting Regulatory Impact Assessments.[44]　This
19　　　　guidance directs federal agencies to provide estimates of net benefits from proposed
20　　　　regulations using a discount rate of 7 percent as a base case.　When the costs of proposed
21　　　　regulations are likely to be reflected in higher consumer prices, however, a discount rate of 3
22　　　　percent is more appropriate.　Thus OMB guidance advises federal agencies to evaluate
23　　　　proposed regulations using both 3 percent and 7 percent discount rates.

24　　### 3.4.4.3 Effect of Credit Flexibility on Emissions

25　　　　Consistent with the Energy Independence and Security Act (EISA), NHTSA's NPRM not only
26　　proposes new CAFE standards for passenger cars and light trucks, but also revises provisions regarding
27　　the creation and application of CAFE credits.　In this context, CAFE credits refer to flexibilities allowed
28　　under the Energy Policy and Conservation Act (EPCA) provisions governing use of Alternative Motor
29　　Fuels Act (AMFA) credits, allowable banked credits, and transfers of credits between the car and truck
30　　fleets allowed under EISA.　The additional flexibility to transfer credits between manufacturing
31　　companies is addressed separately below.　Because EPCA prohibits NHTSA from considering these
32　　flexibilities when determining the stringency of CAFE standards, NHTSA did not attempt to do so when
33　　it developed proposed standards by using the Volpe Model to estimate the stringency at which net
34　　benefits to society would be maximized.

[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).

1　　　　Under the EISA, AMFA credits are being phased out. The allowable credits are reduced so that
2　by 2020 such credits will no longer be allowed under law.

3　　　　However, responding to the Federal Register notice regarding the scope of analysis required by
4　NEPA, EPA and the California Attorney General have indicated that, notwithstanding EPCA's
5　constraints regarding the context for the establishment of CAFE standards, NHTSA should attempt to
6　account for the creation and application of CAFE credits when evaluating the effects of proposed CAFE
7　standards.

8　　　　As we explained in the NPRM, NHTSA believes that manufacturers are likely to take advantage
9　of these flexibility mechanisms, thereby reducing benefits and costs. With respect to AMFA credits, for
10　example, the product plans of manufacturers identify the models and quantities of flex-fuel vehicles they
11　intend to build. While individual product plans are protected as confidential commercial information, in
12　the aggregate they reveal that manufacturers could make use of AMFA credits to assist in compliance
13　with the standards. Manufacturers building dual fuel vehicles are entitled to a CAFE benefit of up to 1.2
14　mpg in 2011-2014 and 1.0 mpg in 2015 for each fleet. The agency tentatively estimates that the impact of
15　the use of AMFA credits identified in these product plans could result in an average reduction of
16　approximately 0.7 mpg in each year for model years 2011 through 2015, and a related increase in CO_2
17　emissions. The agency recognizes that these product plans were submitted in May 2007, and our AMFA
18　credit estimate may change based on updated product plan projections. With respect to other than AMFA
19　credits (e.g., CAFE credits earned through over-compliance, credits transferred between fleets, and credits
20　acquired from other manufacturers), the agency does not have a sound basis to predict the extent to which
21　manufacturers might use them, particularly since the credit transfer and credit trading programs have been
22　only recently authorized.

23　### 3.4.4.3.1 Difficulties in Quantifying Emissions Implications of Credits

24　　　　Questions NHTSA might need to address in performing an analysis of potential credit use and the
25　resulting emissions include the following:

26　　　　■　Would manufacturers that have never made use of CAFE flexibilities do so in the future?

27　　　　■　Would flexibility-induced increases in the sale of flexible fuel vehicles (FFVs) lead to
28　　　　　　increases in the use of alternative fuels?

29　　　　■　Having earned CAFE credits in a given model year, in what model year would a given
30　　　　　　manufacturer most likely apply those credits?

31　　　　■　Having earned CAFE credits in one fleet (i.e., passenger or nonpassenger), to which fleet
32　　　　　　would a given manufacturer most likely apply those credits?

33　　　　Such questions are similar to, though possibly less tractable than the behavioral and strategic
34　questions that would be entailed in attempting to represent manufacturers' ability to "pull ahead" the
35　implementation of some technologies, and in attempting to estimate CAFE-induced changes in market
36　shares. As discussed on pp. 24393-24394 of the NPRM, data and approaches are lacking on how to
37　analyze manufacturers' ability to develop and strategically time the application of new technologies.
38　Significant concerns remain on how to develop a credible market share model for integration into the
39　modeling system NHTSA has used to analyze the costs and effects of CAFE standards.

40　### 3.4.4.3.2 Market Behavior

1 Some manufacturers make significant use of current flexibilities. Other manufacturers regularly
2 exceed CAFE standards applicable to one or both fleets, and allow the corresponding excess CAFE
3 credits to expire. Some manufacturers transfer earned CAFE credits to future (or past) model years, but
4 do not produce FFVs and create corresponding CAFE credits. Finally, still other manufacturers regularly
5 pay civil penalties for noncompliance, even when producing FFVs would significantly reduce the
6 magnitude of those penalties.

7 Notwithstanding these uncertainties, NHTSA anticipates that manufacturers would make varied
8 use of the flexibilities provided by EPCA, as amended by EISA. These flexibilities may result in
9 somewhat lower benefits (i.e., CO_2 emission reduction) than estimated here, as manufacturers' actions
10 would cause VMT levels, fuel consumption, and emissions to be higher than reported here. The agency
11 expects that all of the seven alternatives reported here—including the No Action Alternative relative to
12 which the effects of the other six are measured—would be affected. Insofar as the No Action Alternative
13 would be affected, it is even less certain how the net effects of each of the other six would change.

14 NHTSA expects that use of flexibilities would tend to be greater under more stringent standards.
15 As stringency increases, the potential for manufacturers to face greater cost increases, and for some,
16 depending on its level of technological implementation, may rise significantly. The economic advantage
17 of employing allowed flexibilities increases and may affect manufacturer behavior in this regard. A
18 critical factor in addressing the fuel and emissions impacts of such flexibilities is that the likely extent of
19 utilization cannot be assumed constant across the alternatives.

20 ### 3.4.4.3.3 Trading Between Companies

21 The allowable trading between manufacturers is categorically different from the case discussed
22 above. The provisions in section104 of Title I of the EISA require that fuel savings, and thus, GHG
23 emissions, be conserved in any trades effected between manufacturers. As such, there would not be an
24 environmental impact of any such since any increases in fuel use or emissions would have to be offset by
25 the manufacturer buying the credits.

26 ### 3.4.4.4 Direct and Indirect Effects on Climate Change

27 The direct and indirect effects of the alternatives on climate change are described in the following
28 section in terms of (1) atmospheric CO_2 concentrations, (2) temperature, (3) precipitation, and (4) sea
29 level rise. Within each section, the MAGICC results are reported first, followed by the results of the
30 scaling approach.

31 ### 3.4.4.4.1 Atmospheric Carbon Dioxide Concentrations

32 ### MAGICC Results

33 The MAGICC is a simple climate model that is well calibrated to the mean of the multi-model
34 ensemble results for three of the most commonly used emission scenarios – B1 (low), A1B (medium),
35 and A2 (high) from the IPCC SRES series -- as shown in Table 3.4-4.[45] As the table indicates, the model
36 runs developed for this analysis achieves relatively good agreement with IPCC WG1 estimates in terms of
37 both CO_2 concentrations and surface temperature.

TABLE 3.4-4

---

[45] The default climate sensitivity in MAGICC of 2.6 °C was used.

Comparison of MAGICC Results and Reported IPCC Results (IPCC 2007a)					
Scenario	CO₂ Concentration (ppm)		Radiative Forcing (W/m²)		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

1
2   As discussed earlier in methodology, Section 3.4.2, the SRES A1B (medium) scenario was used
3 to represent the No Action Alternative in the MAGICC runs. The results of MAGICC simulations for the
4 No Action Alternative and the six alternative CAFE levels, in terms of CO_2 concentrations and increase in
5 global mean surface temperature in 2030, 2060, and 2100 are presented in Table 3.4-5 and Figures 3.4-4
6 to 3.4-7. As Figures 3.4-4 and 3.4-5 show, the impact on the growth in CO_2 concentrations and
7 temperature is just a fraction of the total growth in CO_2 concentrations and global mean surface
8 temperature. However, the relative impact of the CAFE alternatives is illustrated by the reduction in
9 growth of both CO_2 concentrations and temperature in the Technology Exhaustion Alternative, which is
10 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 CO₂ Concentration and Global Mean Surface Temperature Increase in 2100 Using MAGICC						
Totals by Alternative	CO₂ 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

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

11

1

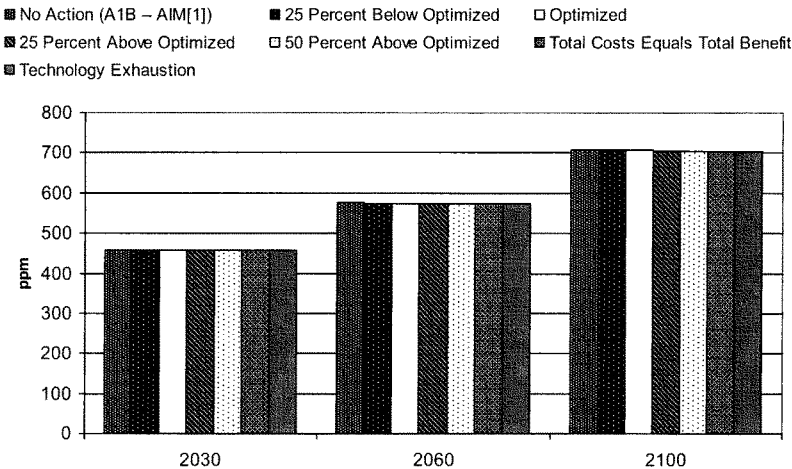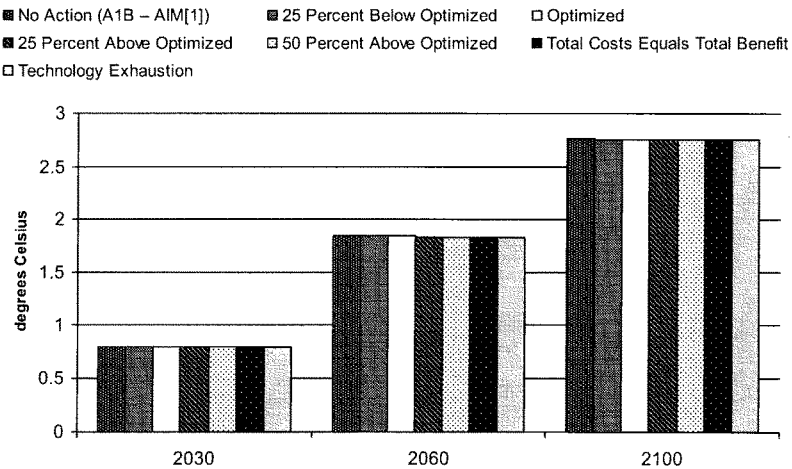**Figure 3.4-4 CO2 Concentrations for the A1B Scenario and CAFE Alternatives**

▦ No Action (A1B – AIM[1])   ■ 25 Percent Below Optimized   □ Optimized
▨ 25 Percent Above Optimized   ▨ 50 Percent Above Optimized   ▨ Total Costs Equals Total Benefit
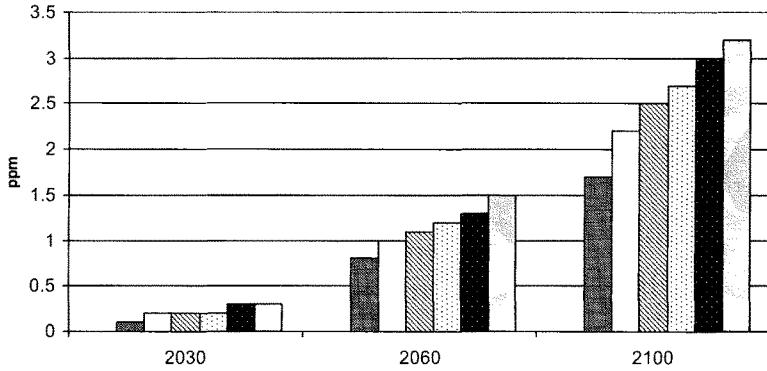▨ Technology Exhaustion

2
3   **Figure 3.4-5 Increase in Global Mean Surface Temperature for the A1B Scenario and**
4   **CAFE Alternatives**

▦ No Action (A1B – AIM[1])   ▨ 25 Percent Below Optimized   □ Optimized
▨ 25 Percent Above Optimized   □ 50 Percent Above Optimized   ■ Total Costs Equals Total Benefit
□ Technology Exhaustion

5

Figure 3.4-6 Reduction in the Growth of CO_2 Concentrations for the A1B Scenario and CAFE Alternatives

■ No Action (A1B – AIM[1]) ▨ 25 Percent Below Optimized □ Optimized
▨ 25 Percent Above Optimized ▢ 50 Percent Above Optimized ■ Total Costs Equal Total Benefits
□ Technology Exhaustion

3
4
5
Figure 3.4-7 Reduction in the Growth of Global Mean Temperature for the A1B Scenario and CAFE Alternatives

■ No Action (A1B – AIM[1]) ▨ 25 Percent Below Optimized □ Optimized
▨ 25 Percent Above Optimized ▢ 50 Percent Above Optimized ■ Total Costs Equal Total Benefits
□ Technology Exhaustion

6
7
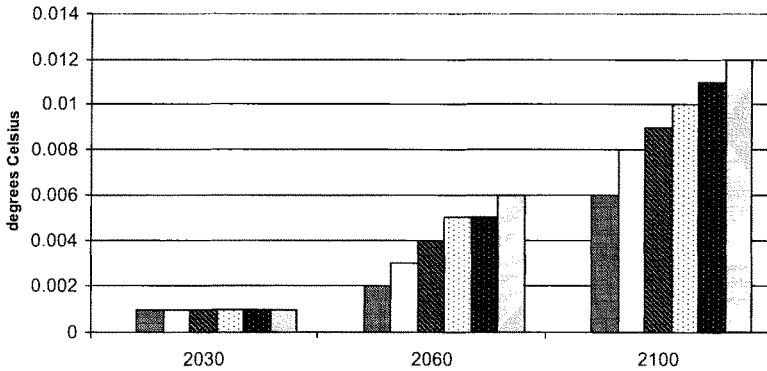
1   As shown in the table and figures, there is a fairly narrow band of estimated CO_2 concentrations
2   as of 2100, from 705 ppm for the most stringent alternative to 709 ppm for the No Action Alternative.
3   For earlier years, the range is tighter. As CO_2 concentrations are the key driver of all the other climate
4   effects (which in turn act as drivers on the resource impacts discussed in Chapter 4), this narrow range
5   implies that the differences among alternatives are difficult to distinguish.

6   ### Scaling Results

7   The global emission scenarios developed by the IPCC in the SRES (Nakicenovic et al., 2000),
8   showed ranges of cumulative emissions from 1990 to 2100 of CO_2 from 770 Gt[46] C to 2,450 Gt C (2,825
9   to 8,985 billion metric tons of CO_2). The three scenarios used in the IPCC WG1 Fourth Assessment
10   Report (IPCC, 2007) have the following emissions of CO_2 from 2005 to 2100[47]:

11   ▪ Low – B1: 3,145 gigatons (Gt) CO_2
12   ▪ Mid – A1B: 5,020 Gt CO_2
13   ▪ High – A2: 6,640 Gt CO_2

14   As indicated earlier in Table 3.4-4, for these emission scenarios, CO_2 concentrations increase
15   from 379 ppm in 2005 to mid-range estimates in 2100 of 550 ppm for the B1 (low) scenario, 715 ppm for
16   the A1B (medium) scenario, and 836 ppm for the A2 (high) scenario (IPCC, 2007). This implies that 42
17   percent, 52 percent, and 53 percent of the emitted CO_2 from 2005 to 2100 in the SRES B1 (low), A1B
18   (medium), and A2 (high) scenarios, respectively, is still in the atmosphere in 2100.[48] These percentages
19   can be used in a scaling approach. The amount of emitted CO_2 that remains in the atmosphere as of 2100
20   varies considerably depending upon when the CO_2 is emitted, which determines the length of time it is
21   subject to land and ocean uptake.

22   By applying the scaling factors developed above, the emission reductions for the six alternatives
23   yield CO_2 concentrations, as of 2100, as shown in Table 3.4-6. The results for scenario A1B (medium) in
24   this table (713 to 715 ppm) agree relatively well with the MAGICC results in Table 3.4-5 above (705 to
25   709 ppm). These concentrations are considerably higher than current concentrations, which were
26   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					
	CO_2 Emissions 2005-2100 (Bt CO_2)			CO_2 Concentrations in 2100 (ppm) a/		
Totals by Alternative	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

[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 CO₂ Concentrations in 2100 for the 2011-2015 CAFE Alternatives					
	CO₂ Emissions 2005-2100 (Bt CO₂)			CO₂ Concentrations in 2100 (ppm) a/		
Totals by Alternative	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

a/ Emission reduction estimates based on share of emitted CO₂ 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 (°C)
S = Climate sensitivity
CO_2 = CO₂ 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

1   temperature increase resulting from a sustained doubling of atmospheric CO_2 concentrations over pre-
2   industrial levels (IPCC, 2007). The calculations are also shown for three different emission scenarios: B1
3   (low), A1B (medium), and A2 (high). The range of GMSTE reductions (with respect to the No Action
4   Alternative) due to the different CAFE alternatives is 0.005 °C to 0.023 °C depending upon the climate
5   sensitivity and the CAFE alternative.

6   The IPCC estimates that for the A1B (medium) and B1 (low) scenarios, the average warming
7   from the AOGCMs as of 2100 is 65 to 70 percent of the estimated eventual equilibrium warming in the
8   21st century. With this information, and the data in Table 3.4-6, one can construct a bounding analysis on
9   the effects of the CAFE alternatives on average warming by 2100. The lower bound combines the lower
10   ends of the ranges on (a) the proportion of warming as of 2100 compared to eventual warming (viz., 65
11   percent), (b) the lowest value for the reduction in temperature for an action alternative compared to the
12   No Action Alternative from the table (viz., 0.005 °C, the value for the 25 Percent Below Optimized
13   Alternative, A2 (high) emission scenario, and climate sensitivity at 2.5 °C). This yields an estimate of a
14   lower bound temperature effect (compared to the No Action Alternative) of 65 percent * 0.005°C =
15   0.003°C. The upper bound, derived by the same approach but using high end values, is 70 percent *
16   0.023°C = 0.016°C for the Technology Exhaustion Alternative using a climate sensitivity of 4.5°C.

17   The range of 0.003°C to 0.016°C from the scaling approach encompasses the range of MAGICC
18   values (in Table 3.4-5) of 0.006°C to 0.012°C. Note that the scaling approach uses three different values
19   for climate sensitivity, whereas MAGICC only uses one (2.6 °C, the middle value used for the scaling
20   analysis), and so the greater range with the scaling approach is to be expected. The use of the scaling
21   approach illustrates that the alternatives' effectiveness in reducing temperature increases is somewhat
22   broader than the range projected in the DEIS using the MAGICC, and that the results are sensitive to the
23   value of climate sensitivity.

24   Table 3.4-8 summarizes the regional changes to warming and seasonal temperatures from the
25   IPCC fourth assessment. It is not possible at this point to quantify the changes to regional climate from
26   the CAFE alternatives but it is expected that they would reduce the changes relative to the reduction in
27   global mean surface temperature.

28   **3.4.4.4.3 Precipitation**

29   <u>MAGICC Results</u>

30   According to the IPCC WG1 (IPCC, 2007), global mean precipitation is expected to increase
31   under all the scenarios. Generally, precipitation increases occur in the tropical regions and high latitudes,
32   with decreases in the sub-tropics. The results from the AOGCMs suggest considerable uncertainty in
33   future precipitation for the three SRES scenarios.

34   Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has
35   relied on CEQ's regulations regarding incomplete or unavailable information (see 40 CFR § 1502.22(b)).
36   In this case, the IPCC (2007) summary of precipitation represents the most thoroughly reviewed, credible
37   assessment of this highly uncertain factor. NHTSA expects that the CAFE alternatives would reduce the
38   changes in proportion to their effects on temperature.

39

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 (°C)								
				GMSTE: Climate Sensitivity=2.5 °C			GMSTE: Climate Sensitivity=3 °C			GMSTE: Climate Sensitivity =4.5 °C		
	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. *Very likely* fewer very cold days.
	South Asia	*Likely* to be above the global mean	*Very likely* fewer very cold days.
	Southeast Asia	*Likely* to be similar to the global mean	
North America	Northern regions/Northern North America	*Likely* to exceed the global mean warming	Warming is *likely* to be greatest in winter. Minimum winter temperatures are *likely* to increase more than the average.
	Southwest		Warming is *likely* to be greatest in summer. Maximum summer temperatures are *likely* to increase more than the average.
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		

1

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	

2
3   The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium),
4   and B1 (low) scenarios (IPCC, 2007) is given as the scaled change in precipitation (as a percentage
5   change from 1980-1999 averages) divided by the increase in global mean surface warming for the same
6   period (per degree C) as shown in Table 3.4-9 below. The IPCC provides scaling factors in the year
7   ranges of 2011-2030, 2046-2065, 2080-2099, and 2180-2199. The scaling factors for the A1B (medium)
8   scenario were used in our analysis since MAGICC does not directly estimate changes in global mean
9   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

10
11   Applying these to the reductions in global mean surface warming provides estimates of changes
12 in global mean precipitation. Given that the CAFE alternatives reduce temperature increases slightly with
13 respect to the No Action Alternative, they also reduce predicted increases in precipitation slightly, as
14 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 (°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 (°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

1　is projected to increase but there would be longer periods between rainfall events. There
2　is a tendency for drying of the mid-continental areas during summer, indicating a greater
3　risk of droughts in those regions. Precipitation extremes increase more than does the
4　mean in most tropical and mid- and high-latitude areas."

5　　　　Regional variations and changes in the intensity of precipitation events cannot be quantified
6　further. This is due primarily to the availability of AOGCMS required to estimate these changes. These
7　models are typically used to provide results between scenarios with very large changes in emissions such
8　as the SRES B1 (low), A1B (medium), and A2 (high) scenarios and very small changes in emission
9　profiles would produce results that would be difficult to resolve between scenarios with small changes in
10　emissions. In addition, the multiple AOGCMs produce results that are regionally consistent in some
11　cases but for other areas inconsistent.

12　Scaling Results

13　　　　Given that the MAGICC approach is based on a scaling methodology (per Table 3.4-9 above), a
14　separate scaling calculation was not employed to characterize precipitation.

15　　　　Table 3.4-11 summarizes the regional changes to precipitation from the IPCC fourth assessment.
16　It is not possible at this point to quantify the changes to regional climate from the CAFE alternatives but it
17　is expected that they would reduce the changes relative to the reduction in global mean surface
18　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.	
		Precipitation in summer is *likely* to increase.	

	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.	
		Precipitation in summer is *likely* to increase.	
		Very likely to be an increase in the frequency of intense precipitation.	
		Extreme rainfall and winds associated with tropical cyclones are *likely* to increase.	
	South Asia	Precipitation in summer is *likely* to increase.	
		Very likely to be an increase in the frequency of intense precipitation.	
		Extreme rainfall and winds associated with tropical cyclones are *likely* to increase.	
	Southeast Asia	Precipitation in boreal winter is *likely* to increase in southern parts.	
		Precipitation in summer is *likely* to increase in most parts of southeast Asia.	
		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.	

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**
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.	

2
3   **3.4.4.4.4 Sea Level Rise**

4   IPCC identifies four primary components to sea level rise: thermal expansion of ocean water;
5 melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in
6 Greenland (IPCC, 2007). Ice sheet discharge is an additional factor that could influence sea level over the
7 long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise,
8 using a non-linear temperature- and pressure-dependent expansion coefficient (Wigley, 2003). It also
9 addresses the other three primary components through ice-melt models for small glaciers, and the
10 Greenland and Antarctic ice sheets.

11   The state-of-the-science reflected as of the publication of the IPCC AR4 report (IPCC 2007)
12 project sea level to rise of 18 to 59 centimeters (cm) by 2090 to 2099 (Parry, 2007 as cited by National
13 Science and Technology Council, 2008). This projection does not include all changes in ice sheet flow or
14 the potential for rapid acceleration in ice loss (Alley et al, 2005; Gregory and Huybrechts, 2006; Hansen,
15 2005 as cited by Pew, 2007). Several recent studies have found the IPCC's estimates of potential sea
16 level rise may be underestimated regarding ice loss from the Greenland and Antarctic ice sheets
17 (Shepherd and Wignham, 2007; Csatho et al., 2008) and ice loss from mountain glaciers (Meier et al.,
18 2007). Further, IPCC results for sea level projections may underestimate sea level rise that would be
19 gained through changes in global precipitation (Wentz et al., 2007; Zhang et al., 2007). Rahmstorf (2007)
20 used a semi-empirical approach to project future sea-level rise. The approach yielded a proportionality
21 coefficient of 3.4 millimeters (mm) per year per degree C of warming, and a projected sea-level rise of
22 0.5 to 1.4 meters (m) above 1990 levels in 2100 when applying IPCC Third Assessment Report warming
23 scenarios. Rahmstorf (2007, p. 370) concludes that, "A rise over 1 meter by 2100 for strong warming
24 scenarios cannot be ruled out."

25   Sea level rise is discussed in more detail in Section 4.5.5, Coastal Ecosystems.

26   **MAGICC Results**

27   MAGICC reports sea level rise in increments of 0.1 centimeter (i.e., 1 millimeter). The impact on
28 sea level rise from the scenarios is at the threshold of the model's reporting: the alternatives reduce sea

1 level rise by 0.1 centimeter (Table 3.4-12). Although the model does not report enough significant figures
2 to distinguish between the effects of the alternatives, it is clear that the more stringent the alternative (i.e.,
3 the lower the emissions), the lower the temperature (as shown above); and the lower the temperature, the
4 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

5
6 <u>Scaling Results</u>

7 One of the areas of climate change research where there have been many recent developments is
8 the science underlying the projection of sea level rise. As noted above, there are four key components of
9 sea level rise. The algorithms in MAGICC do not reflect some of the recent developments in the state-of-
10 the-science, so the scaling approach is an important supplement.

11 Table 3.4-13 presents estimates of sea level rise provided by the IPCC WG1, excluding the effect
12 of scaled-up ice sheet discharge, where further accelerations have been observed but could not be
13 quantified with confidence (IPCC, 2007). Note that "for each scenario the lower/upper bound for sea
14 level rise is larger/smaller than the total of the lower/upper bounds of the contributions, since the
15 uncertainties of the contributions are largely independent" (IPCC 2007a, p. 620). The midpoint value for
16 the A1B (medium) scenario is 0.35 meter or 35 centimeters, in good agreement with the MAGICC
17 estimate of 38 centimeters. The midpoints for the B1 (low) and A2 (high) scenarios are 28 centimeters
18 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

1   centimeter. Thus, despite the fact that MAGICC does not reflect some of the more recent developments
2   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

3
4   In summary, the impacts of the MY 2011-2015 CAFE alternatives on global mean surface
5   temperature, sea level rise, and precipitation are relatively small in the context of the expected changes
6   associated with the emission trajectories in the SRES scenarios. This is due primarily to the global and
7   multi-sectoral nature of the climate problem. Emissions of CO_2, the primary gas driving the climate
8   effects, from the United States automobile and light truck fleet represented about 2.5 percent of total
9   global emissions of all GHGs in the year 2000 (EPA, 2008; CAIT, 2008). While a significant source, this
10   is a still small percentage of global emissions, and the relative contribution of CO_2 emissions from the
11   United States light vehicle fleet is expected to decline in the future, due primarily to rapid growth of
12   emissions from developing economies (which are due in part to growth in global transportation sector
13   emissions). In the SRES A1B (medium) scenario (Nakicenovic et al., 2000), the share of liquid fuel use –
14   mostly petroleum and biofuels – from Organization for Economic Cooperation and Development (OECD)
15   countries declines from 60 percent in 2000 to 17 percent in 2100.

16

1 **3.5   OTHER POTENTIALLY AFFECTED RESOURCE AREAS**

2   This section describes the affected environment and environmental consequences of the
3 alternatives on Water Resources (3.5.1), Biological Resources (3.5.2), Land Use and Development
4 (3.5.3), Safety (3.5.4), Hazardous Materials and Regulated Wastes (3.5.5), Natural Areas Protected under
5 Section 4(f) (3.5.6), Historic and Cultural Resources (3.5.7), Noise (3.5.8), and Environmental Justice
6 (3.5.9). These sections discuss the current and projected future threats to these resources from non-global
7 climate change impacts relevant to the alternatives, and provide primarily qualitative assessments of any
8 potential consequences of the alternatives, either positive or negative, on these resources.

9   This section does not describe the affected environment in relation to, or address potential
10 environmental consequences resulting from, global climate change. For a description of potential impacts
11 of global climate change, see Chapter 4.

12 **3.5.1   Water Resources**

13 **3.5.1.1 Affected Environment**

14   Water resources include surface water and groundwater. Surface waters are waterbodies open to
15 the atmosphere, such as rivers, streams, lakes, oceans, and wetlands; surface waters can contain either
16 fresh or salt water. Groundwater is found in natural reservoirs or aquifers below the earth's surface.
17 Sources of groundwater include rainfall and surface water, which penetrate the ground and recharge the
18 water table. The following section discusses the current and projected future threats to these resources
19 from non-global climate change impacts relevant to the proposed action. The production and combustion
20 of fossil fuels and the production of biofuels are the identified relevant sources of impact. Biological
21 Resources, in Section 3.5.2, describes relevant aspects of surface water resources from a habitat
22 perspective. For a discussion of the effects of global climate change on freshwater sand coastal systems,
23 please see Sections 4.5.3 and 4.5.5.

24   Impacts to water resources during recent decades have come from a number of different sources.
25 These impacts include increased water demand for human and agricultural use, pollution from point and
26 non-point sources, and climatic changes. One of the major anthropogenic, or human-made, causes of
27 water quality impacts has been the extraction, refining, and combustion of petroleum products, or oil.

28   **3.5.1.1.1 Oil Extraction and Refining**

29   Oil refineries, which produce the gasoline and diesel used for transportation fuels and the motor
30 vehicles that combust petroleum based fuels, are major sources of VOCs, SO_2, NOx, CO, and other air
31 pollutants (EPA, 2008; EPA, 1997). In the atmosphere, SO_2 and NOx pollutants contribute to the
32 formation of acid rain (the wet, dry, or fog deposition of SO_2 and NOx), which enters water bodies either
33 directly or as runoff from terrestrial systems (see Section 3.3. for further information on air quality).
34 Once in surface waters, these pollutants can cause acidification of the waterbody, changing the pH of the
35 system and affecting the function of freshwater ecosystems (Van Dam, 1996; Baum, 2001; EPA, 2008).
36 An EPA survey of sensitive freshwater lakes and streams, those with a low capacity to neutralize, or
37 buffer against, decreases in pH, found that 75 percent of the lakes and 50 percent of the streams had
38 experienced acidification as a result of acid rain (EPA, 2008). EPA has identified the areas of the United
39 States most sensitive to acid rain as, "the Adirondacks and Catskill Mountains in New York State, the
40 mid-Appalachian highlands along the east coast, the upper Midwest, and mountainous areas of the
41 western United States (EPA, 2008)."

1   Water quality may also be affected by petroleum products released during the refining and
2   distribution process. Oil spills can lead to contamination of surface and ground water, and can result in
3   impacts to drinking water, marine, and freshwater ecosystems (Section 3.5.2). EPA estimates that of the
4   volume of oil spilled in "harmful quantities," as defined under the Clean Water Act, 83.8 percent was
5   deposited in internal/headland waters and nearshore (within 3 miles of shore), with 17.5 percent spilled
6   from pipeline spills, often in inland areas (EPA, 2004). The environmental impacts on and recovery time
7   for individual water bodies vary based on a number of factors (e.g., salinity, water movement, wind,
8   temperature), with faster moving and warm water locations recovering more quickly (EPA, 2008b).

9   During oil extraction, the primary waste product is a highly saline liquid called "produced water"
10 which may contain metals and other potentially toxic components (Section 3.5.5 Hazardous Materials for
11 more on produced water). Produced water and other oil extraction wastes are most commonly disposed
12 of via reinjection to the well, which increases pressure thus forcing out more oil. Potential impacts from
13 these wastes generally occur if large amounts are spilled and enter surface waters, decommissioned wells
14 are improperly sealed, or saline water from the wells intrudes into fresh surface water or ground water
15 (Kharaka and Otton, 2005).

16   Water quality impacts also occur as a result of contamination by VOCs. A nationwide study of
17 groundwater aquifers conducted by United States Geological Survey (USGS) found VOCs in 90 of 98
18 major aquifers sampled (Zogorski et al., 2006). The study concluded that, "[t]he widespread occurrence
19 of VOCs indicates the ubiquitous nature of VOC sources and the vulnerability of many of the Nation's
20 aquifers to low-level VOC contamination." Several of the most commonly identified VOCs were a
21 gasoline additive (gasoline oxygenate methyl tertiary butyl ether [MTBE]) and a gasoline hydrocarbon
22 (toluene). USGS notes, however, that only 1 to 2 percent of the well samples had concentrations of
23 VOCs that were at levels of potential concern to human health; none of the VOCs found in potentially
24 hazardous quantities were primarily used in the manufacture of fuels or as fuel additives (Zogorski et al.,
25 2006). See Section 3.5.5 for a description of toxic chemicals released during fuel production and
26 combustion.

27   **3.5.1.1.2 CO_2 Emissions**

28   Oceanic concentrations of CO_2 from anthropogenic sources, primarily the combustion of fossil
29 fuels, have increased since the industrial revolution and will likely continue to increase into the future. In
30 addition to its role as a GHG, atmospheric CO_2 plays a key role in the biogeochemical cycle of carbon.
31 Atmospheric CO_2 concentrations influence the chemistry of natural waters.

32   Atmospheric concentrations of CO_2 are in equilibrium with aqueous carbonic acid (H_2CO_3),
33 which in turn influences the aqueous concentrations of bicarbonate ion (HCO_3^-) and carbonate ion (CO_3^{2-}).
34 The carbonate system is one of the key features of natural waters in that it affects pH, which controls the
35 availability of some nutrients and toxic materials in freshwater and marine systems.

36   One of the large-scale non-climatic effects of an increase in CO_2 emissions is the potential for
37 ocean acidification. The ocean exchanges huge quantities of CO_2 with the atmosphere, and when
38 atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere
39 into the oceans. This lowers the pH of the oceans, reducing the availability of calcium. According to
40 Richardson and Poloczanska (2008), "declines in ocean pH may impact calcifying organisms, from corals
41 in the tropics to pteropods (winged snails) in polar ecosystems, and will take tens of thousands of years to
42 reequilibrate to preindustrial conditions. For more information on the non-climate effects of CO_2 on plant
43 and animal communities, see Section 3.1.2 and Section 4.7.

1   ### 3.5.1.1.3 Biofuel Cultivation

2   The need to supply agricultural products for a growing population will continue to affect water
3   resources; future irrigation needs are likely to include increased production of both food and biofuel crops
4   (Simpson, 2008). Global demand for water is increasing as a result of population growth and economic
5   development, and irrigation currently accounts for around 70 percent of global water withdrawals
6   (Shiklomanov and Rodda, 2003 as cited in Kundzewicz et al., 2007). The EPA states that, "Demand for
7   biofuels is also likely to have impacts on water including increasing land in agricultural production,
8   resulting in increased risk of runoff of sediments, nutrients, and pesticides. Production of biofuels also
9   uses significant amounts of water" (EPA, 2008, p. 21). Runoff from agricultural sources often contains
10   nitrogen, phosphorus, and other fertilizers and chemicals that harm water quality and can lead to
11   euthropication (the enrichment of a water body with plant-essential nutrients leading to a depletion of
12   oxygen) (Vitousek et al., 1997). If biofuel production in the United States continues to be based on input-
13   intensive crops like corn and soybeans, projected expansions to meet demand will likely result in
14   significantly increased runoff of fertilizer and sediment (Simpson, 2008).

15   ### 3.5.1.2 Environmental Consequences

16   As discussed in Section 3.3, Air Quality, each alternative except the No Action Alternative is
17   expected to decrease the amount of VOCs, SO_2, NOx, and other air pollutants in relation to the No Action
18   Alternative levels. Reductions in these pollutant levels would be the result of lower petroleum fuel
19   consumption by the cars and light trucks, as well as a potential for reduced extraction, transportation, and
20   refining of crude oil. The agency expects that lower releases (air emissions) would decrease the
21   formation of acid rain in the atmosphere as compared to baseline levels (Appendix B-1); these factors
22   would have a beneficial impact on fresh water quality thorough decreased eutrophication and
23   acidification.

24   The positive effects on acid rain formation would likely be relatively low because of the limited
25   overall effect of the release of SO_2 and NOx (Section 3.3).

26   As discussed in Section 3.4, the impact of the CAFE alternatives on CO_2 is relatively small
27   compared to global emissions of CO_2. The United States automobile and light truck fleet represent less
28   than 4 percent of the global emissions of CO_2 from cars and light trucks and these percentage are
29   projected to decline in the future, due primarily to rapid growth of emissions from developing countries.

30   Each alternative to the proposed action could potentially lead to an indirect increase in the
31   production of biofuels, depending upon the mix of tools manufacturers use to meet the increased CAFE
32   standards, economic demand, and technological capabilities. If biofuel production increased, additional
33   agricultural runoff could occur. However, due to the uncertainty surrounding how manufacturers would
34   meet the new requirements, and the fact that none of the proposed standards prescribe increased biofuel
35   use, these potential impacts are not quantifiable.

36   ### 3.5.2 Biological Resources

37   ### 3.5.2.1 Affected Environment

38   Biological resources include vegetation, wildlife, and special status species (those classified as
39   "Threatened" or "Endangered" under the Endangered Species Act). The U.S. Fish and Wildlife Service
40   has jurisdiction over terrestrial and freshwater special status species and the National Marine Fisheries
41   Service has jurisdiction over marine special status species. States and other Federal agencies, such as the
42   Department of the Interior Bureau of Land Management, also have species of concern to which they have

1 assigned additional protections. The following section discusses the current and projected future threats
2 to these biological resources from non-global climate change impacts related to the proposed action. As
3 discussed below, the production and combustion of fossil fuels and the cultivation and production of
4 biofuels from agricultural crops are the identified relevant sources of impact on biological resources. For
5 a discussion of the effects of global climate change on ecosystems, please see Section 4.5.

6 ### 3.5.2.1.1 Petroleum Extraction and Refining

7 Oil extraction activities have the potential to impact biological resources through habitat
8 destruction and encroachment, raising concern about their affects on the preservation of animal and plant
9 populations and their habitats. Oil exploration and extraction result in intrusions into onshore and
10 offshore natural habitats, and may involve construction within natural habitats. "The general
11 environmental effects of encroachment into natural habitats and the chronic effects of drilling and
12 generating mud and discharge water on benthic (bottom-dwelling) populations, migratory bird
13 populations, and marine mammals constitute serious environmental concerns for these ecosystems"
14 (Epstein and Selber, 2002 as cited in O'Rourke and Connolly, 2003, p. 594).

15 Oil extraction and transportation can also result in oil and hazardous material spills. Oil
16 contamination of aquatic and coastal habitats can directly smother small species and is dangerous to
17 animals and fish if ingested or coated on their fur, skin, or scales. Oil refining and related activities result
18 in chemical and thermal pollution of water, both of which can be harmful to animal and plant populations
19 (Epstein and Selber, 2002). Offshore and onshore drilling and oil transport can lead to spills, vessel or
20 pipeline breakage, and other accidents that release petroleum, toxic chemicals, and highly saline water
21 into the environment and affect plant and animal communities.

22 Oil extraction, refining and transport activities, as well as the combustion of fuel during motor
23 vehicle operation, result in air emissions that affect air quality and may result in acid rain production;
24 these effects can create negative impacts on plants and animals. Once present in surface waters, air
25 pollutants can cause acidification of waterbodies, changing the pH of the system and impacting the
26 function of freshwater ecosystems (Section 3.5.1 water resources for a discussion of acid rain). The EPA
27 states that,

28 "plants and animals living within an ecosystem are highly interdependent… Because of
29 the connections between the many fish, plants, and other organisms living in an aquatic
30 ecosystem, changes in pH or aluminum levels affect biodiversity as well. Thus, as lakes
31 and streams become more acidic, the numbers and types of fish and other aquatic plants
32 and animals that live in these waters decrease (EPA, 2008)."

33 Acid rain has also been shown to affect forest ecosystems negatively, both directly and indirectly.
34 These impacts include stunted tree growth and increased mortality, primarily as a result of the leaching of
35 calcium and other soil nutrients (Driscoll, 2001; DeHayes, 1999; Baum, 2001). Declines in biodiversity
36 of aquatic species and changes in terrestrial habitats likely have ripple effects on other wildlife dependent
37 upon these resources.

38 The combustion of fossil fuels and certain agricultural practices have lead to a disruption in the
39 nitrogen cycle, the process by which gaseous nitrogen from the atmosphere is used and recycled by
40 biological organisms, with serious repercussions for biological resources. Nitrogen cycle disruption has
41 occurred through the introduction of large amounts of anthropogenic nitrogen in the form of ammonium
42 and nitrogen oxides to aquatic and terrestrial systems (Vitousek, 1994). Increased availability of nitrogen
43 in these systems is a major cause of eutrophication in freshwater and marine waterbodies. Eutrophic
44 systems usually contain communities dominated by phytoplankton and can result in the contamination of

1   aquatic environments, fish and other aquatic animal kills, and harmful algal blooms. Acid rain enhances
2   eutrophication of aquatic systems through the deposition of additional nitrogen (Lindberg, n.d.).
3   Introduction of large quantities of nitrogen to certain terrestrial systems has also been predicted to lead to
4   an increase in decomposing soil bacteria and subsequent increase in the release of CO_2 into the
5   atmosphere as these bacteria consume organic matter (Black, 2008).

6   ### 3.5.2.1.2 CO_2 Emissions

7   Ocean acidification as a result of increasing concentrations of atmospheric CO_2, primarily from
8   the combustion of fossil fuels, is expected to affect calciferous marine organisms. In conjunction with
9   rapid climate change, ocean acidification could pose severe threats to coral reef ecosystems. Hoegh-
10   Guldberg et al. (2007, p. 1737) state that "Under conditions expected in the 21st century, global warming
11   and ocean acidification will compromise carbonate accretion, with corals becoming increasingly rare on
12   reef systems. The result will be less diverse reef communities and carbonate reef structures that fail to be
13   maintained."

14   In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2
15   concentrations in the atmosphere could increase the productivity of terrestrial systems, because plants use
16   CO_2 as an input to photosynthesis. The IPCC Fourth Assessment Report states that "On physiological
17   grounds, almost all models predict stimulation of carbon assimilation and sequestration in response to
18   rising CO_2, called CO_2 fertilization (Denman et al., 2007, p. 526).

19   Under bench-scale and field-scale experimental conditions, a number of investigators have found
20   that higher concentrations have a "fertilizer" effect on plant growth (e.g., Long et al., 2006; Schimel et al.,
21   2000). IPCC reviewed and synthesized field and chamber studies, finding that:

22   "There is a large range of responses, with woody plants consistently showing NPP [net
23   primary productivity] increases of 23 to 25 percent (Norby et al., 2005), but much smaller
24   increases for grain crops (Ainsworth and Long, 2005) … Overall, about two-thirds of the
25   experiments show positive response to increased CO_2 (Ainsworth and Long, 2005; Luo et
26   al., 2005). Since saturation of CO_2 stimulation due to nutrient or other limitations is
27   common (Dukes et al., 2005; Koerner et al., 2005), it is not yet clear how strong the CO_2
28   fertilization effect actually is."

29   The CO_2 fertilization effect could potentially mitigate some of the increase in atmospheric CO_2
30   concentrations by resulting in more storage of carbon in vegetation.

31   Increased atmospheric CO_2 could potentially in conjunction with other environmental factors and
32   changes in plant communities, alter growth, abundance, and respiration rates of some soil microbes
33   (Lipson et al. 2005; Chung et al. 2007; Lesaulnier et al. 2008).

34   ### 3.5.2.1.3 Biofuel Production

35   Future demands for biofuel production are predicted to require increased commitments of land to
36   agricultural production (EPA, 2008). Putting additional land into agricultural production or returning
37   marginal agricultural land to production for the purpose of growing perennial grass or trees for use in
38   cellulosic ethanol would decrease the area available as natural habitat. A decrease in habitat and potential
39   habitat for plants and animal species would likely result in negative impacts to certain species. Increased
40   agriculture production would also likely result in increased surface runoff of sediments and fertilizers.
41   Additional fertilizer inputs to water could increase eutrophication and associated impacts. Sediment

1 runoff can settle to the bottom of waterbodies and degrade essential habitat for some species of aquatic
2 organism, bury food sources and areas used for spawning, and kill benthic organisms (EPA, 2000).

3.5.2.1.4 Endangered Species

4 Off-shore drilling, on-shore oil and gas drilling, and roads created to access remote extraction
5 sites through habitats used by threatened or endangered species, as designated under the Endangered
6 Species Act, may also affect these plants and animals both directly, through loss of individual animals or
7 habitat, and indirectly, through water quality degradation or cumulative impacts with other projects. Loss
8 of potential habitat to the production of biofuels could also result in negative impacts to some species
9 (e.g. diminished potential for habitat expansion, increased runoff related impacts, etc).

3.5.2.2 Environmental Consequences

11 The decrease in overall fuel consumption by cars and light trucks, anticipated under all of the
12 alternatives except the No Action Alternative, could lead to reductions in oil exploration, extraction,
13 transportation, and refining. The agency expects that a reduction in these activities would result in a
14 decrease in impacts to on- and off-shore habitat and plant and animal species. This decrease could have a
15 small overall benefit to plants and animals mainly through lower levels of direct ground disturbance and
16 oil and hazardous material release.

17 Reductions in fuel consumption would lead to a decrease in the release of SOx and NOx.
18 Reductions in acid rain could lower levels of eutrophication in surface waters caused by acid rain and
19 potentially slow direct impacts to forests and soil leaching. The positive effects on eutrophic water bodies
20 would likely be relatively low because of the limited overall effect of the release of SO_2 and NOx
21 (Appendix B-1 and Chapter 3.3).

22 Reductions in fuel consumption would also lead to a decrease in the release of CO_2. Lower levels
23 of atmospheric CO_2 could slow projected effects to terrestrial plant growth ,calciferous marine organisms,
24 and microorganisms. However, as discussed in Section 3.5.1.2, the reduction in CO_2 as a result of the
25 proposed action and alternatives would be relatively small compared to current and projected global CO_2
26 releases (Chapter 2 and Section 3.3).

27 The alternatives to the proposed action could potentially lead to an increase in the production of
28 biofuels, depending on the mix of tools manufacturers use to meet the proposed CAFE standards,
29 economic demands from consumers and manufacturers, and technological developments. Depending on
30 these factors, increased production of biofuels could result in the conversion of existing food-agricultural
31 lands and non-agricultural areas to biofuel crop production. This change in land use would have
32 implications for environmental issues associated with fertilizer runoff precipitated waterbody
33 eutrophication, and sediment runoff effects to aquatic organism food and spawning habitat. However,
34 due to the uncertainty surrounding how manufacturers would meet the new requirements, and the fact that
35 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

38 Land use and development refers to human activities that alter land (e.g., industrial and
39 residential construction in urban and rural settings, clearing of natural habitat for agricultural or industrial
40 use) and may affect the amount of carbon or biomass in existing forest or soil stocks in the affected areas.
41 For the purposes of this analysis, the potential conversion of agricultural food or non-agricultural lands to

1 biofuel crop production and changes to manufacturing plants that produce cars and light trucks are the
2 identified relevant sources of impact.

3.5.3.1.1 Agricultural Changes

4   Biofuel production is predicted to require increased devotion of land to agricultural production
5 (EPA, 2008; Keeney and Hertel, 2008). Converting areas into cropland would decrease the overall land
6 area kept in a natural state as well as the potential area available for other types of uses (such as
7 commercial development or pastureland) (Keeney and Hertel, 2008). Uncertainty exists regarding how
8 much additional land could be required to meet projected future biofuel needs in the United States as well
9 as how an increase in biofuel production could affect other land uses (Keeney and Hertel, 2008).

3.5.3.1.2 Manufacturing Changes

11   Recent shifts in consumer demand in the United States away from less fuel efficient vehicles have
12 begun to change the types of vehicles produced and the manufacturing plants where they are made. Sharp
13 decreases in demand for trucks and sport utility vehicles have recently resulted in plant closures and
14 production shifts to plants where small cars and gas-electric hybrid vehicle are made (WWJ, 2008;
15 Keenan and Mckenna, 2008; Bunkley, 2008).

3.5.3.2 Environmental Consequences

17   The alternatives could potentially lead to an increase in the production of biofuels, depending on
18 the mix of tools manufacturers use to meet the proposed CAFE standards, economic demands from
19 consumers and manufacturers, and technological developments. Depending on these factors, increased
20 production of biofuels could result in the conversion of existing food-agricultural lands and natural areas
21 to the production of these fuel crops. This change would have implications for environmental issues
22 associated with land use and development. However, due to the uncertainty surrounding how
23 manufacturers would meet the new requirements, and the fact that none of the proposed standards
24 prescribe increased biofuel use, these potential impacts are not quantifiable.

25   Major changes to manufacturing facilities, such as those occurring with the apparent shift in
26 consumer demand toward more fuel efficient vehicles, might have implications for environmental issues
27 associated with land use and development. However, NHTSA's review of existing and available
28 technologies and capabilities shows that the CAFE standards proposed under all of the alternatives can be
29 met by existing and planned manufacturing facilities. Because of the availability of sufficient existing
30 and planned capacity, and because none of the proposed alternatives prescribe particular technologies for
31 meeting these standards, the various alternatives are not projected to force changes in product mixes that
32 would result in plant changes.

3.5.4 Safety and Other Human Health Impacts

34   This section addresses the manner in which future improvements in fuel economy might affect
35 human health and welfare through vehicle safety performance, particularly crashworthiness and the rate
36 of traffic fatalities. It also addresses how the proposed standards might affect energy concerns which
37 could have ramifications for family health and welfare.

3.5.4.1 Affected Environment

39   There are multiple factors that influence traffic fatality rates including driver demographics (age,
40 gender, etc), driver behavior (e.g., driving under the influence, seat belt use, observance of speed limits

1   and other traffic laws, miles driven), and vehicle characteristics such as size, weight, and various
2   technologies designed to increase vehicle safety performance (e.g., air bags, anti-lock braking systems,
3   structural reinforcement, impact crumple zones, etc.). Several studies have attempted to define the
4   relationship between vehicle crashworthiness (specifically as it relates to traffic fatalities) and fuel
5   economy standards, however different methodologies have yielded different conclusions. While much of
6   the research identifies a link between vehicle downsizing and decreased crashworthiness, there are
7   contrasting studies found.

8   The 2002 National Academy of Sciences (NAS)[49] report made explicit links between weight and
9   vehicle safety. The NAS study conclusions were divided, with 11 of 13 committee members representing
10 the majority view and 2 of 13 the minority view. The findings of the majority presented on page 77
11 states, "... the majority of the committee finds that the downsizing and weight reduction that occurred in
12 the late 1970s and early 1980s most likely produced between 1,300 and 2,600 crash fatalities and between
13 13,000 and 26,000 serious injuries in 1993. The proportion of these casualties attributable to CAFE
14 standards is uncertain." Two members provided a minority view which was summarized on page 123:
15 "The relationship between vehicle weight and safety are complex and not measurable with any reasonable
16 degree of certainty at present. The relationship of fuel economy to safety is even more tenuous. ... it
17 appears that in certain kinds of accidents, reducing weight will increase safety risk, while in others it may
18 reduce it. Reducing the weights of light-duty vehicles will neither benefit nor harm all highway users,
19 there will be winners and losers...."

20   The Kahane study[50] estimates the effect of 100-pound reductions in heavy light trucks and vans
21 (LTVs), light LTVs, heavy passenger cars, and light passenger cars. It compares the fatality rates of
22 LTVs and cars to quantify differences between vehicle types, given drivers of the same age/gender, etc. It
23 found that annual fatalities increased with a reduction in weight in all groups of passenger vehicles except
24 light trucks with a curb weight greater than 3,900 pounds. The net safety effect of removing 100 pounds
25 from a light truck is close to zero for the group of all light trucks with a curb weight greater than 3,900
26 pounds.

27   Honda has cited several reports, which it asserted demonstrated that limited weight reductions
28 would not reduce safety and could possibly decrease overall fatalities. Honda stated that the 2003 study
29 by Dynamic Research Inc. (DRI) found that reducing weight without reducing size slightly decreased
30 fatalities, and that this was confirmed in a 2004 study by DRI[51] that assessed new data and methodology
31 changes in the 2003 Kahane Study. DRI submitted an additional study, *Supplemental Results on the*
32 *Independent Effects of Curb Weight, Wheelbase, and Track Width on Fatality Risk in 1985-1998 Model*
33 *Year Passenger Cars and 1985-1997 Model Year LTVs*, (Van Auken, R.M. and J. W. Zellner, May 20,
34 2005) (Docket No. 2003-16128-1456). This DRI study concluded that reductions in footprint are harmful
35 to safety, whereas reductions in mass while holding footprint constant would benefit safety.

36   NHTSA's analyses of the relationships between fatality risk, mass, track width and wheelbase in
37 4-door 1991-1999 passenger cars (Docket No. 2003-16318-16) found a strong relationship between track
38 width and the rollover fatality rate, but only a modest (although significant) relationship between track
39 width and fatality rate in non-rollover crashes. Even controlling for track width and wheelbase – e.g., by

[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.

1 holding footprint constant – weight reduction in the lighter cars is strongly, significantly associated with
2 higher non-rollover fatality rates in the NHTSA analysis.

3   While further scientific examination continues, EISA included an important reform that requires
4 the Transportation Department to issue "attribute-based standards," which eliminates or reduces the
5 incentive to decrease the size (weight) of the vehicle to comply with the fuel economy standard since
6 smaller footprint (size) vehicles have to achieve higher fuel economy targets. The attribute-based
7 approach was originally recommended by the NAS to remove the apparent incentive to reduce size and/or
8 the weight of vehicles as a means of meeting the standards.

9   NHTSA adopted an attribute based approach for light trucks in 2006. NHTSA continues to
10 examine this important safety issue and has tentatively concluded in its current NPRM that use of the
11 footprint-attribute will achieve greater fuel economy/emissions reductions without creating an incentive
12 to downsize vehicles.

13   Another way that the proposed standards could affect human health and welfare is by increasing
14 the amount of VMT. NHTSA tracks very closely the rate of traffic fatalities as a function of VMT even
15 while recognizing that many other factors are critical in determining fatality risks. In February 2008,
16 NHTSA reported that the fatality rate in 2006 was 1.41 per million miles of VMT, a decline from 2005
17 rates (Subramanian, 2008). These effects are not limited to vehicle occupants only (bicyclists and
18 pedestrians may also have an increased risk as a result of increased VMT). However, as with vehicle
19 occupant fatalities, many other factors are important in determining the overall risk associated with
20 vehicle, pedestrian and bicycle fatalities.

21   Finally, there is scientific literature that posits the relationship between petroleum scarcity and
22 human health. (Frumkin et al., 2007). Frumkin argues that increased oil prices could result in the
23 increase of other fuels used for power generation and increase hospital costs for providing back-up power
24 via diesel generator. Petroleum scarcity could also result in more expensive food (due to transport and
25 agricultural costs) which may be intensified by several factors including climate change, market demand
26 for biofuels (that will inflate some food prices), and agricultural land degradation. These effects may
27 threaten the health of poor people and others with insecure access to food. Other effects of peak
28 petroleum on health are more speculative, but concerns remain for issues such as: 1) higher petroleum
29 prices triggering a persistent economic downturn, which could increase the ranks of the uninsured; 2)
30 social disruptions that may create a substantial burden of anxiety, depression, and other psychological
31 ailments; and 3) resource scarcity, including petroleum scarcity, that could trigger armed conflict, which
32 poses multiple risks to public health. To the extent that the proposed CAFE standards affect petroleum
33 supply or price, they may have an effect on human welfare.

34 **3.5.4.2 Consequences**

35   Because of the attribute based approach recommended by NAS and adopted by NHTSA, the
36 incentive to meet the proposed standards by making more smaller vehicles and fewer larger vehicles
37 should be reduced or eliminated. Further, NHTSA chose fuel economy levels that could be achieved
38 without reductions in weight for vehicles less than 5,000 pounds. Because the proposed action and
39 alternatives do not mandate the method by which the CAFE standards are achieved, vehicle
40 manufacturers could achieve increased fleet fuel economy by reducing vehicle weight. To the extent that
41 manufacturers choose this approach, there may be some additional traffic fatalities, and more serious
42 injuries resulting from vehicle accidents. The extent to which these effects may be experienced cannot be
43 estimated without knowing the extent to which manufacturers choose to meet the proposed CAFE
44 standards by making lighter vehicles of a similar footprint.

1   The PRIA for the CAFE Standards of MY 2011–2015 passenger cars and light trucks concluded
2 that increases in fleet fuel economy is likely to lead to more miles being driven by the United States
3 population (NHTSA, 2008). Known as the "rebound effect," higher CAFE standards would lead to the
4 perception of a lower cost of driving, which is typically the largest component of the cost of operating a
5 vehicle. In response to the perception of lowered costs, consumers would increase the number of miles
6 they drive. By one estimate, a 10 percent increase in fuel economy would ultimately result in a 2.4
7 percent increase in total miles traveled (Small and Dender, 2005). The recent and unprecedented decline
8 in miles driven – a 4.3 percent drop in the total miles driven in March of 2008 as compared to March of
9 2007, a decrease of 11 billion miles (FHWA, 2008) – in response to recent surges in the price of gasoline,
10 underscores the relationship between the cost of operating a passenger vehicle and driver behavior as it
11 relates to miles driven. Because increased average fuel economy would lead to vehicles that cost less to
12 operate, it can be expected that individuals would drive more miles, and traffic accidents and fatalities of
13 vehicle occupants, bicyclists and pedestrians would increase on the whole, however, an estimate of
14 increased fatalities based on miles driven is influenced, in part, by unpredictable market forces, and is
15 uncertain to predict.

16   The proposed standards and the alternatives will reduce petroleum use. To the extent that
17 petroleum scarcity will be reduced by higher fuel economy standards, any adverse health impacts as
18 described by Frumkin will also be reduced.

19 **3.5.5 Hazardous Materials and Regulated Wastes**

20 **3.5.5.1 Affected Environment**

21   Hazardous wastes are defined here as solid wastes, which also include certain liquid or gaseous
22 materials, that because of their quantity and concentration, or their physical, chemical, or infectious
23 characteristics may cause or contribute to an increase in mortality or an increase in serious irreversible or
24 incapacitating reversible illness or may pose a substantial hazard to human health or the environment
25 when improperly treated, stored, used, transported, disposed of, or otherwise managed. Hazardous wastes
26 are generally designated as such by individual states or the EPA, under the Resource Conservation and
27 Recovery Act of 1976. Additional Federal and State legislation and regulations, such as The Federal
28 Insecticide, Fungicide, and Rodenticide Act, determine handling and notification standards for other
29 potentially toxic substances. For the purposes of this analysis, hazardous materials and wastes generated
30 during the oil extraction and refining processes as well as by agricultural production are the identified
31 relevant sources of impact.

32 **3.5.5.1.1 Wastes Produced during the Extraction Phase of Oil Production**

33   The primary waste created during the extraction of oil is "produced water," a highly saline water
34 pumped from oil and gas wells during mining (The American Petroleum Institute, 2000; EPA, 2000a). In
35 1995, approximately 15 billion barrels of produced water were generated by the onshore oil and gas
36 industry (The American Petroleum Institute, 2000). Produced waters are generally, "highly saline (total
37 dissolved solids may exceed 350,000 milligrams per liter [mg/L] dissolved solids), may contain toxic
38 metals, organic and inorganic components, and radium-226/228 and other naturally occurring radioactive
39 materials (Kharaka and Otton, 2005, p. 2)." Drilling wastes, primarily mud and rock cuttings, account for
40 149 million barrels of extraction wastes and "associated wastes", generally the most hazardous wastes
41 produced during extraction (often containing benzenes, arsenic, and toxic metals), account for another 22
42 million barrels (The American Petroleum Institute, 2000; EPA, 2000).

43   Wastes produced during oil and gas extraction have been known to have serious environmental
44 effects on soil, water, and ecosystems (Kharaka and Otton, 2005; O'Rourke and Connolly, 2003).

1　Onshore environmental effects result, "primarily from the improper disposal of large volumes of saline
2　water produced with oil and gas, from accidental hydrocarbon and produced water releases, and from
3　abandoned oil wells that were not correctly sealed" (Kharaka and Otton, 2005, p. 1). Offshore effects
4　result from improperly treated produced water released into the waters surrounding the oil platform (EPA,
5　2000).

6　### 3.5.5.1.2　Wastes Produced during the Refining Phase of Oil Production

7　　　　Wastes produced during the petroleum refining process are primarily released to the air and
8　water, accounting for 75 percent (air emissions) and 24 percent (wastewater discharges) of the total
9　respectively (EPA, 1995). EPA defines a release as the, "on-site discharge of a toxic chemical to the
10　environment…emissions to the air, discharges to bodies of water, releases at the facility to land, as well as
11　contained disposal into underground injection wells" (EPA, 1995). EPA reports that nine of the ten most
12　common toxic substances released by the petroleum refining industry are volatile chemicals, highly
13　reactive substances prone to state changes or combustion, that include benzene, toluene, ethylbenzene,
14　xylene, cyclohexane, 1,2,4-trimethylbenzene and ethylbenze (EPA, 1995). These substances occur within
15　both crude oil and finished petroleum products. Other potentially dangerous substances commonly
16　released during the refining process include ammonia, "gasoline additives (i.e., methanol, ethanol, and
17　MTBE) and chemical feedstocks (propylene, ethylene, and napthalene)" (EPA, 1995). Spent sulfuric acid
18　is by far the most commonly produced toxic substance; however, it is generally reclaimed instead of
19　released or transferred for disposal (EPA, 1995).

20　　　　Wastes released during the oil refining process can cause environmental impacts to water quality,
21　air quality, and human health. The volatile chemicals released during the refining process are know to
22　react in the atmosphere and contribute to ground-level ozone and smog (EPA, 1995). Several of the
23　produced volatile chemicals are also known or suspected carcinogens, and many others are known to
24　cause respiratory problems and impair internal organ functions, particularly in the liver and kidneys
25　(EPA, 1995). Ammonia is a form of nitrogen and can contribute to eutrophication in surface waters.

26　### 3.5.5.1.3　Agricultural Materials

27　　　　Agricultural production, especially of the type required to grow the corn and soy beans mostly
28　commonly used to produce biofuels in the United States, also results in the release of potentially
29　hazardous materials and wastes. Wastes from agricultural production can include pesticide (insecticides,
30　rodenticides, fungicides, and herbicides) and fertilizer runoff and leaching, wastes used in the
31　maintenance and operation of agricultural machinery (used oil, fuel spills, organic solvents, metal
32　machining wastes, spent batteries), and other assorted process wastes (EPA, 2000).

33　　　　Agricultural wastes in the form of runoff from agricultural fields can cause environmental
34　impacts to water and human health. Fertilizers can run off into surface waters and cause eutrophication,
35　while pesticides can directly affect beneficial insects and wildlife (EPA, 2000). A National Renewable
36　Energy Lab report concludes that the negative environmental impacts on soil and water due to impacts of
37　increased biofuel production are likely to occur disproportionately in the Midwest, where the majority of
38　these crops are grown (Powers 2005). Human health can also be affected by improperly handled or
39　applied pesticides, with potential effects ranging from minor respiratory or skin inflammation to death
40　(EPA, 2000). Nitrogen fertilizer runoff to drinking water sources can lead to methemogloinemia, the
41　potentially fatal binding of a form of nitrogen to hemoglobin in infants (Powers, 2005).

42　　　　Ethanol, as a biofuel additive to gasoline, is suspected of enhancing the plume size after a
43　gasoline-blended ethanol spill and may decrease degradation of the spilled hydrocarbon and related
44　compounds, such as benzene (Powers et al., 2001; Deeb et al., 2002; Williams et al., 2003).

1   ### 3.5.5.1.4 Automobile Production and Assembly

2   Hazardous materials and toxic substances are produced by the motor vehicles and motor vehicle
3   equipment industry, businesses engaged in the manufacture and assembly of cars, trucks, and busses.
4   EPA reports that solvents (xylene, methyl ethyl ketone, acetone, etc.) are the most commonly released
5   toxic substance it tracks for this industry (EPA, 1995a). These solvents are used to clean metal and in the
6   vehicle finishing process during assembly and painting and to clean metal (EPA, 1995a). Additional
7   industry wastes include metal paint and component part scrap.

8   ### 3.5.5.1.5 CO_2 Emissions

9   CO_2 is not currently classified as a hazardous material or regulated waste. For a discussion of the
10   release of CO_2 relevant to the proposed action and its impacts on climate change, see Section 3.4. For
11   discussions of the impacts of CO_2 on water resources, see Section 3.5.1. For discussions of the impacts of
12   CO_2 on biological resources, see Section 3.5.2.

13   ### 3.5.5.2 Environmental Consequences

14   The projected reduction in fuel production and consumption as a result of the proposed action and
15   alternatives may lead to a reduction in the amount of hazardous materials and wastes created by the oil
16   extraction and refining industries. The agency expects corresponding decreases in the associated
17   environmental and health impacts of these substances. However, these effects would likely be small if
18   they occurred because of the limited overall effect of the proposed action on these areas.

19   All of the alternatives to the proposed action could potentially lead to an increase in the
20   production of biofuels, depending on the mix of tools manufacturers use to meet the proposed CAFE
21   standards, economic demands from consumers and manufacturers, and technological developments. If
22   biofuel production increased, additional runoff of agricultural fertilizers and pesticides could occur.
23   However, due to the uncertainty surrounding how manufacturers would meet the new requirements, and
24   the fact that none of the proposed standards prescribe increased biofuel use, these potential impacts are
25   not quantifiable.

26   ### 3.5.6 Land Uses Protected under Section 4(f)

27   ### 3.5.6.1 Affected Environment

28   Section 4(f) resources are publicly owned parks, recreational areas, wildlife and waterfowl
29   refuges, or public and private historical sites, which are given special consideration by the DOT.
30   Originally included as part of the Department of Transportation Act of 1966, Section 4(f) stipulates that
31   DOT agencies cannot approve the use of land from publicly owned parks, recreational areas, wildlife and
32   waterfowl refuges, or public and private historical sites unless: "(1) there is no feasible and prudent
33   alternative to the use of such land, and (2) such program includes all possible planning to minimize harm
34   to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use" (49
35   U.S.C. 303).

36   ### 3.5.6.2 Environmental Consequences

37   "Section 4(f) only applies where land is permanently incorporated into a transportation facility
38   and when the primary purpose of the activity on the 4(f) resource is for transportation" (FHWA, 2005).
39   Therefore, these resources are not affected by the types of environmental issues under consideration as
40   part of the proposed action or alternatives.

1   **3.5.7   Historic and Cultural Resources**

2   **3.5.7.1 Affected Environment**

3   National Historic Preservation Act of 1966, Section 106 states that agencies of the Federal
4   government must take into account the impacts of their action to historic properties; the regulations to
5   meet this requirement can be found at 36 CFR Part 800. This process, known as the "Section 106
6   process" is intended to support historic preservation and mitigate impacts to significant historical or
7   archeological properties through the coordination of Federal agencies, states, and other affected parties.
8   Historic properties are generally identified through the National Register of Historic Places, which lists
9   properties of significance to the United States or a particular locale because of their setting or location,
10   contribution to or association with history, or unique craftsmanship or materials. National Register
11   eligible properties must also be sites: "A. That are associated with events that have made a significant
12   contribution to the broad patterns of our history; or B. That are associated with the lives of persons
13   significant in our past; or C. That embody the distinctive characteristics of a type, period, or method of
14   construction, or that represent the work of a master, or that possess high artistic values, or that represent a
15   significant and distinguishable entity whose components may lack individual distinction; or D. That have
16   yielded, or may be likely to yield, information important in prehistory or history" (NPS, n.d.). Acid rain
17   as a result of the processing of petroleum products and the combustion of petroleum-based fuels is the
18   identified relevant source of impact to historic and cultural resources for this analysis.

19   Acid rain, the primary source of which is the combustion of fossil fuels, is one cause of
20   degradation to exposed cultural resources and historic sites. EPA states that, "[a]cid rain and the dry
21   deposition of acidic particles contribute to the corrosion of metals (such as bronze) and the deterioration
22   of paint and stone (such as marble and limestone). These effects significantly reduce the societal value of
23   buildings, bridges, cultural objects (such as statues, monuments, and tombstones), and cars" (EPA, n.d.).

24   **3.5.7.2 Environmental Consequences**

25   The projected reduction in fuel production and combustion as a result of the proposed action and
26   alternatives may lead to a minor reduction in the amount of acid rain causing pollutants in relation to
27   current levels. A decrease in the production of acid rain-causing pollutants could result in a
28   corresponding decrease in the amount of acid rain-caused damage to historic and other structures.
29   However, the affects of any such effects are not quantifiable.

30   **3.5.8   Noise**

31   **3.5.8.1 Affected Environment**

32   Excessive amounts of noise, which is measured in decibels, can present a disturbance and a
33   hazard to human health at certain levels. Potential health hazards from noise range from annoyance
34   (sleep disturbance, lack of concentration, and stress) to hearing loss at high levels (Delucchi and Hsu,
35   1998; Geary, 1998; Fleming et al., 2005). Motor vehicle noise also effects property value; a study of the
36   impacts of roadway noise on property value estimated this cost to be roughly 3 billion dollars in 1991
37   dollars (Delucchi and Hsu, 1998). The noise from motor vehicles has been shown to be one of the
38   primary causes of noise disturbance in homes (OECD, 1988 as cited in Delucchi and Hsu, 1998; Geary,
39   1998). Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to
40   occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of
41   surrounding property. Hybrid gas-electric vehicles have been shown to have lower noise emissions than
42   standard internal combustion engines (Hogan and Gregory, 2006).

1 **3.5.8.2 Environmental Consequences**

2   As a result of the "Rebound-Effect," the increase in VMT as the cost per mile for fuel decreases,
3 NHTSA predicts that increased vehicle use will occur under all of the proposed alternatives; higher
4 overall VMTs would result in increases in vehicle road noise. However, determining if noise impacts will
5 occur is not possible based on the available data. Noise levels are location specific, meaning factors such
6 as the time of day at which increases in traffic occur, existing ambient noise levels, the presence or
7 absence of noise abatement structures, and the location of school, residences, and other sensitive noise
8 receptors all influence whether noise impacts will occur.

9   All of the alternatives to the proposed action could potentially lead to an increase in use of hybrid
10 vehicles, depending on the mix of tools manufacturers use to meet the proposed CAFE standards,
11 economic demands from consumers and manufacturers, and technological developments. An increased
12 percentage of hybrid vehicles could result in reduced road noise, potentially offsetting some of the
13 increase in road noise predicted to result from increased VMT. However, due to the uncertainty
14 surrounding how manufacturers would meet the new requirements, and the fact that none of the proposed
15 standards prescribe increased production of hybrid vehicles, and the location specific quality of noise
16 impacts, these potential impacts are not quantifiable.

17 **3.5.9   Environmental Justice**

18 **3.5.9.1 Affected Environment**

19   Federal agencies must identify and address disproportionably high and adverse impacts to
20 minority and low-income populations in the United States (Executive Order 12898- Federal Actions to
21 Address Environmental Justice in Minority Populations and Low-Income Populations). DOT Order
22 5610.2 to Address Environmental Justice in Minority Populations and Low-Income Populations
23 establishes the process the department uses to "incorporate environmental justice principles (as embodied
24 in the Executive Order) into existing programs, policies, and activities." The production and use of fossil
25 fuels and the production of biofuels are the identified relevant sources of impact to environmental
26 populations for this analysis. For a discussion of the effects of changes in climate on environmental
27 justice populations, please see Section 4.6.

28   Numerous studies have noted that a historic and ongoing relationship between the environmental
29 impacts of petroleum extraction, processing, and use and environmental justice populations appears to
30 exist (Pastor et al., 2001; O'Rourke and Connolly, 2003; Lynch et al., 2004; Hymel, 2007; Srinivasan,
31 2003).

32   Potential impacts of the oil exploration and extraction process on environmental justice
33 communities include "human health and safety risks for neighboring communities and oil industry
34 workers, and displacement of indigenous communities" (O'Rourke and Connolly 2003, p. 594).
35 Subsistence use activities (collecting plants or animals to fulfill basic needs for food, clothing, or shelter)
36 can also be affected by extraction and exploration through the direct loss of subsistence use areas or
37 impacts to culturally/economically important plants and animals as a result of a spill or hazardous
38 material release (O'Rourke and Connolly, 2003; Kharaka and Otton, 2005).

39   It has been shown that minority and low income populations often disproportionately reside near
40 high risk polluting facilities, such as oil refineries (Pastor et al., 2001; Graham et al., 1999; O'Rourke and
41 Connolly, 2003), and "mobile" source of air toxins and pollutants, such as highways (Morello-Frosch,
42 2002; Jerret et al., 2001; O'Neil et al., 2003). Populations near refineries may be disproportionately
43 impacted by exposure to potentially dangerous petroleum and by-products of the refining process, such as

1 benzene (Epstein and Selber, 2002). Exposure to the toxic chemicals associated with refineries, primarily
2 by refinery workers, has been shown to be related to increases in certain diseases and types of cancer
3 (Pukkala, 1998; Chan, 2005); the precise nature and severity of these health impacts are still under debate.
4 Pollutants from transportation sources, such as NO_2 and CO from roadway traffic, are often unevenly
5 distributed and tend to remain near their release locations (O'Neil et al., 2003). A correlation between
6 this uneven distribution of some pollutants and minority and low income populations has been
7 documented, demonstrating the potential for a disproportionate allocation of the health impacts of these
8 air pollutants to environmental justice populations (Jerret et al., 2001; Morello-Frosch, 2002). Recent
9 reviews by health and medical researchers indicate a general consensus that proximity to high-traffic
10 roadways could result in health effects in the areas of cardiovascular health (Adar and Kaufman, 2007),
11 and asthma and respiratory health (Heinrich and Wichmann, 2004; Salam et al., 2008). The exact nature
12 of the relationship between these health impacts, traffic-related emissions, and the influence of
13 confounding factors such as traffic noise are not known at this time (Samet, 2007).

14   The production of biofuels could, depending on the mix of agricultural crops or crop residues
15 used in its production, affect food prices. The International Food Policy Research Institute states, "An
16 aggressive biofuel scenario that assumes that current plans for expansion of the sector in Africa, Asia,
17 Europe, and North and South America are actually realized could lead to significant price increases for
18 some food crops by 2020—about 80 percent for oilseeds and about 40 percent for maize—unless new
19 technologies are developed that increase efficiency and productivity in both crop production and biofuel
20 processing" (von Braun and Pachauri, 2006, p. 11). Such an increase in food prices would
21 disproportionately affect low income and minority populations, as these groups are less likely to be
22 capable of absorbing the impacts of higher prices.

23 **3.5.9.2 Environmental Consequences**

24   The projected reduction in fuel production and consumption as a result of the action alternatives
25 may lead to a minor reduction in the amount of direct land disturbance that occurs as a result of oil
26 exploration and extraction, and the amount of air pollution produced by the oil refineries. Corresponding
27 decreases in impacts on environmental justice populations could occur as a result of the alternatives to the
28 proposed action, but the effects of any such decreases are not quantifiable and would likely be minor
29 should they occur.

30   As stated in Section 3.3, the overall decrease in toxic air and criteria air pollutants predicted to
31 occur as a result of the alternatives is not evenly distributed due to the increase in traffic in some areas
32 from the "rebound effect"; some criteria and toxic air pollutants are predicted to increase in some air
33 quality NAAs, potentially resulting in adverse impacts to environmental justice and other resident
34 populations (see Appendix C for the increases in air pollutant levels by year and non-attainment area).
35 These localized increases are a decline in the rate of reductions being achieved by implementation of the
36 CAA. Environmental justice populations often occur in disproportionate numbers along travel corridors,
37 therefore, it is possible that location-specific disproportionate impacts could occur in some of these non-
38 attainment areas; however, it is not possible to determine the specific locations where these impacts might
39 occur at this time. As discussed in Section 3.3, the incremental increase as a result of the proposed action
40 is small and overall pollutant levels are decreasing.

41   All of the alternatives to the proposed action could potentially lead to an increase in the
42 production of biofuels, depending on the mix of tools manufacturers use to meet the increased CAFE
43 standards, economic demands from consumers and manufacturers, and technological developments. If
44 grain-based biofuel production increased, effects to food prices could occur. However, because of the
45 uncertainty surrounding how manufacturers would meet the new requirements, and the fact that none of
46 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).

1

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

2

3 **4.1.1   Approach to Scientific Uncertainty and Incomplete Information**

4 **4.1.1.1 CEQ Regulations**

5   The CEQ regulations recognize that many Federal agencies confront limited information and
6 substantial uncertainties when analyzing the potential environmental impacts of their actions under NEPA
7 (40 CFR §1502.22). Accordingly, the regulations provide agencies with a means of formally
8 acknowledging incomplete or unavailable information in NEPA documents. Where "information relevant
9 to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of
10 obtaining it are exorbitant or the means to obtain it are not known," the regulations require an agency to
11 include in its NEPA document:

12   1)   a statement that such information is incomplete or unavailable;

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

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

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

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

10   Throughout this Draft Environmental Impact Statement (DEIS), the National Highway
11 Transportation Safety Administration (NHTSA) uses these two mechanisms – acknowledging incomplete
12 or unavailable information and incorporation by reference – to address areas where the agency is unable
13 to estimate precisely the potential environmental impacts of the proposed standards or reasonable
14 alternatives. In particular, NHTSA recognizes that information about the potential environmental impacts
15 of changes in emissions of CO_2 and other greenhouse gases (GHG) and associated changes in
16 temperature, including those expected to result from the proposed rule, is incomplete. In this DEIS,
17 NHTSA often relies on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment
18 Report (2007) as a recent "summary of existing credible scientific evidence which is relevant to
19 evaluating the reasonably foreseeable significant adverse impacts on the human environment" (40 CFR §
20 1502.22(b)(3)).

21 **4.1.1.2 Uncertainty within the IPCC Framework**

22   The IPCC Reports communicate uncertainty and confidence bounds using descriptive words in
23 italics, such as *likely* and *very likely*, to represent levels of confidence in conclusions. This is briefly
24 explained in the IPCC Fourth Assessment Synthesis Report[1] and the IPCC Fourth Assessment Report
25 Summary for Policy Makers.[2] A more detailed discussion of the IPCC's treatment of uncertainty can be
26 found in the IPCC's Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on
27 Addressing Uncertainties.[3]

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

33 **4.1.2 Temporal and Geographic Boundaries**

34   When evaluating cumulative effects, the analyst must consider expanding the geographic study
35 area beyond that of the proposed action, as well as expanding the temporal (time) limits to consider past,

---

[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 .

1   present, and reasonably foreseeable future actions that may affect the environmental resources of concern.
2   The timeframe for this cumulative impacts analysis extends through year 2100 and considers potential
3   cumulative impacts on a national, as well as global, basis.

1 **4.2   ENERGY**

2   The NEPA analysis must consider the cumulative impacts of the proposed action. In the case of
3 the model year (MY) 2011-2015 passenger cars and light trucks this involves evaluating their lifetime
4 fuel consumption.

5 **4.2.1   Affected Environment**

6   According to Energy Information Administration (EIA), net imports of total liquids, including
7 crude oil and refined products, will fall to 51 percent in 2022 and then rise again to 54 percent in 2030.
8 This change is attributed to both changes in the Corporate Average Fuel Economy (CAFE) standards and
9 the greater use of biofuels. These imports will replace declining production in meeting the increasing
10 demand for liquid fuels in the United States. The large volume of crude oil imports has a number of
11 impacts on the domestic economy. Further decreases or increases in imports, likely under some of the
12 CAFE alternatives, may well affect the world price of crude oil. However, over time the United States'
13 share of global demand for liquid fuels will decline due to rapid increases in demand in developing
14 economies, including China and India, reducing the relative impact of the CAFE standards on global
15 markets.

16   Over time a larger share of liquid fuels is expected to be produced from unconventional sources
17 such as biofuels, shale oil, coal-to-liquids, and gas-to-liquids. These alternate sources would affect CO_2
18 and other emission reductions from the CAFE alternatives. This shift would be driven by changes to the
19 Renewable Fuels Standard in the Energy Independence and Security Act (EISA), which forecasts that 36
20 billion gallons of renewable fuels will be required by 2022 for use primarily in the transportation sector.
21 The EIA Annual Energy Outlook 2008 forecasts that domestic production of non-hydro renewable energy
22 will increase from less than 4 quadrillion British thermal units (BTUs) in 2006 to over 10 quadrillion
23 BTUs in 2030[4]. In the United States, liquid fuels from gas, coal, and biomass are projected to increase
24 from 0.0 quadrillion BTUs in 2006 to 0.53 quadrillion BTUs. Overall, NHTSA expects in the short-term,
25 the impact from these changes would net out. Over the long-term, the impact of these changes remains
26 uncertain.

27   Changes to the CAFE standards are unlikely to affect domestic production, given the level of
28 crude oil imports. The domestic environmental impacts over the life of the MY 2011-2020 vehicles are
29 unlikely to change, whatever the alternative elected. Impacts on production will occur outside of the
30 United States, and will be determined by the balance between the decline in United States imports and the
31 increase in demand from developing countries.Impacts on petroleum products will be mixed. United
32 States imports of petroleum products and are often targeted for specific product requirements, or to
33 optimize the inputs and outputs from refineries. Petroleum imports are dependent on specific product
34 demands and the mix of crudes being processed in the refineries, which are projected change considerably
35 over time. Consequently, any decline in demand for petroleum products is likely to have some effect on
36 both overseas and domestic refineries.

37 **4.2.2   Consequences**

38   Implementing alternative CAFE standards would result in different future levels of fuel use, total
39 energy, and petroleum consumption, which would in turn have an impact on emissions of GHG and
40 criteria air pollutants. An important measure of the impact of alternative CAFE standards is the impact on
41 total fuel consumption over the expected lifetimes of passenger cars and light trucks produced during the

---

[4] EIA Annual Energy Outlook 2008, http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html

1 model years to which those standards apply. The impact of alternative CAFE standards, by affecting
2 petroleum consumption, total energy, and emissions, ultimately would determine many of the indirect
3 environmental impacts of adopting higher CAFE standards.

4   Figure 4.2-1 shows the estimated lifetime fuel consumption of passenger cars and light trucks
5 under the various CAFE standards. Figure 4.2.2-2 shows the savings in lifetime fuel consumption for
6 passenger cars and light trucks depending on the CAFE alternative examined.

7 **Figure 4.2-1 Lifetime Fuel Consumption of Light Trucks and Passenger Cars under**
8 **Alternative CAFE Standard**

9
10

1
2
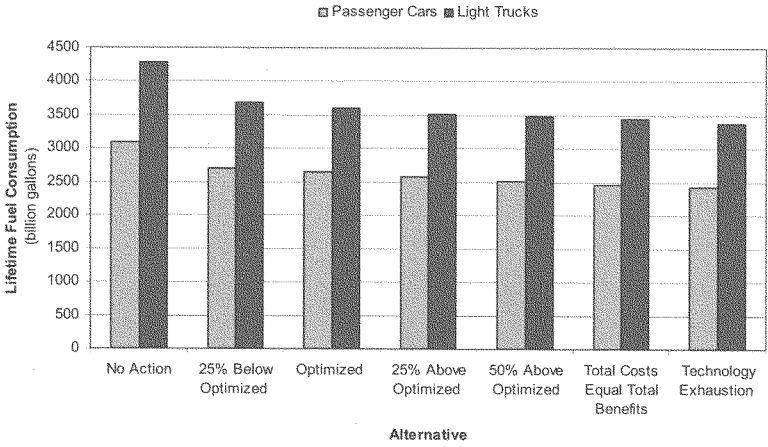
Figure 4.2-2 Savings in Lifetime Fuel Consumption by Light Trucks and Passenger Cars under Alternative CAFE Standard

3
4

1
2
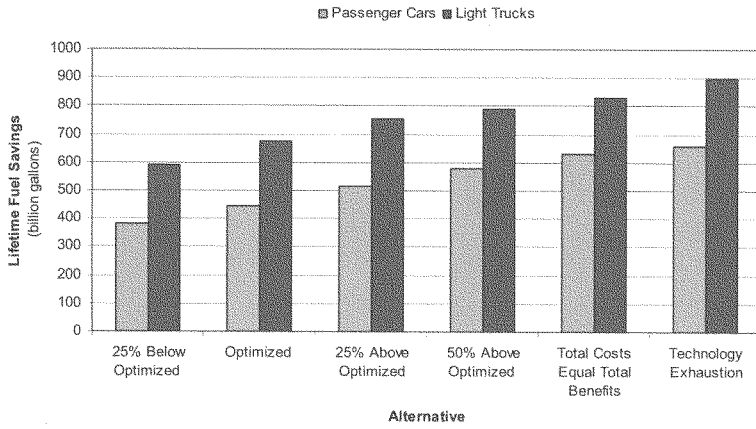
[This page intentionally left blank]

1   **4.3   AIR QUALITY**

2   **4.3.1   Affected Environment**

3   The air quality affected environment is described in Section 3.3.1.

4   **4.3.2   Consequences**

5   **4.3.2.1 Methodology**

6   The analysis methodology for air quality cumulative impacts is the same as described in Section
7   3.3.2, except that the potential CAFE standards for MY 2016-2020 were added because the EISA requires
8   that passenger cars and light trucks achieve an average of 35 miles per gallon (mpg) by 2020. The MY
9   2016-2020 standards are thus a reasonably foreseeable future action that must be considered.
10
11   The cumulative impacts analysis consists of three components analyzed together:
12   ▪   CAFE implementation through MY 2010,
13   ▪   The proposed MY 2011-2015 CAFE standard rules, and
14   ▪   Assumed MY 2016-2020 rules based on EISA requirements for 35 mpg by 2020.
15
16   For comparison, the non-cumulative impacts analysis (Section 3.3.2) consists of only two
17   components:
18   ▪   CAFE implementation through MY 2010, and
19   ▪   The proposed MY 2011-2015 CAFE standard rules.
20
21   For the calendar years 2016-2020, the non-cumulative impacts analysis (Ssection 3.3.2) assumes
22   that MY 2016-2020 and later passenger cars and light trucks would continue to meet the MY 2015
23   standard under the proposed rules. By contrast, the cumulative impacts analysis assumes that MY 2016-
24   2020 passenger cars and light trucks would meet the potential MY 2016-2020 standards and that MY
25   2021 and later passenger cars and light trucks would meet the potential MY 2020 standard.

26   **4.3.2.1.1 Treatment of Incomplete or Unavailable Information**

27   As noted in Section 3.3.2, the estimates of emissions rely on models and forecasts that contain
28   numerous assumptions and data that are uncertain. Examples of areas in which information is incomplete
29   or unavailable include future emission rates, vehicle manufacturers' decisions on vehicle technology and
30   design, the mix of vehicle types and model years, emissions from fuel refining and distribution, and
31   economic factors. Where information in the analysis included in the DEIS is incomplete or unavailable,
32   the agency has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR §
33   1502.22(b)). NHTSA has used the best available models and supporting data. The models used for the
34   DEIS were subjected to scientific review and have received the approval of the agencies that sponsored
35   their development. NHTSA believes that the assumptions that the DEIS makes regarding uncertain
36   conditions reflect the best available information and are valid and sufficient for this analysis

37   **4.3.2.1.2 Results of the Emissions Analysis**

38   The Clean Air Act (CAA) has been a success in reducing emissions from on-road mobile sources.
39   As discussed in Section 3.3.1, pollutant emissions from vehicles have been declining since 1970 and U.S.
40   Environmental Protection Agency (EPA) projects that they will continue to decline. This trend will
41   continue regardless of the alternative that is chosen for future CAFE standards. The analysis by
42   alternative in this section shows that the alternative CAFE standards would lead to further reductions in

1 emissions from passenger cars and light trucks. The amount of the reductions would vary by alternative
2 CAFE standard. The more restrictive alternatives would result in greater emission reductions compared
3 to the No Action Alternative. In no case is there an emission increase that would exceed any general
4 conformity threshold.

5
6 **4.3.2.2 Alternative 1: No Action**

7   With the No Action Alternative, the CAFE standards would remain at the MY 2010 level in
8 future years. Current trends in the levels of emissions from vehicles would continue, with emissions
9 continuing to decline due to the EPA emission standards despite a growth in total vehicle-miles traveled
10 (VMT). Therefore, there would be no cumulative impacts due to future actions. Table 4.3-2 summarizes
11 the cumulative national emissions from passenger cars and light trucks. Appendix B-1 contains tables
12 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

13

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

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

1 in total VMT. The No Action Alternative (Alternative 1) would not result in any other increase or
2 decrease in toxic air pollutant emissions in nonattainment and maintenance areas throughout the United
3 States

4 Table 4.3-4 summarizes the cumulative national toxic air pollutant emissions from passenger cars
5 and light trucks for the No Action Alternative for each of the toxic air pollutants and analysis years. As
6 with the criteria pollutants, the No Action Alternative has the highest emissions of all the alternatives for
7 all toxic air pollutants except acrolein. Table 4.3-4 shows increases for acrolein with the action
8 alternatives because data on upstream emissions reductions were not available. Thus, the emissions for
9 acrolein in Table 4.3-4 reflect only the increases due to the rebound effect. Appendix B-1 contains tables
10 that present the cumulative emissions of toxic air pollutants for each nonattainment area (NAA) for the
11 No Action Alternative.

12 Table 4.3-5 presents the net changes in nationwide cumulative emissions from passenger cars and
13 light trucks for the No Action Alternative for each of the air toxic pollutants and analysis years. The other
14 alternatives (Alternatives 2 through 7) are presented in left-to-right order of increasing fuel economy
15 requirements. In Table 4.3-5 the nationwide emissions reductions become greater from left to right,
16 reflecting the increasing fuel economy requirements that are assumed under successive alternatives,
17 except for acrolein. Table 4.3-5 shows increases for acrolein with the action alternatives because data on
18 upstream emissions reductions were not available. Thus, the emissions changes for acrolein in Table 4.3-
19 5 reflect only the increases due to the rebound effect.

	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	15,741	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

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

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.

l

	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

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.

1   All individual NAAs would experience reductions in emissions of all criteria pollutants for all
2 analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions
3 more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix
4 B-1 contains tables that present the emission reductions for each NAA.

5   **4.3.2.4.2 Air Toxics**

6   For the same reason as with the criteria pollutants, air toxics emissions would be different for
7 cumulative impacts compared to non-cumulative impacts. With Alternative 3, cumulative emissions of
8 acetaldehyde and benzene would be slightly higher in 2035 than non-cumulative emissions, and
9 cumulative emissions of acrolein would be slightly higher in all analysis years than non-cumulative
10 emissions. Emissions of DPM, benzene, 1,3-butadiene, and formaldehyde would be slightly lower in all
11 analysis years.

12   With the Optimized Alternative many NAAs would experience net increases in emissions of one
13 or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also, data were not
14 available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only the increases
15 due to the rebound effect. However, the sizes of the emission increases are quite small, as shown in
16 Appendix B-1. The agency concludes that potential air quality impacts from these increases would not be
17 notable because the VMT and emission increases would be distributed throughout each NAA.

18   **4.3.2.5 Alternative 4: 25 Percent Above Optimized**

19   **4.3.2.5.1 Criteria Pollutants**

20   With the 25 Percent Above Optimized Alternative, the CAFE standards would increase fuel
21 economy more than would Alternatives 1 through 3 but less than would Alternatives 5 through 7. As
22 with Alternative 3, cumulative emissions of CO and PM would be slightly higher in all analysis years
23 than non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly
24 lower than non-cumulative emissions.

25   All individual NAAs would experience reductions in emissions of all criteria pollutants for all
26 analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions
27 more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix
28 B-1 contains tables that present the emission reductions for each NAA.

29   **4.3.2.5.2 Air Toxics**

30   As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic
31 air pollutants with the 25 Percent Above Optimized Alternative compared to Alternatives 1 through 3.
32 With Alternative 4, cumulative emissions of benzene would be slightly higher in 2035 than non-
33 cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, and 1,3-butadiene would be
34 slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM and formaldehyde
35 would be slightly lower in all analysis years.

36   With the 25 Percent Above Optimized Alternative many NAAs would experience net increases in
37 emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also,
38 data were not available to quantify upstream emissions of acrolein, so emissions of acrolein and DPM
39 reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite
40 small as shown in Appendix B-1. The agency concludes that potential air quality impacts from these

1 increases would not be notable because the VMT and emission increases would be distributed throughout
2 each NAA.

4.3.2.6 Alternative 5: 50 Percent Above Optimized

4.3.2.6.1 Criteria Pollutants

5   With the 50 Percent Above Optimized Alternative, the CAFE standards would increase fuel
6 economy more than would Alternatives 1 through 4 but less than would Alternatives 6 and 7. As with
7 Alternative 4, cumulative emissions of CO and PM would be slightly higher in all analysis years than
8 non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly lower
9 than non-cumulative emissions.

10   All individual NAAs would experience reductions in emissions of all criteria pollutants for all
11 analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions
12 more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix
13 B-1 contains tables that present the emission reductions for each NAA.

4.3.2.6.2 Air Toxics

15   As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic
16 air pollutants with the 50 Percent Above Optimized Alternative compared to Alternatives 1 through 4.
17 With Alternative 4, cumulative emissions of benzene and formaldehyde would be slightly higher in 2035
18 than non-cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, and 1,3-butadiene
19 would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM would
20 be slightly lower in all analysis years.

21   With the 50 Percent Above Optimized Alternative many NAAs would experience net increases in
22 emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also,
23 data were not available to quantify upstream emissions of acrolein, so emissions of acrolein reflect only
24 the increases due to the rebound effect. However, the sizes of the emission increases are quite small as
25 shown in Appendix B-1. The agency concludes that potential air quality impacts from these increases
26 would not be notable because the VMT and emission increases would be distributed throughout each
27 NAA.

4.3.2.7 Alternative 6: Total Costs Equal Total Benefits

4.3.2.7.1 Criteria Pollutants

30   With the Total Costs Equal Total Benefits Alternative, the CAFE standards would increase fuel
31 economy more than would Alternatives 1 through 5 but less than would Alternative 7. As with
32 Alternative 5, cumulative emissions of CO and PM would be slightly higher in all analysis years than
33 non-cumulative emissions, while cumulative emissions of NOx, SOx, and VOC would be slightly lower
34 than non-cumulative emissions.

35   All individual NAAs would experience reductions in emissions of all criteria pollutants for all
36 analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions
37 more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix
38 B-1 contains tables that present the emission reductions for each NAA.

1   **4.3.2.7.2 Air Toxics**

2   As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic
3   air pollutants with the Total Costs Equal Total Benefits Alternative compared to Alternatives 1 through 5.
4   With Alternative 6, cumulative emissions of benzene and formaldehyde would be slightly higher in 2035
5   than non-cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, and 1,3-butadiene
6   would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM would
7   be slightly lower in all analysis years.

8   With the Total Costs Equal Total Benefits Alternative many NAAs would experience net
9   increases in emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix
10   B-1). Also, data were not available to quantify upstream emissions of acrolein, so emissions of acrolein
11   reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite
12   small, as shown in Appendix B-1. The agency concludes that potential air quality impacts from these
13   increases would not be notable because the VMT and emission increases would be distributed throughout
14   each NAA.

15   **4.3.2.8 Alternative 7: Technology Exhaustion**

16   **4.3.2.8.1 Criteria Pollutants**

17   With the Technology Exhaustion Alternative, the CAFE standards would increase fuel economy
18   the most of all the Alternatives. As with the Total Costs Equal Total Benefits Alternative, cumulative
19   emissions of CO and PM would be slightly higher in all analysis years than non-cumulative emissions,
20   while cumulative emissions of NOx, SOx, and VOC would be slightly lower than non-cumulative
21   emissions.

22   All individual NAAs would experience reductions in emissions of all criteria pollutants for all
23   analysis years. Emissions of criteria pollutants decrease because the reduction in upstream emissions
24   more than offsets the increase in VMT and emissions due to the rebound effect in every NAA. Appendix
25   B-1 contains tables that present the emission reductions for each NAA.

26   **4.3.2.8.2 Air Toxics**

27   As with the criteria pollutants, there would be greater reductions in nationwide emissions of toxic
28   air pollutants with the Technology Exhaustion Alternative than with any other alternatives. With
29   Alternative 7, cumulative emissions of formaldehyde would be slightly higher in 2035 than non-
30   cumulative emissions, and cumulative emissions of acetaldehyde, acrolein, benzene and 1,3-butadiene
31   would be slightly higher in all analysis years than non-cumulative emissions. Emissions of DPM would
32   be slightly lower in all analysis years.

33   With the Technology Exhaustion Alternative many NAAs would experience net increases in
34   emissions of one or more toxic air pollutants in at least one of the analysis years (Appendix B-1). Also,
35   data were not available to quantify upstream emissions of acrolein, and so emissions of acrolein and DPM
36   reflect only the increases due to the rebound effect. However, the sizes of the emission increases are quite
37   small, as shown in Appendix B-1. The agency concludes that potential air quality impacts from these
38   increases would not be notable because the VMT and emission increases would be distributed throughout
39   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.

1   Global climate change refers to long-term fluctuations in global surface temperatures,
2 precipitation, ice cover, sea levels, cloud cover, ocean temperatures and currents, and other climatic
3 conditions. Scientific research has shown that in the past century, Earth's surface temperature and sea
4 levels have risen, and most scientists attribute this to GHGs released by human activities, primarily the
5 combustion of fossil fuels. The IPCC recently asserted that, "Most of the observed increase in global
6 average temperatures since the mid-20th century is *very likely* due to the observed increase in
7 anthropogenic GHG concentrations" (IPCC, 2007, p. 10).

8   The primary GHGs—CO_2, methane (CH_4), nitrous oxide (N_2O)—are created by both natural and
9 human activities. Human activities that emit GHGs to the atmosphere include the combustion of fossil
10 fuels, industrial processes, solvent use, land use change and forestry, agriculture production, and waste
11 management. These gases trap heat in the earth's atmosphere, changing the climate, which then impacts
12 resources such as ecosystems, water resources, agriculture, forestry, and human health. As the world
13 population grows and developing countries industrialize, fossil fuel use and resulting GHG emissions and
14 their concentrations in the atmosphere are expected to grow substantially over the next century. For a
15 more in depth discussion of the science of climate change, please refer to Section 3.4.1.

16 ### 4.4.2   Affected Environment

17   The affected environment can be characterized in terms of GHG emissions and climate. Section
18 3.4.2 provides a discussion of both topics, including a description of both United States conditions and the
19 global environment. As there is no distinction between the affected environment for purposes of the
20 direct/indirect effects analysis and the cumulative impacts analysis, the reader is referred to Section 3.4.1.

21 ### 4.4.3   Methodology

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

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

26   Each element is discussed below.

27   When using either method, this DEIS expresses results for each of the alternatives in terms of the
28 environmental attribute being characterized (emissions, CO_2 concentrations, temperature, precipitation,
29 sea level). It also expresses the change between the No Action Alternative and each of the other
30 alternatives to illustrate the differences in environmental impacts across the CAFE alternatives.

31   The methods used to characterize emissions and climate change impacts involve considerable
32 uncertainty. Sources of uncertainty include the pace and effects of technology change in both the
33 transportation sector and other sectors that emit GHGs; changes in the future fuel supply that could affect
34 emissions; the sensitivity of climate to increased GHG concentrations; the rate of change in the climate
35 system in response to changing GHG concentrations; the potential existence of thresholds in the climate
36 system (which could be difficult to predict and simulate); regional differences in the magnitude and rate
37 of climate changes; and many other factors.

38   Moss and Schneider (2000) characterize the "cascade of uncertainty" in climate change
39 simulations (Figure 4.4-1). As indicated in the figure, the emission estimates used in this DEIS have
40 narrower bands of uncertainty than the global climate effects, which in turn have less uncertainty than the
41 regional climate change effects. The effects on climate are in turn less uncertain than the impacts of

1 climate changes on affected resources (e.g., terrestrial and coastal ecosystems, human health, and other
2 sectors discussed in section 4.5).

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

15 **Figure 4.4-1. From Moss and Schneider (2000, p. 39): "Cascade of uncertainties typical in**
16 **impact assessments showing the 'uncertainty explosion' as these ranges are multiplied**
17 **to encompass a comprehensive range of future consequences, including physical,**
18 **economic, social, and political impacts and policy responses."**

19
20

21 NHTSA notes that it is aware of the USCCSP's recent release for comment of a draft Synthesis
22 and Assessment Product (SAP) 3.1 regarding the strengths and limitations of climate models.[5] The reader
23 might find the discussions in this draft SAP useful in understanding the methodological limitations
24 regarding modeling the environmental impacts of the proposed action and the range of alternatives on
25 climate change.

26 **4.4.3.1 Methodology for Greenhouse Gas Emissions Modeling**

27 GHG emissions were estimated using the Volpe model, described earlier in Section 3.2. The
28 Volpe model assumes that major manufacturers will exhaust all available technology before paying

[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.

1 noncompliance civil penalties. In the more stringent alternatives, the Volpe model predicts that
2 increasing numbers of manufacturers will run out of technology to apply and, theoretically, resort to
3 penalty payment. Setting standards this high may not be technologically feasible, nor may it serve the
4 need of the nation to conserve fuel and/or reduce emissions.

5   Fuel savings from stricter CAFE standards also result in lower emissions of CO_2, the main GHG
6 emitted as a result of refining, distribution, and use of transportation fuels.[6] Lower fuel consumption
7 reduces carbon dioxide emissions directly, because the primary source of transportation-related CO_2
8 emissions is fuel combustion in internal combustion engines. NHTSA estimates reductions in carbon
9 dioxide emissions resulting from fuel savings by assuming that the entire carbon content of gasoline,
10 diesel, and other fuels is converted to CO_2 during the combustion process.[7] Reduced fuel consumption
11 also reduces CO_2 emissions that result from the use of carbon-based energy sources during fuel
12 production and distribution. NHTSA currently estimates the reductions in CO_2 emissions during each
13 phase of fuel production and distribution using CO_2 emission rates obtained from the Greenhouse Gases
14 Regulated Emissions, and Energy Use in Transportation (GREET) model, using the previous assumptions
15 about how fuel savings are reflected in reductions in each phase. The total reduction in CO_2 emissions
16 from the improvement in fuel economy under each alternative CAFE standard is the sum of the reductions
17 in emissions from reduced fuel use and from lower fuel production and distribution.

18 ### 4.4.3.2 Methodology for Estimating Climate Effects

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

21   • Changes in CO_2 concentrations
22   • Changes in global temperature
23   • Changes in regional temperature and precipitation
24   • Changes in sea level

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

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

---

[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.

---

[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

1   SRES (Nakicenovic et al., 2000) to develop global emission scenario and the assumptions used in the
2   Volpe model in terms of economic growth, energy prices, energy supply, and energy demand.

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

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

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

20 ### 4.4.3.5.1 Tipping Points and Abrupt Climate Change

21   In a linear system, a system response is proportional to the change in a driver. Temperature and
22 CO_2 are two key drivers of climate. However, the climate system is vastly complex; there are many
23 positive and negative feedback mechanisms. Moreover, there may be thresholds in the response of the
24 system. Below the thresholds, the response may be small or zero, and above the thresholds, the response
25 could be much quicker than previously observed or had been expected. The term "tipping point" refers to
26 a situation where the climate system reaches a point at which is there is a strong and amplifying positive
27 feedback from only a moderate additional change in a driver, such as CO_2 or temperature increase. These
28 tipping points could potentially result in abrupt climate change, as defined in Alley at al (2002) (cited in
29 Meehl et al., 2007) to "occur when the climate system is forced to cross some threshold, triggering a
30 transition to a new state at a rate determined by the climate system itself and faster than the cause."

31   While climate models do take positive (and negative, i.e., dampening) feedback mechanisms into
32 account, the magnitude of their effect and the threshold at which a tipping point is reached may not be
33 well understood in some cases. In fact, MacCracken et al., (2008) note that existing climate models may
34 not include some critical feedback loops, and Hansen et al., (2007a) states that the predominance of
35 positive feedback mechanisms in the climate system have the potential to cause large rapid fluctuations in
36 climate change effects. The existence of these mechanisms and other evidence has led some climate
37 scientists including Hansen et al., (2007b) to conclude that a CO_2 level exceeding about 450 parts per
38 million (ppm) is "dangerous".[9]

39   A number of these positive feedback loops may occur with the melting of land ice cover,
40 including glaciers and the Greenland and West Antarctic ice sheets. As land ice cover melts, the ground
41 underneath is exposed. This ground has a lower albedo (it reflects less infrared radiation back to the

---

[9] Defined as more than 1 degreeCelsiusabove the level in 2000.

1 atmosphere) compared to the ice, and absorbs more heat, further raising temperatures. In addition,
2 increased surface temperatures cause more precipitation to fall as rain instead of snow, increasing surface
3 melt water, which may further increase ice flow (Meehl et al., 2007). The albedo effect is also relevant
4 for sea ice melt, as darker open water absorbs the heat of the sun at a higher rate than the lighter sea ice
5 does, with the warmer water leading to further melting.

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

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

26   Overall, however, IPCC concludes that these abrupt changes are unlikely to occur this century
27 (Meehl et al., 2007). Whether these tipping points exist, and the levels at which they occur, are still a
28 matter of scientific investigation. Where information in the analysis included in the DEIS is incomplete
29 or unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable
30 information (40 CFR § 1502.22(b)). In this case, the DEIS acknowledges that information on tipping
31 points or abrupt climate change is incomplete, but the state of the science does not allow for a
32 characterization how the CAFE alternatives influence these risks, other than to say that the greater the
33 emission reductions, the lower the risk of abrupt climate change.

34 **4.4.4 Consequences**

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

37 **4.4.4.1 Greenhouse Gas Emissions**

38   To estimate the emissions resulting from changes in passenger car and light truck CAFE
39 standards, NHTSA uses the Volpe Model (see Section 3.1.3 for a discussion of the model). The change
40 in fuel use projected to result from each alternative CAFE standard determines the resulting impacts on
41 total and petroleum energy use, which in turn affects the amount of CO_2 emissions, These CO_2 emission
42 estimates also include upstream emissions, which occur from the use of carbon-based energy during crude
43 oil extraction, transportation, and refining, as well in the transportation, storage and distribution of refined
44 fuel. Because CO_2 accounts for such a large fraction of total GHG emitted during fuel production and use

1 – more than 95 percent, even after accounting for the higher global warming potentials of other GHG –
2 NHTSA's consideration of GHG impacts focuses on reductions in CO_2 emissions resulting from the
3 savings in fuel use that accompany higher fuel economy.[10]

4 NHTSA considers three measures of the cumulative impact of alternative CAFE standards (for
5 MY 2011-2015 *and* using the assumption of getting to 35 mpg by 2020 to estimate the foreseeable MY
6 2016-2020) on CO_2 emissions:

7 1. CO_2 emissions from the vehicles they would affect, namely, model year 2011-2020 passenger
8   cars and light trucks;

9 2. CO_2 emissions by the entire United States passenger car and light truck fleets that would
10   result during future years (2021-2100) from each alternative increase in CAFE standards; and

11 3. Cumulative emission reductions over the history of the CAFE program, including those
12   projected to result from each alternative increase in CAFE standards considered for the
13   agency's proposed action. Emission reductions represent the differences in total annual
14   emissions by all cars or light trucks in use between their estimated future levels under the No
15   Action Alternative (baseline), and with each alternative CAFE standard in effect.

16 Under NEPA the assessment of cumulative impacts must include the impact on the environment
17 resulting from "the incremental impact of the action when added to other past, present, and reasonable
18 foreseeable future actions" (40 CFR § 1508.7). Thus, the agency evaluated the effect of CAFE standards
19 to date, as well as potential CAFE standards for MY 2016-2020 because they are considered a reasonably
20 foreseeable action. With the potential MY 2016-2020 standards, model years after 2020 would continue
21 to meet the MY 2020 standards.

22 NHTSA estimates that the cumulative CO_2 reductions from CAFE to date, from 1978-2007, have
23 been 8,911 MMTCO$_2$, according to DOT's Volpe model. Assuming no further increases in fuel economy
24 standards, i.e., the standards for MY 2010 vehicles remain in force through 2100, NHTSA estimates that
25 continuation of the MY 2010 standard would result in further emission reductions of 130,904 MMTCO$_2$
26 as compared to a reference scenario of no CAFE standards.

27 Emission reductions resulting from the CAFE standard for MY 2011-2020 cars and light trucks
28 were estimated from 2010 to 2100. Reductions begin in the year 2010, the first year that MY 2011
29 vehicles are on the road. For each alternative, all vehicles after MY 2020 were assumed to meet the MY
30 2020 CAFE standard. Emissions were estimated for all alternatives through 2100, and these emissions
31 were compared against the Notice of Proposed Rulemaking (NPRM) baseline (which assumes all vehicles
32 post-MY 2010 meet the MY 2010 standard) to estimate emission reductions. The Volpe model estimates
33 emissions through the year 2060. As a simplifying assumption, annual emission reductions from 2061-
34 2100 were held constant at 2060 levels.

---

[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.

1   Total emission reductions from 2010-2100 new passenger cars and light trucks from for each of
2 the seven alternatives are shown below in Table 4.4-1. Projections of emission reductions over the 2010
3 to 2100 timeframe due to the MY 2011-2020 CAFE standard ranged from 38,294 to 53,365 MMTCO$_2$.
4 Compared against global emissions of 4,850,000 MMTCO$_2$ over this period (projected by the A1B-
5 medium scenario), the incremental impact of this rulemaking is expected to reduce global CO$_2$ emissions
6 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

7
8   To gain a sense of the relative impact of these reductions, it can be helpful to compare them
9 against emission projections from the transportation sector, as well as expected or stated goals from
10 existing programs designed to reduce CO$_2$ emissions. For ease of comparison, NHTSA focuses on the
11 Optimized, or preferred alternative for this discussion.

12   In their *Annual Energy Outlook 2007*, the EIA projects United States transportation CO$_2$
13 emissions will increase from 2,037 MMTCO$_2$ in 2010 to 2,682 MMTCO$_2$ in 2030, with cumulative
14 emissions from transportation over this period reaching 49,287 MMTCO$_2$. Over this same timeframe, the
15 emissions reductions from this rulemaking are projected to be 2,595 to 4,002 MMTCO$_2$, which would
16 yield a 5 to 8 percent emissions reduction from the transportation sector. The environmental impact from
17 increasing fuel economy standards would grow as new vehicles enter the fleet and older vehicles are
18 retired. For example, in 2030, projected emission reductions would be 287 to 407 MMTCO2, an 11 to 15
19 percent decrease from projected United States transportation emissions of 2,682 MMTCO$_2$ in 2030. It is
20 important to note that the EIA did not take into account the expected effects of this rulemaking into their
21 forecast (EIA, 2007), thus allowing a comparison of the impact of this rulemaking to United States
22 transportation emissions under the No Action Alternative.

23   As another measure of the relative environmental impact of this rulemaking, these emission
24 reductions can be compared to existing programs designed to reduce GHG emissions within the United
25 States. In 2007, Arizona, California, New Mexico, Oregon, and Washington formed the Western Climate
26 Initiative (WCI) to develop regional strategies to address climate change. The WCI has a stated goal of
27 reducing 350 MMTCO$_2$ equivalent over the period from 2009-2020 (WCI, 2007). By comparison, this
28 rulemaking is expected to reduce CO$_2$ emissions by 455-830 MMTCO$_2$ over the same time period. In the
29 northeast, nine northeast and Mid-Atlantic States have formed the Regional Greenhouse Gas Initiative
30 (RGGI, 2006) to reduce CO$_2$ emissions from power plants in that region. Emission reductions from 2006-

1   2024 are estimated at 268 MMTCO$_2$.[11] By comparison, NHTSA forecasts that this rulemaking will
2   reduce CO$_2$ emissions by 1,100-1,834 MMTCO$_2$ over this timeframe. It is, important to note, however,
3   that these projections are only estimates, and the scope of these climate programs differs from this
4   rulemaking in geography, sector, and purpose.

5   Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has
6   relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In
7   this case, the comparison of emission reductions from the CAFE alternatives to emission reductions
8   associated with other programs is intended to assist decision makers by providing relative benchmarks,
9   rather than absolute metrics for selecting among alternatives. In summary, the alternatives analyzed here
10   deliver GHG emission reductions that are on the same scale as many of the most progressive and
11   ambitious GHG emission reduction programs underway in the United States.

12   **4.4.4.2 Direct and Indirect Effects on Climate Change**

13   The approach to estimating the cumulative effects of climate change from the MY 2011-2020
14   CAFE alternatives mirrors that used to estimate the direct and indirect effects of the MY 2011-2015
15   CAFE alternatives. Again, because EISA requires average fuel economy of the passenger car and light
16   truck fleet to reach a combined 35 mpg by 2020, the MY 2016-2020 CAFE standards are a reasonably
17   foreseeable future action. Accordingly, the cumulative impacts analysis assumes the minimum MY 2016-
18   2020 CAFE standards necessary to get to 35 mpg by 2020, based on where the alternatives are at 2015 for
19   purposes of analyzing the cumulative environmental impacts of the range of alternatives. Overall, the
20   emission reductions for the MY 2011-2015 CAFE alternatives have a small impact on climate change.
21   The emission reductions and resulting climate impacts for the MY 2011-2020 CAFE standards are larger,
22   though they are still relatively small in absolute terms.

23   The direct and indirect effects of the alternatives on climate change are described in the following
24   section in terms of (1) atmospheric CO$_2$ concentrations, (2) temperature, (3) precipitation, and (4) sea
25   level rise. Within each section, the MAGICC results are reported first, followed by the results of the
26   scaling approach. An explanation of the methodology and purpose of the scaling approach is discussed in
27   Section 3.4.3.

28   **4.4.4.2.1 Atmospheric Carbon Dioxide Concentrations**

29   <u>MAGICC Results</u>

30   The MAGICC model is a simple climate model that is well calibrated to the mean of the multi-
31   model ensemble results for three of the most commonly used emission scenarios – B1 (low), A1B
32   (medium), and A2 (high) from the IPCC SRES series – as shown in Table 4.4-2.[12] As the table indicates,
33   the model runs developed for this analysis achieve relatively good agreement with IPCC Work Group 1
34   (WG1) estimates in terms of both CO$_2$ concentrations and surface temperature.

---

[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)					
	CO₂ Concentration (ppm)		Radiative Forcing (W/m²)		Global Mean Increase in Surface Temperature (°C)	
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

1
2   The mid-range results of MAGICC model simulations for the No Action Alternative and the six
3 alternative CAFE levels, in terms of CO_2 concentrations and increase in global mean surface temperature
4 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
5 4.4-3 show, the impact on the growth in CO_2 concentrations and temperature is just a fraction of the total
6 growth in CO_2 concentrations and global mean surface temperature. However, the relative impact of the
7 CAFE alternatives is illustrated by the reduction in growth of both CO_2 concentrations and temperature in
8 the Technology Exhaustion Alternative, which is nearly double that of the 25 Percent Below Optimized
9 Alternative, as shown in Figures 4.4-4 to 4.4-5.

10   As shown in the table and figures, there is a fairly narrow band of estimated CO_2 concentrations
11 as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative. As
12 CO_2 concentrations are the key driver of all the other climate effects, this narrow range implies that the
13 differences among alternatives are difficult to distinguish. The MAGICC simulations of mean global
14 surface air temperature increases are also shown below in Table 4.4-5. For all alternatives, the
15 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
16 among alternatives are small. As of 2100, the reduction in temperature increase, with respect to the No
17 Action Alternative, ranges from 0.012°C to 0.018°C. These estimates include considerable uncertainty
18 due to a number of factors of which the climate sensitivity is the most important. The IPCC AR4
19 estimates a range of the climate sensitivity from 2.5 to 4.0 degrees C with a mid-point of 3.0 degrees C
20 which directly relates to the uncertainty in the estimated global mean surface temperature.

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

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

1
2 **Figure 4.4-2 CO$_2$ Concentrations for the A1B scenario and MY 2011-2015 Standard and Potential 2016-2020 Standard**

▨ No Action (A1B – AIM[1])   ▨ 25 Percent Below Optimized   ▢ Optimized
▨ 25 Percent Above Optimized   ▢ 50 Percent Above Optimized   ▨ Total Costs Equal Total Benefits
▨ Technology Exhaustion
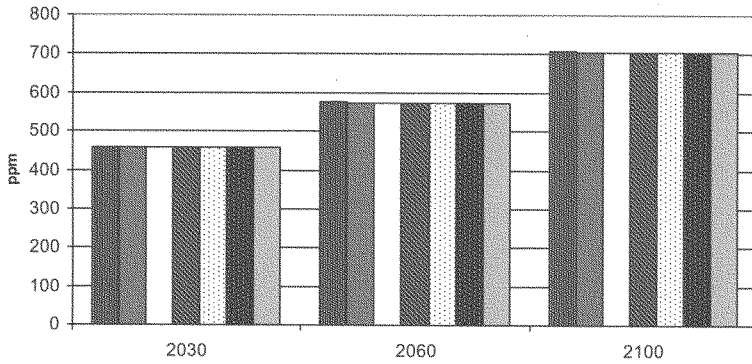
3
4 **Figure 4.4-3 Increase in Global Mean Surface Temperature for the A1B Scenario and MY**
5 **2011-2015 Standard and Potential 2016-2020 Standard**

▨ No Action (A1B – AIM[1])   ▨ 25 Percent Below Optimized   ▢ Optimized
▨ 25 Percent Above Optimized   ▢ 50 Percent Above Optimized   ▨ Total Costs Equal Total Benefits
▨ Technology Exhaustion

6
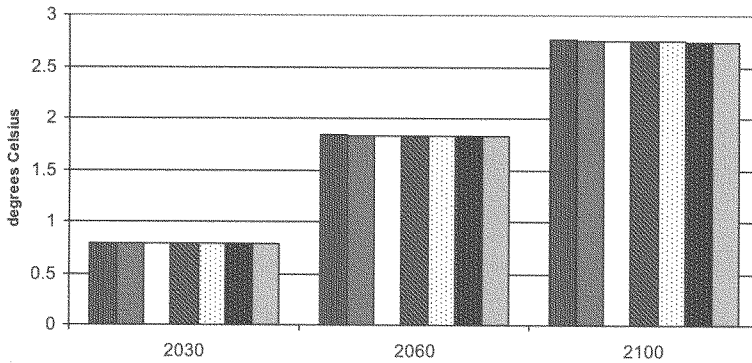
Figure 4.4-4 Reduction in the Growth of CO_2 Concentrations for the A1B Scenario and
MY 2011-2015 Standard and Potential 2016-2020 Standard

No Action (A1B – AIM[1])   25 Percent Below Optimized Optimized
25 Percent Above Optimized 50 Percent Above Optimized Total Costs Equals Benefits
Technology Exhaustion
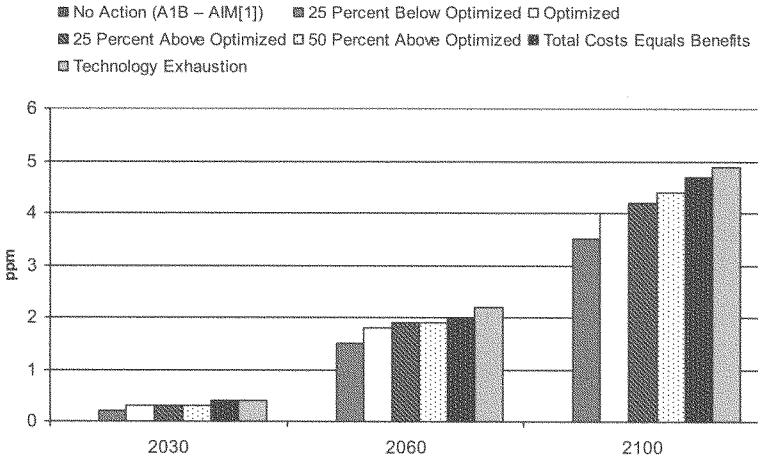
Figure 4.4-5 Reduction in the Growth of Global Mean Temperature for the A1B Scenario
and MY 2011-2015 Standard and Potential 2016-2020 Standard

No Action (A1B – AIM[1])   25 Percent Below Optimized   Optimized
25 Percent Above Optimized 50 Percent Above Optimized Total Costs Equal Total Benefits
Technology Exhaustion
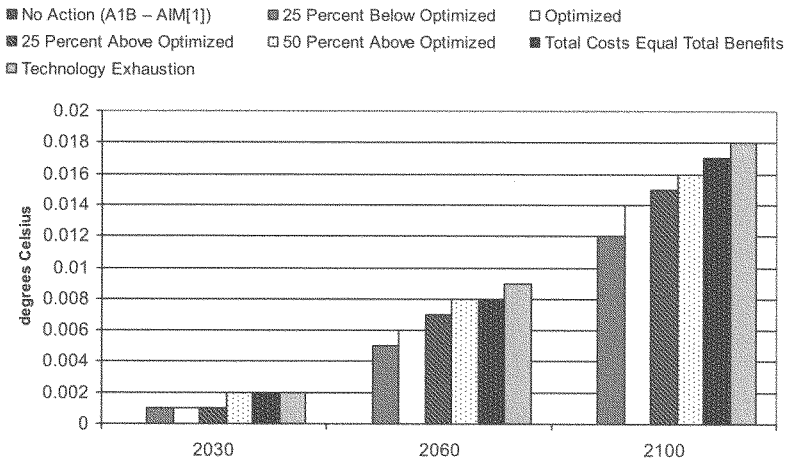
1
2   As shown in the table and figures, there is a fairly narrow range of estimated CO_2 concentrations
3   as of 2100, from 704 ppm for the most stringent alternative to 709 ppm for the No Action Alternative.
4   For earlier years, the range is even tighter. As CO_2 concentrations are the key driver of all the other
5   climate effects (which in turn act as drivers on the resource impacts discussed in this chapter), this narrow
6   range implies that the differences among alternatives are difficult to distinguish.

7   <u>Scaling Results</u>

8   The global emission scenarios developed by the IPCC in the SRES (Nakicenovic et al., 2000),
9   showed ranges of cumulative emissions from 1990 to 2100 of CO_2 from 770 Gt[13] Carbon to 2,450 Gt C
10   (2,825 to 8,985 billion metric tons of CO_2). The three scenarios used in the IPCC WG1 Fourth
11   Assessment Report (IPCC, 2007) have the following emissions of CO_2 from 2005 to 2100[14]:

12   ▪ Low – B1: 3,145 Gt CO_2
13   ▪ Mid – A1B: 5,020 Gt CO_2
14   ▪ High – A2: 6,640 Gt CO_2

15   As indicated earlier in Table 4.4-3, for these emission scenarios, CO_2 concentrations increase
16   from 379 ppm in 2005 to mid-range estimates in 2100 of 550 ppm for the B1 (low) scenario, 715 ppm for
17   the A1B (medium) scenario, and 836 ppm for the A2 (high) scenario (IPCC, 2007). This implies that 42
18   percent, 52 percent, and 53 percent of the emitted CO_2 from 2005 to 2100 in the SRES B1 (low), A1B
19   (medium), and A2 (high) scenarios, respectively, is still in the atmosphere in 2100[15] (these percentages
20   can be used in the agency's scaling approach). The amount of emitted CO_2 that remains in the
21   atmosphere as of 2100 varies considerably depending upon when the CO_2 is emitted, which determines
22   the length of time it is subject to land and ocean uptake.

23   By applying the scaling factors developed above, the emission reductions for the seven MY 2011-
24   2020 CAFE alternatives yield CO_2 concentrations, as of 2100, as shown in Table 4.4-4. The results for
25   scenario A1B (medium) in this table (712-715 ppm) agree relatively well with the MAGICC results in
26   Table 4.4-3 (704-709 ppm). These concentrations are considerably higher than current concentrations,
27   which were approximately 379 ppm in 2005 (IPCC, 2007).

---

[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.

1

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

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.

2
3   **4.4.4.2.2 Temperature**

4   MAGICC Results

5   The MAGICC simulations of mean global surface air temperature increases are shown above in
6 Table 4.4-3. For all alternatives, the cumulative global mean surface temperature increase is about 0.8
7 degree Celsius as of 2030, 1.8 degree Celsius as of 2060, and 2.8 degree Celsius as of 2100 (Table 4.4-3).
8 The projected differences regarding reductions in temperature increase alternatives are small. As of 2100,

1 the reduction in temperature increase, with respect to the No Action Alternative, ranges from 0.012
2 degree Celsius to 0.018 degree Celsius.

3 <u>Scaling Results</u>

4 The relationship between emissions and temperature is a dynamic one, given all of the feedback
5 loops and transient phenomena involved in the climate system. The scaling approach used here is based
6 on the relationship between emissions and the global mean surface temperature at equilibrium (GMSTE),
7 i.e., the temperature increase if CO_2 concentrations were to equilibrate at levels reached as of 2100.

8 Where information in the analysis included in the DEIS is incomplete or unavailable, NHTSA has
9 relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)). In
10 this case, the methodology uses three different emission scenarios (B1-low, A1B-medium, and A2-high)
11 to provide a range of values to address uncertainty in the factors that drive global GHG emissions.

12 According to IPCC (2007), temperature change can be estimated using the following equation:

13 $$\Delta T = S \times \log(CO2 / 280 \text{ ppm}) / \log(2)$$

14 Where:
15 T = Temperature (°C)
16 S = Climate sensitivity
17 CO_2 = CO_2 concentration (ppm)
18
19 Using this equation, the impact of the emission reductions from the MY 2011-2020 CAFE
20 alternatives for the range of climate sensitivities provided by the IPCC (IPCC, 2007a) are estimated and
21 shown in Table 4.4-5, below. These are shown for three different levels of "climate sensitivity," i.e., the
22 mean temperature increase resulting from a sustained doubling, over pre-industrial levels, of atmospheric
23 CO_2 concentrations (IPCC 2007a). The calculations are also shown for three different emission
24 scenarios: B1 (low), A1B (medium), and A2 (high). The range of GMSTE reductions (with respect to the
25 No Action Alternative) due to the different CAFE alternatives ranges from 0.011 °C to 0.034 °C
26 depending upon the climate sensitivity and the CAFE alternative.

27 The IPCC estimates that for the A1B (medium) and B1 (low) scenarios, the average warming
28 from the AOGCMs as of 2100 is 65 to 70 percent of the estimated eventual equilibrium warming in the
29 21st century. With this information, and the data in Table 4.4-5, the agency constructed a bounding
30 analysis on the effects of the CAFE alternatives on average warming by 2100. The lower bound
31 combines the lower ends of the ranges on (a) the proportion of warming as of 2100 compared to eventual
32 warming (viz., 65 percent), (b) the lowest value for the reduction in temperature for a CAFE alternative
33 compared to the No Action Alternative from the table (viz., 0.011 degree C, the value for the 25 Percent
34 Below Optimized Alternative, A2 (high) emission scenario, and climate sensitivity at 2.5 degrees C).
35 This yields an estimate of a lower bound temperature effect (compared to the No Action Alternative) of
36 65%* 0.011°C = 0.007°C. The upper bound, derived by the same approach but using high end values, is
37 70% * 0.034°C = 0.024°C for the Technology Exhaustion Alternative using a climate sensitivity of 4.5
38 degrees C.

39 The range of 0.007 degree Celsius to 0.024 degree Celsius from the scaling approach
40 encompasses the range of MAGICC values (in Table 4.4-5) of 0.012 degree Celsius to 0.018 degree C.
41 Note that the scaling approach uses three different values for climate sensitivity, whereas MAGICC only
42 uses one (2.6 degrees C, the middle value used for the scaling analysis), and so the greater range with the
43 scaling approach is to be expected. The use of the scaling approach illustrates that the alternatives'

1 effectiveness in reducing temperature increases is somewhat broader than the range projected in this DEIS
2 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

	Concentration (ppm)			Global Mean Surface Temperature at Equilibrium from CO_2 Only ($^\circ$C)								
				GMEST – CS = 2.5 $^\circ$C			GMEST – CS = 3 $^\circ$C			GMEST – CS = 4.5 $^\circ$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

3

| 1 | Table 4.4-6 summarizes the regional changes to warming and seasonal temperatures from the |
| 2 | IPCC Fourth Assessment Report. It is not possible at this point to quantify the changes to regional |

1   Table 4.4-6 summarizes the regional changes to warming and seasonal temperatures from the
2   IPCC Fourth Assessment Report. It is not possible at this point to quantify the changes to regional
3   climate from the CAFE alternatives (40 CFR § 1502.22(b)).[16] Where information in the analysis included
4   in the DEIS is incomplete or unavailable, NHTSA has relied on CEQ's regulations regarding incomplete
5   or unavailable information. In this case, the IPCC (2007) summary of regional changes to warming and
6   seasonal temperatures represents the most thoroughly reviewed, credible assessment of this highly
7   uncertain factor. NHTSA expects that the CAFE alternatives would reduce the changes in regional
8   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 *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	

[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 Minimum winter temperatures are *likely* to increase more than the average
	Southwest		Warming is *likely* to be largest in summer 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	

1

1   **4.4.4.2.3 Precipitation**

2   <u>MAGICC Results</u>

3   According to the IPCC WG1 (IPCC, 2007), global mean precipitation is expected to increase
4 under all the scenarios. Generally, precipitation increases occur in the tropical regions and high latitudes,
5 with decreases in the sub-tropics. The results from the AOGCMs suggest considerable uncertainty in
6 future precipitation for the three SRES scenarios. Where information in the analysis included in the DEIS
7 is incomplete or unavailable, the agency has relied on CEQ's regulations regarding incomplete or
8 unavailable information (see 40 CFR § 1502.22(b)). In this case, the IPCC (2007) summary of
9 precipitation represents the most thoroughly reviewed, credible assessment of this highly uncertain factor.
10 NHTSA expects that the CAFE alternatives would reduce the changes in proportion to their effects on
11 temperature.

12   The global mean change in precipitation provided by the IPCC for the A2 (high), A1B (medium),
13 and B1 (low) scenarios (IPCC, 2007a) is given as the scaled change in precipitation (as a percentage
14 change from 1980-1999 averages) divided by the increase in global mean surface warming for the same
15 period (per degree C) as shown in Table 4.4-7 below. IPCC provided scaling factors in the year ranges
16 2011-2030; 2046-2065; and 2080-2099. The scaling factors for the A1B (medium) scenario were used in
17 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

18
19   Applying these to the reductions in global mean surface warming provides estimates of changes
20 in global mean precipitation. Given that the CAFE alternatives would reduce temperature increases
21 slightly with respect to the No Action Alternative, they also would reduce predicted increases in
22 precipitation slightly, as shown in Table 4.4-8 (again, based on the A1B (medium) scenario).

1

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 (°C) 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 (°K) 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

2
3   In addition to changes in mean annual precipitation, climate change is anticipated to affect the
4   intensity of precipitation as described below (IPCC, 2007, p. 750):

5   *"Intensity of precipitation events is projected to increase, particularly in tropical and*
6   *high latitude areas that experience increases in mean precipitation. Even in areas where*
7   *mean precipitation decreases (most subtropical and mid-latitude regions), precipitation*

1   *intensity is projected to increase but there would be longer periods between rainfall*
2   *events. There is a tendency for drying of the mid-continental areas during summer,*
3   *indicating a greater risk of droughts in those regions. Precipitation extremes increase*
4   *more than does the mean in most tropical and mid- and high-latitude areas."*

5   Regional variations and changes in the intensity of precipitation events cannot be quantified
6   further. This is due primarily to the availability of AOGCMS required to estimate these changes. These
7   models are typically used to provide results between scenarios with very large changes in emissions such
8   as the SRES B1 (low), A1B (medium), and A2 (high) scenarios and very small changes in emission
9   profiles would produce results that would be difficult to resolve between scenarios with relatively small
10   changes in emissions. In addition, the multiple AOGCMs produce results that are regionally consistent in
11   some cases but are inconsistent in other areas.

12   ### Scaling Results

13   Given that the MAGICC modeling approach is based on a scaling methodology (per Table 4.4-7),
14   a separate scaling calculation was not employed to characterize precipitation.

15   Table 4.4-9 summarizes the regional changes to precipitation from the IPCC Fourth Assessment.
16   It is not possible at this point to quantify the changes to regional climate from the CAFE alternatives but it
17   is expected that they would reduce the changes relative to the reduction in global mean surface
18   temperature.[17]

---

[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).

			Snow Season and
Land Area	**Sub-region**	**Precipitation**	**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	
		Precipitation in summer is *likely* to increase	
	Eastern Asia	Precipitation in boreal winter is *likely* to increase	
		Precipitation in summer is *likely* to increase	
		Very likely to be an increase in the frequency of intense precipitation	
		Extreme precipitation and winds associated with tropical cyclones are *likely* to increase	
	South Asia	Precipitation in summer is *likely* to increase	
		Very likely to be an increase in the frequency of intense precipitation	
		Extreme precipitation and winds associated with tropical cyclones are *likely* to increase	
	Southeast Asia	Precipitation in boreal winter is *likely* to increase in southern parts	
		Precipitation in summer is *likely* to increase in most parts of southeast Asia	
		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)

			Snow Season and
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	

1
2   **4.4.4.2.4 Sea Level Rise**

3   IPCC identifies four primary components to sea level rise: thermal expansion of ocean water;
4   melting of glaciers and ice caps; loss of land-based ice in Antarctica; and loss of land-based ice in
5   Greenland (IPCC, 2007). Ice sheet discharge is an additional factor that could influence sea level over the
6   long term. MAGICC calculates the oceanic thermal expansion component of global-mean sea level rise,
7   using a non-linear temperature- and pressure-dependent expansion coefficient (Wigley, 2003). It also
8   addresses the other three primary components through ice-melt models for small glaciers and the
9   Greenland and Antarctic ice sheets.

10   The state-of-the-science reflected in the IPCC Fourth Assessment Report (IPCC, 2007) projects
11   sea level to rise of 18 to 59 centimeters (cm) by 2090-2099 (Parry, 2007 in National Science and
12   Technology Council, 2008). This projection does not include all changes in ice sheet flow or the potential
13   for rapid acceleration in ice loss (Alley et al., 2005; Gregory and Huybrechts, 2006; Hansen, 2005 in Pew,
14   2007). Several recent studies have found the IPCC's projections of potential sea level rise may
15   underestimate ice loss from the Greenland and Antarctic ice sheets (Shepherd and Wignham, 2007;
16   Csatho, et al., 2008) and ice loss from mountain glaciers (Meier et al., 2007). Further, IPCC may
17   underestimate sea level rise that would be gained through changes in global precipitation (Wentz et al.,
18   2007; Zhang et al., 2007). Rahmstorf (2007) used a semi-empirical approach to project future sea level
19   rise. The approach yielded a proportionality coefficient of 3.4 millimeters (mm) per year per °C of
20   warming, and a projected sea level rise of 0.5 to 1.4 meter (m) above 1990 levels in 2100 when applying
21   IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that, "A rise over 1 m
22   by 2100 for strong warming scenarios cannot be ruled out."

23   Sea level rise is discussed in more detail in Section 4.5.5, Coastal Systems and Low-lying Areas.

1   <u>MAGICC Results</u>

2   MAGICC reports sea level rise in increments of 0.1 centimeter (cm) (i.e., 1 millimeter [mm]).
3   The impact on sea level rise from the scenarios is at the threshold of the model's reporting: the
4   alternatives reduce sea level rise by 0.1 to 0.2 cm (Table 4.4-10). Although the model does not report
5   enough significant figures to distinguish between the effects of the alternatives, it is clear that the more
6   stringent the alternative (i.e., the lower the emissions), the lower the temperature (as shown above); and
7   the lower the temperature, the lower the sea level. Thus, the more stringent alternatives are likely to
8   result in slightly less sea level rise.

9   <u>Scaling Results</u>

10   One of the areas of climate change research where there have been many recent developments is
11 the science underlying the projection of sea level rise. As noted above, there are four key components of
12 sea level rise. The algorithms in MAGICC do not reflect some of the recent developments in the state-of-
13 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

1
2   Table 4.4-11 presents estimates of sea level rise provided by the IPCC WG1, excluding the effect
3 of scaled-up ice sheet discharge, where further accelerations have been observed but could not be
4 quantified with confidence (IPCC, 2007). Note that "for each scenario the lower/upper bound for sea
5 level rise is larger/smaller/ than the total of the lower/upper bounds of the contributions, since the
6 uncertainties of the contributions are largely independent" (IPCC, 2007, p. 820). The midpoint value for
7 the A1B (medium) scenario is 0.35 m or 35 cm, in good agreement with the MAGICC estimate of 38 cm.
8 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

9
10   The scaling approach to estimate the impact of changes in sea level rise involved the following
11 steps:

12   1. Changes in global mean temperature due to the alternative CAFE standards were compared
13   with the difference between the global mean temperature increase from B1 (low) to A1B
14   (medium). These values were taken from Table 4.4-5.

244

1   2. The change in sea level between scenarios B1 (low) and A1B (medium) was calculated (the
2   simple difference in cm).

3   3. The resulting temperature ratios were used to interpolate within the interval of sea level
4   estimates for the B1 (low) and A1B (medium) scenarios, reported by the IPCC.

5   This approach captures two effects which could overstate the impacts by just scaling the sea level
6 rise by changes in global temperature. The first effect is the current "commitment" (i.e., the inertia in the
7 climate system that would result in climate change even if concentrations did not increase in the future) to
8 global warming, which will occur despite the emission reduction from the CAFE alternatives. The
9 second is the current commitment to sea level rise similar to the current commitment to global warming.
10 By examining the difference between the low (B1) scenario and the mid-level (A1B) scenario, these
11 terms, which will be the same in both scenarios, are eliminated.

12   The commitment to increases in temperature, precipitation, and sea level rise is described in the
13 IPCC WG1 Fourth Assessment Report (IPCC, 2007), which indicates that if concentrations of GHGs
14 were to stabilize at current levels then an additional warming of 0.5 degree Celsius would occur along
15 with an additional increase of global averaged precipitation would increase 1 to 2 percent, and sea level
16 would rise due to thermal expansion by an additional 0.3 to 0.8 meters by 2300 relative to the 1980 to
17 1999 period.

18   Where information in the analysis included in this DEIS is incomplete or unavailable, NHTSA
19 has relied on CEQ's regulations regarding incomplete or unavailable information (40 CFR § 1502.22(b)).
20 In this case, the approach seeks to apply some of the results from state-of-the-art models to address the
21 complex issues of climate system commitment and sea level rise commitment. NHTSA believes this
22 approach provides a valid approximation, while recognizing that the recent developments in the science
23 of sea level rise suggest that these estimates may be understated (as noted earlier).

24   The results are shown below in Table 4.4-12 for scenario A1B (medium). Across the CAFE
25 alternatives, the mean change in the global mean surface temperature, as a ratio of the increase in
26 warming between the B1 (low) to A1B (medium) scenarios, ranges from 1.2 percent to 1.7 percent. The
27 resulting change in sea level rise (compared to the No Action Alternative) ranges across the alternatives
28 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,
29 despite the fact that MAGICC does not reflect some of the more recent developments in the state-of-the-
30 science, the results are of the same magnitude.

1

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 °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	2.640	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

2
3   In summary, the impacts of the MY 2011-2020 CAFE alternatives on global mean surface
4   temperature, sea level rise, and precipitation are relatively small in the context of the expected changes
5   associated with the emission trajectories in the SRES scenarios. This is due primarily to the global and
6   multi-sectoral nature of the climate problem. Emissions of CO_2, the primary gas driving the climate
7   effects, from the United States automobile and light truck fleet represented about 2.5 percent of total
8   global emissions of CO_2 in the year 2000 (EPA, 2008; WRI, 2008). While a significant source, this is a
9   still small percentage of global emissions, and the relative contribution of CO_2 emissions from the United
10 States light vehicle fleet is expected to decline in the future, due primarily to rapid growth of emissions
11 from developing economies (which are due in part to growth in global transportation sector emissions).
12 In the SRES A1B (medium) scenario (Nakicenovic et al., 2000), the share of liquid fuel use, mostly
13 petroleum and biofuels, from the Organization for Economic Cooperation and Development (OECD)
14 countries declines from 60 percent in 2000 to 17 percent in 2100.

1
2
3

[This page intentionally left blank]

1 **4.5   RESOURCE IMPACTS OF CLIMATE CHANGE**

2 **4.5.1   Introduction**

3   The effects of the CAFE alternatives on climate as described in Section 4.4 – CO_2 concentrations,
4 temperature, precipitation, and sea level rise – can translate into impacts on key natural and human
5 resources, including freshwater resources; terrestrial ecosystems; coastal systems and low-lying areas;
6 managed ecosystems that produce food, fiber and forest products; industry, settlements, society, and other
7 aspects of the built environment; and human health. This section describes the impacts on each of the
8 resources associated with climate change.

9   After a discussion of methodology, Section 4.5 is divided into six subsections, one for each of the
10 resource areas. Each subsection discusses the affected environment, provides an overview of the resource
11 globally and in the United States, and addresses the consequences of climate change on that resource.
12 Observed changes are also reported. In each subsection, an attempt has been made to present both
13 positive and negative effects of climate change, as they are represented in the literature. The subsections
14 are:

15   ■   Freshwater resources
16   ■   Terrestrial ecosystems
17   ■   Coastal systems and low-lying areas
18   ■   Food, fiber, and forests
19   ■   Industry, settlements, and society
20   ■   Human health
21

22   The subsections generally follow the organization of topic areas in the climate literature, notably
23 by IPCC, which is a key source for much of the information presented in this section, and by USCCSP.
24 These categories do not follow the classification of resources typically found in an EIS. Please refer to
25 the chart in Section 4.1 to find where specific NEPA topics are covered.

26   As shown in Section 4.4, although the alternatives have the potential to substantially decrease
27 GHG emissions, they do not prevent climate change from occurring, but only result in small reductions in
28 the anticipated increases in CO_2 concentrations, temperature, precipitation, and sea level. As discussed
29 below, NHTSA's assumption is that these reductions in climate effects will be reflected in reduced
30 impacts on affected resources. However, the magnitude of the changes in these climate effects that the
31 alternatives produce – a few ppm of CO_2, a hundredth of a degree Celsius difference in temperature, a
32 small percentage-wise change in the rate of precipitation increase, and 1 or 2 mm of sea level – are too
33 small to address quantitatively in terms of their impacts on resources. Given the enormous resource
34 values at stake, these distinctions may be important – very small percentages of huge numbers can still
35 yield substantial results – but they are too small for current quantitative techniques to resolve.
36 Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but
37 rather provides a qualitative review of the benefits of reducing GHG emissions and the magnitude of the
38 risks involved in climate change.

39 **4.5.2   Methodology**

40   Various reports were reviewed in order to assess the cumulative impacts of the proposed action.
41 The key reports consulted for material include IPCC's Fourth Assessment Report by Working Group II
42 entitled *Climate Change 2007- Impacts, Adaptation and Vulnerability* (IPCC, 2007), and the USCCSP
43 SAP reports. Multiple SAP reports were reviewed such as, *Scientific Assessment of the Effects of Global*

1   *Climate Change on the United States and SAP reports 4.1-4.7.* More information on the SAP reports can
2   be found at www.climatescience.gov/Library/sap.

3   The SAP report titles include: SAP 4.1 (*Coastal Elevations and Sensitivity to Sea Level Rise*),
4   SAP 4.2 (*Thresholds of Change in Ecosystems*), *SAP 4.3 (*The Effects of Climate Change on Agriculture,
5   Land Resources, Water Resources, and Biodiversity*), SAP 4.4 (*Preliminary Review of Adaptation
6   Options for Climate-Sensitive Ecosystems and Resources*, *SAP 4.5 (*Effects of Climate Change on Energy
7   Production and Use in the United States*), *SAP 4.6 (*Analyses of the Effects of Global Change on Human
8   Health and Welfare and Human Systems*) and SAP 4.7 (*Impacts of Climate Variability and Change on
9   Transportation Systems and Infrastructure -- Gulf Coast Study*). Note that not all of the SAP reports have
10   been finalized; although publicly available and generally in later stages of review and revision, some were
11   still in draft form at the time of the preparation of this document. Researchers also referenced additional
12   studies published since the release of the IPCC and SAP reports.

13   Research was compiled on the following sectors: freshwater resources; ecosystems and
14   biodiversity; coastal and low lying areas; industry, settlement and society; food, fiber, and forest products;
15   and human health. Each sector provided an introduction to what is included in the section and addressed
16   the impacts and adaptations anticipated for both the United States and global spheres. In order to assess
17   the impacts of climate change on the United States, NHTSA first consulted the SAP reports for their
18   respective sector and then examined more recent materials of relevance such as the Natural Resources
19   Defense Council's (NRDC) *Cost of Climate Change* (May 2008), Union of Concerned Scientists (UCS)
20   *Confronting Climate Change in the U.S. Northeast* (Frumhoff et al., 2007), and the University of
21   Maryland's (UMD) *The US Economic Impacts of Climate Change and the Costs of Inaction* (CIER,
22   2007). The global impacts sections focused on the IPCC report as it is the most recent, comprehensive,
23   and peer reviewed material on this topic. Articles and studies cited within the IPCC's report were
24   consulted for additional information on various topics.

25   In order to accurately reflect the likelihood of climate change impacts for each sector, NHTSA
26   referenced the IPCC's uncertainty guidelines. This provides a consistent approach to defining the levels
27   of confidence that a predicted impact will occur and the probability of an outcome or result in terms of
28   percentages. More information on the uncertainty guidelines can be found in the *Treatment of
29   Uncertainties in the IPCC's Working Group II Assessment* in Solomon et al., 2007.

30   **4.5.2.1 Cumulative Climate Impacts of Alternative CAFE Standards**

31   As described in Chapter 3, the alternative CAFE options under consideration result in different
32   time streams of CO_2 emissions associated with the operation of United States vehicles. These emissions,
33   in combination with United States GHG emissions from other sources (such as power plants, natural gas
34   use, and agricultural production) and with emissions of all GHGs globally, will alter atmospheric
35   concentrations of GHGs. As the modeling results presented in Section 4.4 display, different atmospheric
36   concentrations of GHGs will be associated with long-term changes in global climate variables, including
37   global average temperature, precipitation, and rising sea level. In turn, these climate changes will result
38   in changes to a range of natural and human resources and systems, including water supplies, human
39   health, the built environment, and a host of others.

40   The most common approach to assessing the impacts of climate change is to construct future
41   scenarios that represent combinations of changes in levels, and sometimes patterns or variability, of
42   temperature, precipitation, sea level rise, and other relevant climatic and related variables (IPCC, WGII,
43   p.31). In some case these scenarios will represent the results of specific climate modeling (i.e., the output
44   of General Circulation Models [GCMs]), often downscaled to provide results at a finer level of
45   geographic resolution). In other cases, scenarios may be designed to be representative of the *types and*

1 *range* of effects that are expected to occur under climate change, and not the results of specific models
2 (Parsons et al., 2007). Impacts associated with these scenarios are then estimated using a variety of
3 techniques, including models of individual systems (e.g., specific ecosystems or geographic areas, such as
4 a park) and examination of performance under similar historical conditions.

5 The impacts literature suggests that some regions and sectors will experience positive effects of
6 future climate change, particularly at lower levels of temperature change (less than 1 to 3 degrees Celsius
7 above 1990 levels), while others will experience negative effects (Policy Makers Summary, WGII report).
8 Working Group II of AR4 found that, at higher levels of temperature, on balance the net global effects are
9 expected to be negative: "while developing countries are expected to experience larger percentage losses,
10 global mean losses could be 1 to 5 percent gross domestic product (GDP) for 4°C of warming" (WGII
11 report, p. 17). To put these numbers in context, the IPCC has projected longer-term warming (associated
12 with a doubling of CO_2 concentrations) in the range of 2 degrees Celsius to 4.5 degrees Celsius (IPCC
13 WGI). The modeling results presented in Section 4.4 suggest that, for the CAFE alternatives, the
14 cumulative climate effects under a moderate emissions scenario lie in the range of 2.7 to 2.8 degrees
15 Celsius as of 2100.

16 NHTSA's presumption, consistent with the general literature cited above and reviewed for
17 Section 4.5, is that reducing emissions and concomitant climate effects will reduce the net negative long
18 term effects that have been projected for climate change. NHTSA has not, however, conducted a
19 quantitative comparison of the climate impacts of the CAFE alternatives, for several reasons.

20 First, as indicated above, analyses of impacts often focus on discrete climate scenarios, rather
21 than a continuum of climate outcomes; the information to analyze small changes in climate variables is
22 not, therefore, generally available in the literature. Moreover, as the global climate changes, so will
23 regional and local climates. Changes in global climate variables will be reflected in regional and local
24 changes in average climate variables, as well as in the variability and patterns of climate, such as seasonal
25 and annual variations, the frequency and intensity of extreme events, and other physical changes, such as
26 the timing and amount of snowmelt. Impacts assessments often rely on highly localized data for both
27 climate and other conditions and circumstances (Gamble et al., 2005). Thus, changes in impacts due to
28 changes in global average climate, as projected in this analysis, will likely not be adequately represented
29 by a simple scaling of results. Where information in the analysis included in the DEIS is incomplete or
30 unavailable, the agency has relied on CEQ's regulations regarding incomplete or unavailable information
31 (*see* 40 CFR § 1502.22(b)). Information on the effect of very small changes in temperature, precipitation,
32 and sea level rise (at the scale of the distinctions between the CAFE alternatives) is not currently
33 available. Nevertheless, NHTSA's qualitative characterization – viz. that the greater the reductions in
34 GHG emissions, the lower the environmental impact – is consistent with theoretical approaches and
35 research methods generally accepted in the scientific community.

36 Second, there is considerable debate about the likely shape of a global climate impacts damage
37 function; although many believe it to be upwardly sloped (so that marginal net damages rise with
38 increasing levels of climate change), there is less agreement on the shape, i.e., how *rapidly* net climate
39 damages rise as temperature and other variables increase (IPCC WGII). There is also the important
40 question of whether thresholds exist, e.g., stress points at which ecosystems collapse, or negative impacts
41 rapidly accelerate—a topic important enough to warrant attention in a SAP on which the U.S. Geological
42 Survey (USGS) is the lead agency. Finally, much of the work on impacts—both globally and more
43 localized—is, in and of itself, qualitative, rather than quantitative, and so does not lend itself to further
44 quantification.

45 NHTSA's presumption is that reductions in climate effects due to the CAFE alternatives will be
46 reflected in reduced impacts on affected resources. However, the magnitudes of the changes in these

1   climate effects that the alternatives produce – a few ppm of CO_2, a hundredth of a degree Celsius
2   difference in temperature, a small percentage-wise change in the rate of precipitation increase, and 1 or 2
3   mm of sea level – are too small to address quantitatively in terms of their impacts on resources.
4   Consequently, the discussion of resource impacts does not distinguish among the CAFE alternatives, but
5   rather provides an overview of climate impacts and therefore a qualitative review of the benefits of
6   reducing GHG emissions and the magnitude of the risks involved in climate change.

7   NHTSA's presumption is that reductions in emissions and, therefore, climate effects will be
8   reflected in reduced impacts on affected resources. However, the magnitudes of the changes in these
9   climate effects that the CAFE alternatives produce are too small to address quantitatively in terms of their
10 impacts on resources. Consequently, as discussed further in Section 4.5.2, the discussion of resource
11 impacts does not distinguish among the CAFE alternatives. Where information in the analysis included
12 in the DEIS is incomplete or unavailable, the agency has relied on CEQ's regulations regarding
13 incomplete or unavailable information (40 CFR § 1502.22(b)). Information on the effect of very small
14 changes in temperature, precipitation, and sea level rise (at the scale of the distinctions between the CAFE
15 alternatives) is not currently available. Nevertheless, NHTSA's qualitative characterization – viz., that
16 the greater the reductions in GHG emissions, the lower the environmental impact – is consistent with
17 theoretical approaches and research methods generally accepted in the scientific community.

18 **4.5.2.2 Treatment of Uncertainties in the Working Group I Assessment**

19   Uncertainties can be classified in several different ways. "Value uncertainties" and "structural
20 uncertainties" are two primary types of uncertainties. When data are inaccurate or do not fully represent
21 the phenomenon of interest, value uncertainties arise. These types of uncertainties are usually estimated
22 with statistical techniques, and are then expressed probabilistically." An incomplete understanding of the
23 process that controls particular values or results generates structural uncertainties. These types of
24 uncertainties are described by giving the authors' collective judgment of their confidence in the
25 correctness of a result." As stated in the Working Group I Assessment, a "careful distinction between
26 levels of confidence in scientific understanding and the likelihoods of specific results" are drawn in the
27 uncertainty guidance provided for the Fourth Assessment Report.

28   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

29

1   The standard terms used to define the likelihood of an outcome or result where this can be
2   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

3
4   **4.5.3   Freshwater Resources**

5   This section addresses climate-related impacts on freshwater resources. Water is necessary to
6   support life, societal welfare, and economic activity. "Given water's importance, plant, animal, and
7   human communities are all sensitive to variations in the availability, storage, fluxes, and quality of
8   surface and groundwater. These, in turn, are sensitive to climate change" (USCCSP, 2008, p.145).

9   **4.5.3.1   Affected Environment**

10   This affected environment section was derived from World Water Resources at the Beginning of
11   the 21st Century (Shiklomanov and Rodda, 2003), United Nations Educational, Scientific and Cultural
12   Organization – World Water Assessment Program (UNESCO-WWAP) World Water Development
13   Report 2 (UNESCO et al., 2006), and Pilot Analysis of Global Ecosystems: Freshwater Systems
14   (Revenga et al., 2000).

15   Water supports all life on Earth. While about 70 percent of the Earth's surface is covered by
16   water, most (97.5 percent) is contained in the oceans. Freshwater refers to the 2.5 percent of the Earth's
17   hydrosphere that is not saline. Freshwater is portioned between glaciers (68.7 percent), groundwater
18   (30.1 percent), permafrost (0.8 percent), and surface and atmospheric water (0.4 percent). This 0.4
19   percent is portioned between freshwater lakes (67.4 percent) and wetlands (8.5 percent); rivers (1.6
20   percent); soil moisture (12.2 percent); water in the atmosphere (9.5 percent); and water in living
21   organisms (0.8 percent) (Shiklomanov and Rodda, 2003 in UNESCO et al., 2006).

22   The largest volume of freshwater is stored in a frozen state in the planet's glaciers and ice sheets,
23   most of which are in Antarctica (almost 90 percent), while the remainder are found in Greenland (almost
24   10 percent) and in mountain glaciers. Permafrost extends over northeast Europe and the north and
25   northeastern parts of Asia, including the Arctic islands, northern Canada, and the fringes of Greenland
26   and Antarctica, as well as high-altitude areas of South America.

27   Groundwater is the second largest source of freshwater. Groundwater is found across the world
28   in the pores of soils and fractures of rocks and is the largest source of unfrozen freshwater. Groundwater
29   feeds springs, streams, and lakes, supports wetlands, and is a critical source of water for human
30   consumption. Groundwater also includes aquifers (underground strata of water) bearing permeable rock

1 or unconsolidated materials (e.g., sand, gravel, and some silts and clays) from which water can be
2 extracted using well systems.

3   Lakes, which can be broadly defined as bodies of water collected in depressions in the Earth's
4 surface, are widespread (there are around 15 million) and store the largest volume of fresh surface waters.
5 Reservoirs, which could be considered a lake, are enclosed areas constructed for the storage of water, and
6 are typically created by damming a river channel in a valley.

7   Wetlands, such as marshes, swamps, bogs, and estuaries are transitional zones between land and
8 water environments where the soil is frequently or permanently waterlogged. Wetlands of various types
9 exist all over the world, and it is estimated that during the 20th century, half of them were lost as land was
10 converted to agriculture and urban use or filled to combat disease.

11   Rivers are bodies of flowing water that drain surface runoff from land into the seas and oceans.
12 They begin in higher elevations such as mountains and hills where rainwater and snowmelt collect
13 forming small tributary streams that flow into larger streams and rivers.

14   Soil moisture is water that drains into the soil, mainly the top two meters, and becomes part of the
15 soil water store, where it is used by plants. Water exists in the atmosphere in the form of water vapor,
16 water drops, and ice crystals, and falls as precipitation, which occurs as rain, snow, sleet, hail, frost, or
17 dew. Biological water is the water contained in living organisms such as plants and animals.

18   Much of the discussion that follows below is drawn from the following studies and their citations:
19 the IPCC *Freshwater Resources and their Management* (Kundzewicz et al., 2007), the USCCSP
20 *Scientific Assessment of the Effects of Global Change on the United States* (USCCSP, 2008), and *World*
21 *Water Resources at the Beginning of the 21st Century* (Shiklomanov and Rodda, 2003), *Pilot Analysis of*
22 *Global Ecosystems: Freshwater Systems* (Revenga et al., 2000), and *Threats to the World's Freshwater*
23 *Resources* (Gleick et al., 2001).

24 **4.5.3.2 Non-climate Threats to Freshwater Resources**

25   Pressure on global freshwater resources during recent decades has come from non-climatic as
26 well as climatic drivers. The non-climate threats include changes in population, economy, and
27 technology. Population growth and economic development create increasing demands from the
28 industrial, municipal, and agricultural sectors. For example, irrigated agriculture to support the demand
29 for food accounts for nearly 70 percent of global freshwater withdrawals and for more than 90 percent of
30 global consumptive use (Shiklomanov and Rodda, 2003 in Kundzewicz et al., 2007). The extent of
31 irrigated areas, which is expected to expand in areas that are already water-stressed, will determine the
32 effect that this use will have on global water use in the future.

33   The driving threats to the world's supply of freshwater resources are consistently reported in the
34 literature: population growth and increased demand; infrastructure development (e.g., dams, dikes, levees,
35 and river diversions); poor land use (e.g., urbanization, conversion to crop or grazing lands, wetland
36 removal or reduction, deforestation); overexploitation (e.g., groundwater aquifer depletion and reduced
37 water levels in lakes, rivers, and wetlands); and water pollution from industrial, municipal, and
38 agricultural sources (e.g. phosphorus and nitrogen from fertilizers, pesticides, pathogens and microbial
39 contaminants, heavy metals, toxic organic compounds and micro-organic pollutants; silt and suspended
40 particles; acidification (from air pollution); and thermal pollution (from industrial discharges and slow
41 flows caused by dams and reservoirs).

1   Shiklomanov and Rodda (2003) state that "Every year human influences grow and cause more
2 and more changes to natural processes…These changes bring about alterations to the water balance and to
3 water resources and their availability. The rapid growth of population, the development of industrial
4 production and the rise of agriculture have resulted in the increased use of water…Human activities have
5 also changed the character of groundwater…more often the water table has been lowered to provide water
6 for drinking…The construction of reservoirs has led to the slowing down of the movement of river
7 waters. Slowing the movement of water can influence its quality particularly by the accumulation of
8 pollutants" (p. 17).

9   The freshwater resources in the United States are affected by the same non-climate threats
10 discussed above. The USCCSP (2008) found that "most water quality changes observed so far across the
11 continental United States are likely attributable to causes other than climate change" (p. 14). The EPA
12 cites siltation, nutrients, and metals (e.g. mercury) as the main sources of pollution in United States
13 waters, mostly as a result of nonpoint source pollution from urban and agricultural lands (EPA, 2000;
14 EPA, 2002).

15   Ecosystem integrity, as defined by Gleick et al., (2001), is the interaction between the biological
16 and chemical processes that support the functioning of an ecosystem and the health of the species
17 supported by it. Water withdrawal and consumption by humans is directly connected to the integrity of
18 freshwater ecosystems, because it competes with natural systems for water and leads to pollution,
19 disrupting the natural processes that take place. As a result, the health of habitats, and the species that
20 live in them, is affected. Revenga et al., (2000) found that between 1900 and 1995, world water
21 withdrawals increased six-fold, more than twice the rate of population growth. As water withdrawals
22 increase, more stress will be put on freshwater ecosystems.

23 4.5.3.3 Consequences

24   Much of the discussion that follows is drawn from the following studies including the citations
25 therein: IPCC's *Freshwater Resources and their Management* (Kundzewicz et al., 2007), *Scientific*
26 *Assessment of the Effects of Global Change on the United States* (USCCSP, 2008), and *The Effects of*
27 *Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*
28 (Lettenmaier et al., 2008). Additional recent studies from peer-reviewed literature are also cited.

29   Non-climate-related impacts on freshwater resources have received more attention than climate-
30 related impacts to date. However, "climate change is expected to result in increasing effects in the future"
31 (USCCSP, 2008, p. 154). Climate change effects are especially relevant to freshwater resource
32 management for the future. Freshwater resource infrastructure has been designed to accommodate the
33 variability in water supply based on the historical record. This assumption that, on average, the future
34 will be the same as the past is referred to as the stationarity assumption (Lettenmaier et al., 2008 in
35 USCCSP, 2008). However, this assumption is now challenged by the demonstrated occurrence of climate
36 change (Arnell, 2002; Lettenmaier, 2003; and Milly et al., 2008 in USCCSP, 2008). As a result, "the
37 global population is highly vulnerable to climate change impacts on freshwater resources" (USCCSP,
38 2008, p. 154).

39   Global warming resulting from the enhanced greenhouse effect causes changes in temperature,
40 precipitation, and ice melt, as well as other climate change effects. Evaporation, transpiration, and the
41 water-holding capacity of the atmosphere all increase at higher temperatures. Increased atmospheric
42 water content favors increased climate variability—more intense droughts and more intense precipitation
43 (Trenberth et al., 2003 in Kundzewicz et al., 2007).

1   "While temperatures are expected to increase everywhere over land and during all seasons of the
2   year, although by different increments, precipitation is expected to increase globally and in many river
3   basins, but to decrease in many others" (Kundzewicz et al., 2007, p. 176). Precipitation may also increase
4   in one season and decrease in another (Meehl et al., 2007, Section 10.3.2.3 in Kundzewicz et al., 2007).
5   Changes in temperature and precipitation are the main climatic drivers observed to affect freshwater
6   availability, quality, and water use.

7   **4.5.3.3.1 Globally Observed Climate Effects**

8   General climate change impacts on hydrology and freshwater resources identified to date include
9   the following (Arnell et al., 2001 in Kundzewicz et al., 2007):

10   ▪ Changes in streamflow volume—increases and decreases
11   ▪ Variation in streamflow and groundwater recharge—largely following precipitation
12   ▪ Shifts in peak streamflow timing—earlier snowmelt
13   ▪ Lower streamflow in summer and autumn
14   ▪ Glacier retreat and disappearance of small glaciers
15   ▪ Water quality degradation—higher water temperatures
16   ▪ Increases in flood magnitude and frequency

17   Climate-related trends have already been observed in various inputs, throughputs, and outputs to
18   the freshwater system, including the following (Kundzewicz et al., 2007):

19   ▪ Precipitation – increasing over northern (30°N) latitudes; decreasing over middle latitudes
20   (10°S to 30°N); increasing in intensity.

21   ▪ Snow cover – decreasing in most regions

22   ▪ Glaciers – decreasing almost everywhere

23   ▪ Permafrost – thawing between 0.08 inch per year (Alaska) and 1.8 inches per year (Tibetan
24   plateau)

25   ▪ Streamflow – increasing in Eurasian Arctic, significant increases or decreases in some river
26   basins; earlier spring peak flows and increased winter-based flows in North America and
27   Eurasia

28   ▪ Evapotranspiration – increased actual evapotranspiration in some areas

29   ▪ Lakes – warming, significant increases and decreases in some lake levels, and reduction in
30   ice cover

31   For other anticipated changes in the freshwater system, data are insufficient to observe a climate
32   trend, especially when compared to the non-climatic pressures mentioned previously. The absence of an
33   observed trend does not indicate that freshwater resources will not be sensitive to future climate trends.
34   As described in the section on impacts below, changes are also anticipated for groundwater levels, floods,
35   droughts, water quality, erosion and sediment transport, and irrigation water demand (Kundzewicz et al.,
36   2007):

1   **4.5.3.3.2 Observed and Projected Impacts of Climate Change on Freshwater**
2   **Resources in the United States**

3   Most of the freshwater resource analyses are keyed either to climate scenarios (e.g., what happens
4   if temperature increases by 6°F, and precipitation declines by 10 percent) or to global climate model
5   outputs pegged to IPCC-reported emission scenarios. The projected impacts resulting from such
6   analyses, current sensitivities, and potential vulnerabilities (including extreme events) are summarized in
7   this section, first for the United States and then, in the next section, globally.

8   The climate change impacts on freshwater resources in the United States are described by the
9   USCCSP (USCCSP, 2008; Backlund et al., 2008), Lettenmaier et al., (2008), and Field et al., (2007).

10   "In regards to the hydrologic observing systems on which these sections are based, Lettenmaier et
11   al., (2008) found that the current hydrologic observing system was not designed specifically for the
12   purpose of detecting the effects of climate change on water resources. In many cases, the resulting data
13   are unable to meet the predictive challenges of a rapidly changing climate" (USCCSP, 2008, p. 151).

14   Several recent State and regional studies have examined specific climate change impacts on
15   freshwater resources. For example, many impacts on freshwater resources described above have been
16   predicted for New Mexico (D'Antonio, 2006), New Jersey (EPA, 1997); and the West (Saunders, 2008).

17   "Projections for the western mountains of the United States suggest that warming, and changes in
18   the form, timing, and amount of precipitation will *very likely* lead to earlier melting and significant
19   reductions in snowpack by the middle of the 21st century" (*high confidence*). "In mountainous snowmelt-
20   dominated watersheds, projections suggest advances in the timing of snowmelt runoff, increases in winter
21   and early spring flows (raising flooding potential), and substantially decreased summer flows. Heavily
22   utilized water systems of the western United States that rely on capturing snowmelt runoff, such as the
23   Columbia River system, will be especially vulnerable" (Field et al., 2007 in USCCSP, 2008, p. 153).
24   Trends in declining snowpack are perhaps best illustrated from studies conducted for California. Reduced
25   snowpack has been identified as a major concern for the State (California Energy Commission, 2006 in
26   USCCSP, 2008). Several authors anticipate a coming crisis in water supply for the western United States
27   (Barnett et al., 2008), and have projected that Lake Mead (on the Colorado River system) might go dry
28   (Barnett and Pierce, 2008). While these studies focus on issues already identified in the literature, their
29   findings suggest that freshwater resources may in fact be more sensitive to climate change than previously
30   projected.

31   **4.5.3.3.3 Precipitation**

32   Precipitation is the primary driver of the land surface hydrological system. Precipitation
33   variability, and subsequent surface water availability varies regionally across the United States depending
34   on a catchment's physical, hydrological, and geological characteristics (USCCSP, 2008). In general,
35   conditions become increasingly dry from east to west. Upslope areas in the Cascade and coastal
36   mountain ranges are more humid with relatively low precipitation variability. The Intermountain West
37   and Southwest are driest, and the greatest precipitation variability is in the arid and semi-arid West
38   (Lettenmaier et al., 2008 in USCCSP, 2008). Stream gauge data (Mauget, 2003 in Lettenmaier et al.,
39   2008) showed increases in streamflow from 1939 through 1998 in the eastern United States and a more or
40   less reverse pattern in the western United States (USCCSP, 2008).

1	**4.5.3.3.4 Surface Water**
2	The observed impacts on surface water (Field et al., 2007 in USCCSP, 2008) include the
3	following:

4   ▪ Streamflow in the eastern United States has increased 25 percent in the last 60 years
5   (Groisman et al., 2004), but over the last century has decreased by about 2 percent per decade
6   in the central Rocky Mountain region (Rood et al., 2005).

7   ▪ Since 1950, stream discharge in both the Colorado and Columbia River Basins has decreased,
8   while over the same time period annual evapotranspiration from the conterminous United
9   States increased by 2.2 inches (Walter et al., 2004).

10   ▪ In regions with winter snow, warming has shifted the magnitude and timing of hydrologic
11   events (Mote et al., 2005; Regonda et al., 2005; Stewart et al., 2005). From 1949 to 2004, the
12   fraction of annual precipitation falling as rain (rather than snow) increased at 74 percent of
13   the weather stations studied in the western mountains of the United States (Knowles et al.,
14   2006).

15   ▪ Spring and summer snow cover has decreased in the western United States (Groisman et al.,
16   2004). April snow water equivalent has declined 15 to 30 percent since 1950 in the western
17   mountains of North America, particularly at lower elevations and primarily due to warming
18   rather than changes in precipitation (Mote et al., 2003, 2005; Lemke et al., 2007).

19   ▪ Streamflow peaks in the snowmelt-dominated western mountains of the United States
20   occurred 1 to 4 weeks earlier in 2002 than in 1948 (Stewart et al., 2005).

21   Lettenmaier et al., (2008) assessed the following potential impacts on surface water in the United
22   States (USCCSP, 2008):

23   ▪ There is a trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks
24   across much of the western United States. Evidence suggests this trend is *very likely*
25   attributable, at least in part, to long-term warming, although some part may have been played
26   by decadal-scale variability, including a shift in the Pacific decadal oscillation in the late
27   1970s. Where shifts to earlier snowmelt peaks and reduced summer and fall low flows have
28   already been detected, continuing shifts in this direction are expected and may have
29   substantial impacts on the performance of reservoir systems.

30   ▪ Recent climate model simulations reported in the IPCC Fourth Assessment Report project
31   increased runoff over the eastern United States, gradually transitioning to little change in the
32   Missouri and lower Mississippi, to substantial decreases in annual runoff in the interior of the
33   West (Colorado and Great Basin). The projected drying in the interior of the West is quite
34   consistent among models. These changes are, very roughly, consistent with observed trends
35   in the second half of the 20th century, which show increased streamflow over much of the
36   United States, but sporadic decreases in the West.

37   ▪ Snowpacks in the mountainous headwaters regions of the western United States generally
38   declined over the second half of the 20th century, especially at lower elevations and in
39   locations where average winter temperatures are close to or above 0°C. These trends toward
40   reduced winter snow accumulation and earlier spring melt are also reflected in a tendency

1   toward earlier runoff peaks in the spring, a shift that has not occurred in rainfall-dominated
2   watersheds in the same region.

3   • Climate model projections of increased temperatures and slight precipitation increases
4   indicate that modest streamflow increases are expected in the East, but that larger (in absolute
5   value) declines are expected in the West, where the balance between precipitation and
6   evaporative demand will shift toward increased evaporative demand. However, because of
7   the uncertainty in climate model projections of precipitation change, future projections of
8   streamflow are highly uncertain across most of the United States. One exception is
9   watersheds that are dominated by spring and summer snowmelt, most of which are in the
10   western United States. In these cases, where shifts to earlier snowmelt peaks and reduced
11   summer and fall low flows have already begun to be detected, continuing shifts in this
12   direction are generally expected and may have substantial impacts on the performance of
13   reservoir systems.

14   **4.5.3.3.5 Groundwater**

15   The effects of climate on groundwater—especially groundwater recharge—is an area that
16   requires further research to determine any effects resulting from climate change. The available literature
17   (Vaccaro, 1992; Loaiciga et al., 2000; Hanson and Dettinger, 2005; Scibek and Allen, 2006; and Gurdak
18   et al., 2007 in Lettenmaier et al., 2008) implies that groundwater systems generally respond more slowly
19   to climate change than surface water systems. Groundwater levels correlate most strongly with
20   precipitation. Temperature is a more important factor for shallow aquifers during warm periods
21   (USCCSP, 2008).

22   Groundwater and surface water may also be affected by sea level rise. Saltwater intrusion into
23   aquifers may occur in coastal areas, and increased salinity of ground and estuary water may reduce
24   freshwater availability.

25   **4.5.3.3.6 Water Quality**

26   Chemical and microbial inputs, biogeochemical processes, water temperature, and water levels
27   control water quality. Water temperature and water quantity are sensitive to climate change. However,
28   pollution from land use—especially agricultural runoff, urban runoff, and thermal pollution from energy
29   production—have caused most of the observed changes in water quality (USCCSP, 2008).

30   Rising water temperatures negatively affect aquatic biota, especially certain fish species such as
31   salmon (Bartholow, 2005; Crozier and Zabel, 2006 in Lettenmaier et al., 2008). Rising temperatures also
32   affect dissolved oxygen, redox potentials, lake stratification, and mixing rates. However, the direction of
33   climate change effects associated with water quantity on water quality is not as evident. Increased
34   streamflow can dilute pollutant concentrations or transport additional pollutants into surface water
35   sources. Extreme events—floods and droughts—generally exacerbate water quality problems.

36   Region-specific studies conducted for the United States were reviewed by IPCC (Field et al.,
37   2007; Kundzewicz et al., 2007). Projected impacts on water quality include the following (USCCSP,
38   2008):

39   • Changes in precipitation may increase nitrogen loads from rivers in the Chesapeake and
40   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

1   that per capita water consumption has declined over the past two decades in the United States
2   (Lettenmaier et al., 2008). Reducing water consumption will mitigate the impacts of climate change on
3   freshwater resources.

4   **4.5.3.4 Projected Impacts of Climate Change on Global Fresh Water Resources**

5   The IPCC report is the most recent, comprehensive, and peer reviewed summary of impacts on
6   global freshwater resources that is available. Kundzewicz et al., (2007) summarized the conclusions from
7   the freshwater resources and management chapter as follows:

8   ▪   The impacts of climate change on freshwater systems and their management are mainly due
9   to the observed and projected increases in temperature, sea level, and precipitation variability
10   (*very high confidence*).

11   ▪   More than one-sixth of the world's population live in glacier- or snowmelt-fed river basins
12   and will be affected by the seasonal shift in streamflow, an increase in the ratio of winter to
13   annual flows, and possibly the reduction in low flows caused by decreased glacier extent or
14   snow water storage (*high confidence*).

15   ▪   Sea-level rise will extend areas of salinization of groundwater and estuaries, resulting in a
16   decrease in freshwater availability for humans and ecosystems in coastal areas (*very high
17   confidence*).

18   ▪   Increased precipitation intensity and variability is projected to increase the risks of flooding
19   and drought in many areas (*high confidence*).

20   ▪   Semi-arid and arid areas are particularly exposed to the impacts of climate change on
21   freshwater (*high confidence*).

22   ▪   Many of these areas (e.g., Mediterranean basin, western United States, southern Africa, and
23   northeastern Brazil) will suffer a decrease in water resources due to climate change (*very high
24   confidence*).

25   ▪   Efforts to offset declining surface water availability due to increasing precipitation variability
26   will be hampered by the fact that groundwater recharge will decrease considerably in some
27   already water-stressed regions (*high confidence*), where vulnerability is often exacerbated by
28   the rapid increase in population and water demand (*very high confidence*).

29   ▪   Higher water temperatures, increased precipitation intensity, and longer periods of low flows
30   exacerbate many forms of water pollution, with impacts on ecosystems, human health, water
31   system reliability, and operating costs (*high confidence*).

32   ▪   These pollutants include sediments, nutrients, dissolved organic carbon, pathogens,
33   pesticides, salt, and thermal pollution.

34   ▪   Climate change affects the function and operation of existing water infrastructure as well as
35   water management practices (*very high confidence*).

36   ▪   Adverse effects of climate on freshwater systems aggravate the impacts of other stresses,
37   such as population growth, changing economic activity, land use change, and urbanization
38   (*very high confidence*).

1   ▪   Globally, water demand will grow in the coming decades, primarily due to population growth
2   and increased affluence; regionally, large changes in irrigation water demand as a result of
3   climate change are *likely* (*high confidence*).

4   ▪   Current water management practices are very likely to be inadequate to reduce the negative
5   impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic
6   ecosystems (*very high confidence*).

7   ▪   Improved incorporation of current climate variability into water-related management would
8   make adaptation to future climate change easier (*very high confidence*).

9   ▪   Adaptation procedures and risk management practices for the water sector are being
10   developed in some countries and regions (e.g., Caribbean, Canada, Australia, Netherlands,
11   United Kingdom, United States, and Germany) that have recognized projected hydrological
12   changes with related uncertainties (*very high confidence*).

13   ▪   Since the IPCC Third Assessment, uncertainties have been evaluated, their interpretation has
14   improved, and new methods (e.g., ensemble-based approaches) are being developed for their
15   characterization (*very high confidence*).

16   ▪   Nevertheless, quantitative projections of changes in precipitation, river flows, and water
17   levels at the river-basin scale remain uncertain (*very high confidence*).

18   ▪   The negative impacts of climate change on freshwater systems outweigh its benefits (*high
19   confidence*).

20   ▪   All IPCC regions (see Chapters 3–16 of the IPCC report) show an overall net negative impact
21   of climate change on water resources and freshwater ecosystems (*high confidence*).

22   ▪   Areas in which runoff is projected to decline are *likely* to face a reduction in the value of the
23   services provided by water resources (*very high confidence*).

24   ▪   The beneficial impacts of increased annual runoff in other areas will be tempered by the
25   negative effects of increased precipitation variability and seasonal runoff shifts on water
26   supply, water quality, and flood risks (*high confidence*).

27   Observed global climate-related trends affecting freshwater resources were identified previously.
28 The following discussion identifies key projected impacts on surface waters, groundwater, extreme
29 events, and water quality.

30   **4.5.3.4.1 Surface Water**

31   Data from 24 climate model runs generated by 12 different general circulation models (Milly et
32 al., 2005 in Kundzewicz et al., 2007) generally agreed that by 2050:

33   ▪   Annual average river runoff and water availability will increase by 10 to 40 percent at high
34   latitudes [North America, Eurasia] and in some wet tropical areas,

35   ▪   Annual average river runoff and water availability will decrease by 10 to 30 percent over
36   some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-
37   stressed areas [Mediterranean, southern Africa, and western United States/northern Mexico].

1   Hydrological impact studies have shown that warming leads to changes in the seasonality of river
2   flows where much winter precipitation currently falls as snow, including the European Alps, the
3   Himalayas, western North America, central North America, eastern North America, the Russian territory,
4   Scandinavia, and Baltic regions. Winter flows will increase, summer flows will decrease, and peak flow
5   will occur at least one month earlier in many cases (Kundzewicz et al., 2007).

6   Higher temperatures increase glacier melt. Glacier melt sustains many rivers during the summer
7   in the Hindu Kush Himalaya and the South American Andes (Singh and Kumar, 1997; Mark and Seltzer,
8   2003; Singh, 2003; and Barnett et al., 2005 in Kundzewicz et al., 2007). The mass of some northern
9   hemisphere glaciers is projected to decrease up to 60 percent by 2050 (Schneeberger et al., 2003 in
10   Kundzewicz et al., 2007).

11   Predictions for rain-fed basins describe higher flows in peak flow season with either lower flows
12   in low flow season or extended dry periods (Kundzewicz et al., 2007).

13   Lake levels are determined by river and rain water inputs and evaporation outputs. By the end of
14   the 21st century, water levels are predicted to change between −4.5 feet and +1.15 feet in the Great Lakes
15   (Lofgren et al., 2002; and Schwartz et al., 2004 in Kundzewicz et al., 2007) and to drop about 29.5 feet in
16   the Caspian Sea (Elguindi and Giorgi, 2006 in Kundzewicz et al., 2007).

17   In 2010 to 2015, the ice cover on Siberian rivers is expected to melt 15 to 27 days sooner than it
18   did from 1950 to 1979. The maximum ice cover is also expected to be 20 to 40 percent thinner
19   (Vuglinsky and Gronskaya, 2005 in Kundzewicz et al., 2007).

20   Annual runoff may be affected by a combination of land use changes and climate change. Land
21   use changes are predicted by model studies to have a small effect compared to climate change in the
22   Rhine basin, southeast Michigan, Pennsylvania, and central Ethiopia. In southeast Australia and southern
23   India, predictions are comparable, with climate change having the potential to exacerbate reductions in
24   runoff caused by afforestation (Kundzewicz et al., 2007).

25   Evapotranspiration—water loss from plant leaves—responds to increases in carbon dioxide in
26   two distinct ways. First, higher CO_2 concentrations cause leaf stomata to close, reducing
27   evapotranspiration. On the other hand, CO_2 fertilization encourages plant growth, increasing total leaf
28   area and subsequent evapotranspiration. Considering these vegetation effects, global mean runoff has
29   been predicted to increase by 5 percent for a doubling of CO_2 concentration (Betts et al., 2007; and
30   Leipprand and Gerten, 2006 in Kundzewicz et al., 2007) compared to a 5 to 17 percent increase under
31   climate change alone (Kundzewicz et al., 2007).

32   **4.5.3.4.2 Groundwater**

33   Climate change will mainly affect groundwater recharge rates, although there has been very little
34   research on the issue. Groundwater levels may change as a result of thawing permafrost, vegetation
35   changes, changes in river level (where there is adequate hydraulic connection), and changes in floods.
36   Global hydrological models predict that globally averaged groundwater recharge will increase less
37   (2 percent) than total runoff (9 percent) in the 2050s compared to recharge and runoff rates from 1961 to
38   1990. In northeastern Brazil, southwest Africa, and the southern Mediterranean coast groundwater
39   recharge is predicted to decrease by more than 70 percent. In contrast, recharge is predicted to increase
40   by more than 30 percent in the Sahel, Near East, northern China, Siberia, and the western United States
41   (Döll and Flörke, 2005 in Kundzewicz et al., 2007). Projected impacts on individual aquifers return very
42   site-specific results.

1   Any decrease in groundwater recharge will exacerbate the effect of saltwater intrusion. Saltwater
2   intrusion has been projected for a sea level rise of 0.33 feet on two coral islands off the Indian coast—the
3   thickness of the freshwater lens decreasing from 82 feet to 32 feet and from 118 feet to 92 feet (Bobba
4   et al., 2000 in Kundzewicz et al., 2007). Saltwater intrusion from sea level rise may also affect
5   groundwater/aquifer water supplies on similar small islands.

6   **4.5.3.4.3 Extreme Events—Floods and Droughts**

7   As discussed earlier, increased climate variability increases the risks of both floods and droughts
8   depending on climatic and non-climatic variables. Extreme floods and extreme droughts are predicted to
9   become more frequent in the future under various climate models (Kundzewicz et al., 2007). However,
10   climate change impacts on flood magnitude and frequency can be both positive and negative depending
11   on the global climate model used, snowmelt contributions, catchment characteristics, and location
12   (Reynard et al., 2004 in Kundzewicz et al., 2007).

13   By the 2090s, the proportion of the total land surface in extreme drought is predicted to increase
14   from the current rate of 1 to 3 percent to 30 percent; extreme drought events per 100 years are predicted to
15   double; and mean drought duration is predicted to increase by a factor of six (Burke et al., 2006 in
16   Kundzewicz et al., 2007).

17   More floods are predicted for northern and northeastern Europe, while more drought is predicted
18   for southern and southeastern Europe (Lehner et al., 2005 in Kundzewicz et al., 2007).

19   The area flooded in Bangladesh is projected to increase by 23 to 29 percent for a global
20   temperature rise of 3.6°F (Mirza, 2003 in Kundzewicz et al., 2007). Up to 20 percent of the world's
21   population lives in river basins at risk from increased flooding (Kleinen and Petschel-Held, 2007 in
22   Kundzewicz et al., 2007).

23   **4.5.3.4.4 Water Quality**

24   Higher water temperatures and runoff variations are *likely* to affect water quality negatively (Patz,
25   2001; Lehman, 2002; O'Reilly et al., 2003; and Hurd et al., 2004 in Kundzewicz et al., 2007). Negative
26   impacts on water quality from changes in water quantity include resuspension of bottom sediments,
27   increased turbidity (i.e., suspended solids), pollutant introduction, and reduced dilution. Negative impacts
28   from water temperature include algal blooms, increased microbial concentrations, and out-gassing of
29   volatile and semi-volatile compounds like ammonia, mercury, dioxins, and pesticides (Kundzewicz et al.,
30   2007).

31   Acidic atmospheric deposition is projected to increase acidification in rivers and lakes (Ferrier
32   and Edwards, 2002; Gilvear et al., 2002; and Soulsby et al., 2002 in Kundzewicz et al., 2007).

33   Salt concentration is expected to increase in estuaries and inland reaches under decreasing
34   streamflows. For example, salinity is projected to increase in the tributary rivers above irrigation areas in
35   Australia's Murray-Darling Basin by 13 to 19 percent by 2050 and by 21 to 72 percent by 2100
36   (Kundzewicz et al., 2007).

37   No quantitative studies projecting the impact of climate change on microbiological water quality
38   for developing countries are cited by the IPCC. However, climate change will be an additional stressor
39   affecting water quality and public health. Potential impacts include increased waterborne disease with
40   increases in extreme rainfall, and great incidence of diarrheal and water-related diseases in regions with

1   increased drought (Kundzewicz et al., 2007). A brief overview of the effects of climate change on the
2   availability and quality of drinking water is provided by Anderson et al. (2005).

3   Developed countries are also experiencing water quality issues in their water and wastewater
4   treatment plants. Increased filtration is required in drinking water plants to address micro-organism
5   outbreaks following intense rain, thus increasing some operating costs by 20 to 30 percent (AWWA, 2006
6   in Kundzewicz et al., 2007). Other stressors on water quality include the following (Kundzewicz et al.,
7   2007):

8   ▪   More water impoundments for hydropower (Kennish, 2002; Environment Canada, 2004).

9   ▪   Stormwater drainage operation and sewage disposal disturbances in coastal areas resulting
10   from sea level rise (Haines et al., 2000).

11   ▪   Increasing water withdrawals from low-quality sources.

12   ▪   Greater pollutant loads resulting from increased infiltration rates to aquifers or higher runoff
13   to surface waters (resulting from high precipitation).

14   ▪   Water infrastructure malfunctioning during floods (GEO-LAC, 2003; DFID, 2004).

15   ▪   Overloading the capacity of water and wastewater treatment plants during extreme rainfall
16   (Environment Canada, 2001).

17   ▪   Increased amounts of polluted storm water.

18   In many regions, there is no alternative supply even as water quality declines, and reusing
19   wastewater (i.e., to irrigate crops) can introduce other public health problems.

20   Global adaptation to freshwater resource stressors will require the availability of relevant
21   information, more water resource options (e.g., storage), and proactive responses in the face of climatic
22   changes. These responses will include effluent disposal strategies accounting for reduced biodegradation;
23   water and wastewater treatment plant design accounting for extreme climate conditions; and reducing,
24   reusing and recycling water (Luketina and Bender, 2002; Environment Canada, 2004; and Patrinos and
25   Bamzai, 2005 in Kundzewicz et al., 2007).

26   **4.5.4   Terrestrial Ecosystems**

27   This section addresses climate-related impacts on terrestrial ecosystems. An ecosystem is defined
28   as a complex of biological communities (plants, animals, and microorganisms) and their non-living
29   environments, which act together as a unit (MA, 2005, and Reid, et al., 2005, in Fischlin, et al., 2007).
30   By definition, relationships within an ecosystem are strong while relationships with components outside
31   the ecosystem boundaries are weak (Reid, et al., 2005, part 2, in Fischlin, et al., 2007).

32   **4.5.4.1 Affected Environment**

33   Earth's biosphere is an interconnected network of individuals, populations, and interacting natural
34   systems, referred to as ecosystems. Ecosystems are critical, in part, because they supply humans with
35   services that sustain life and are beneficial to the functioning of society (Fischlin, et al., 2007).
36   Ecosystems include:

1   ▪   terrestrial communities, such as forests, grasslands, shrublands, savanna, and tundra;
2   ▪   aquatic communities, such as rivers, coral reefs, lakes, and estuaries; and
3   ▪   wetlands, such as marshes, swamps, and bogs (Noss, et al., 1995).

4   The focus of this section is on terrestrial ecosystems.

5   **4.5.4.1.1 Global Terrestrial Ecosystems**

6   The World Wildlife Fund (WWF) has developed a widely accepted global ecosystem
7 classification that consists of what are referred to as ecozones, biomes, and ecoregions. Similar to the
8 classification of Miklos Udvary's (1975) biogeographical realm, the ecozone is the biogeographic
9 division of the earth's surface at the largest scale. Terrestrial ecozones follow the floral and faunal
10 boundaries that separate the world's major plant and animal communities. The WWF has identified eight
11 ecozones, as indicated in Figure 4.5-1.
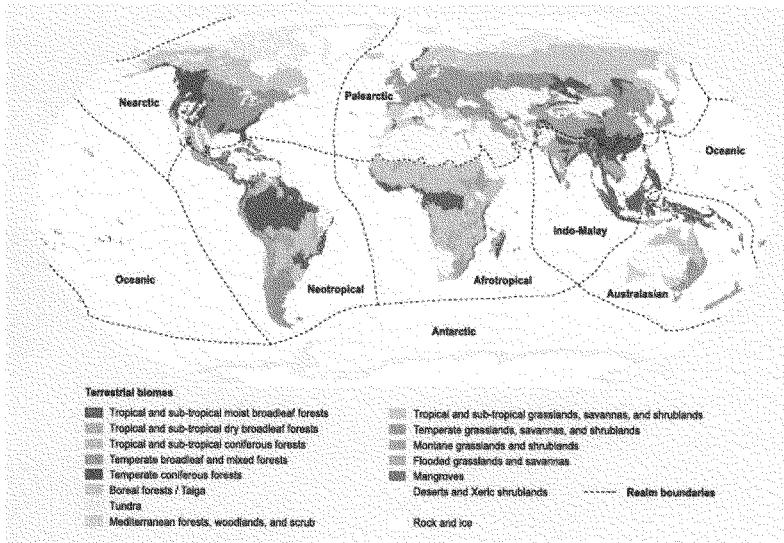
12
13   **Figure 4.5-1 Ecozones and Biomes of the World (source: MA, 2005)**
14
15   Biomes are climatically and geographically defined areas of ecologically-similar communities of
16 plants, animals, and microorganisms. These habitat types are defined by factors such as plant structures,
17 leaf types, plant spacing, and climate. The land classification system developed by WWF identifies 14
18 major terrestrial habitat types, which can be further divided into 825 smaller, more distinct terrestrial
19 ecoregions (WWF, 2008a). The primary terrestrial habitats recognized by WWF are:

1   **Tundra** is a treeless polar desert found at high latitudes in the polar regions, primarily in Alaska,
2   Canada, Russia, Greenland, Iceland, and Scandinavia, as well as sub-Antarctic islands. These regions are
3   characterized by long, dry winters, months of total darkness, and extremely frigid temperatures. The
4   vegetation is composed of dwarf shrubs, sedges and grasses, mosses, and lichens. A wide variety of
5   animals thrive in the tundra, including herbivorous and carnivorous mammals and migratory birds
6   (Chapin et al., 2005).

7   **Boreal Forests and Taiga** are forests found at northerly latitudes in inland Alaska, Canada,
8   Sweden, Finland, Norway, and Russia, as well as parts of the extreme northern continental United States,
9   northern Kazakhstan, and Japan. Annual temperatures are low and precipitation ranges from 15 to 40
10 inches per year and may fall mainly as snow. Vegetation includes coniferous and deciduous trees,
11 lichens, and mosses. Herbivorous mammals and small rodents are the predominant animal species;
12 however, predatory birds and mammals also occupy this habitat type.

13 **Temperate coniferous forests** are found predominantly in areas with warm summers and cool
14 winters. Plant life varies greatly across temperate coniferous forests. In some forests, needleleaf trees
15 dominate, while others consist of broadleaf evergreen trees or a mix of both tree types. Typically, there
16 are two vegetation layers in a temperate coniferous forest: an understory dominated by grasses and
17 shrubs, and an overstory of large tree species.

18 **Temperate broadleaf and mixed forests** experience a wide range of variability in temperature
19 and precipitation. In regions where rainfall is distributed throughout the year, deciduous trees mix with
20 evergreens. Species such as oak, beech, birch, and maple typify the tree composition of this habitat type.
21 Diversity is high for plants, invertebrates, and small vertebrates.

22 **Mediterranean forests, woodlands, and shrub** ecoregions are characterized by hot and dry
23 summers, while winters tend to be cool and moist. Most precipitation arrives during winter. Only five
24 regions in the world experience these conditions: the Mediterranean, south-central and southwestern
25 Australia, the fynbos of southern Africa, the Chilean matorral, and the Mediterranean ecoregions of
26 California. These regions support a tremendous diversity of habitats and species.

27 **Tropical and subtropical coniferous forests** are found predominantly in North and Central
28 America and experience low levels of precipitation and moderate variability in temperature. These
29 forests are characterized by diverse species of conifers, whose needles are adapted to deal with the
30 variable climate conditions. These forests are wintering ground for a variety of migratory birds and
31 butterflies.

32 **Tropical and subtropical moist broadleaf forests** are generally found in large, discontinuous
33 patches centered on the equatorial belt and between the Tropics of Cancer and Capricorn. They are
34 characterized by low variability in annual temperature and high levels of rainfall. Forest composition is
35 dominated by semi-evergreen and evergreen deciduous tree species. These forests are home to more
36 species than any other terrestrial ecosystem. A square kilometer may support more than 1,000 tree
37 species. Invertebrate diversity is extremely high, and dominant vertebrates include primates, snakes,
38 large cats, amphibians, and deer.

39 **Tropical and subtropical dry broadleaf forests** are found in southern Mexico, southeastern
40 Africa, the Lesser Sundas, central India, Indochina, Madagascar, New Caledonia, eastern Bolivia, central
41 Brazil, the Caribbean, valleys of the northern Andes, and along the coasts of Ecuador and Peru.
42 Deciduous trees predominate in most of these forests and they are home to a wide variety of wildlife,
43 including monkeys, large cats, parrots, various rodents, and ground-dwelling birds.

1   **Temperate grasslands, savannas, and shrublands** are known as prairies in North America,
2   pampas in South America, veld in southern Africa and steppe in Asia. They differ from tropical
3   grasslands in species composition and the annual temperature regime under which they thrive. These
4   regions are devoid of trees, except for riparian or gallery forests associated with streams and rivers.
5   Biodiversity in these habitats includes a number of large grazing mammals and associated predators,
6   burrowing mammals, numerous bird species, and a diversity of insects.

7   **Tropical and subtropical grasslands, savannas, and shrublands** are found in the large
8   expanses of land in the tropics that do not receive enough rainfall to support extensive tree cover.
9   However, there may be great variability in soil moisture throughout the year. Grasses dominate the
10   species composition of these ecoregions, although scattered trees may be common. Large mammals that
11   have evolved to take advantage of the ample forage typify the biodiversity associated with these habitats.

12   **Montane grasslands and shrublands** include high elevation grasslands and shrublands such as
13   the puna and paramo in South America, subalpine heath in New Guinea and East Africa, steppes of the
14   Tibetan plateaus, and other similar subalpine habitats around the world. Montane grasslands and
15   shrublands are tropical, subtropical, and temperate. Mountain ecosystem services such as water
16   purification and climate regulation extend beyond the geographical boundaries of the grasslands and
17   shrublands and affect all continental mainlands (Woodwell, 2004). Characteristic plants of these habitats
18   display features such as rosette structures, waxy surfaces, and abundant pilosity (WWF, 2008b).

19   **Deserts and xeric shrublands** across the world vary greatly with respect to precipitation and
20   temperature. Generally, rainfall is less than 10 inches annually and evaporation exceeds precipitation.
21   Temperature variability is also extremely diverse in these remarkable lands. Many deserts, such as the
22   Sahara, are hot year-round but others, such as Asia's Gobi, become quite cold in winter. Woody-stemmed
23   shrubs and plants evolved to minimize water loss characterize vegetation in these regions. Animal
24   species are equally well-adapted to the dry conditions, and species are quite diverse.

25   **Mangroves** occur in the waterlogged, salty soils of sheltered tropical and subtropical shores,
26   where they stretch from the intertidal zone up to the high tide mark. Associated with this tree species are
27   a whole host of aquatic and salt-tolerant plants. Mangroves provide important nursery habitats for a vast
28   array of aquatic animal species.

29   **Flooded grasslands and savannas** are common to four continents. These vast areas support
30   numerous plants and animals adapted to the unique hydrologic regimes and soil conditions. Large
31   congregations of migratory and resident waterbirds may be found in these regions. Ecosystem services
32   include breeding habitat and buffering inland areas from the effects of wave action and storms (MA
33   2005).

34   **4.5.4.1.2 Terrestrial Ecosystems in the United States**

35   Published in 1976, *Ecoregions of the United States* was one of the first attempts to divide the
36   nation into ecosystem regions systematically. Subsequently, Bailey (1980) provided, for each region, a
37   brief description of the dominant physical and biological characteristics based on land-surface form,
38   climate, vegetation, soils, and fauna. Bailey defined four major domains, 12 divisions, and 30 provinces.
39   Since then, the ecoregions of North America have been further refined by the international working group
40   of the Commission of Environmental Cooperation (CEC, 1997). Their system divides the continent into
41   15 broad level I ecoregions, 52 level II ecoregions and approximately 200 level III ecoregions. The level
42   I ecoregions present in the United States include tundra, taiga, northern forests, northwestern forested
43   mountains, marine west coast forests, eastern temperate forests, great plains, North American deserts,

1 Mediterranean California, southern semi-arid highlands, temperate sierras, and tropical humid forests
2 (Figure 4.5-2).

3   Ecosystems are dynamic and may change naturally over time as a result of drivers such as climate
4 change (natural or anthropogenic), geological processes (volcanic eruptions, earthquakes, landslides), fire,
5 disease or pest outbreaks, and evolution. All organisms modify their environment to some extent;
6 however, in the last century and especially in the last 50 years, human population growth and
7 technological innovations have affected ecosystems drastically (Vitousek et al., 1997). In fact, the
8 structure of the world's ecosystems have changed more rapidly in the second half of the 20th century than
9 in any time in recorded human history (MA, 2005). It is expected that during the course of this century,
10 the resilience of many ecosystems is likely to be exceeded by anthropogenic pressures (Fischlin et al.,
11 2007).

12 ### 4.5.4.1.3 Non-Climate Threats to Global Terrestrial Ecosystems

13   The Millennium Ecosystems Assessment (MA), a United Nations research project, focuses on
14 identifying the current inventory and conditions of 10 categories of global ecosystems (including five
15 categories of natural terrestrial ecosystems) and projecting changes and trends into the future.
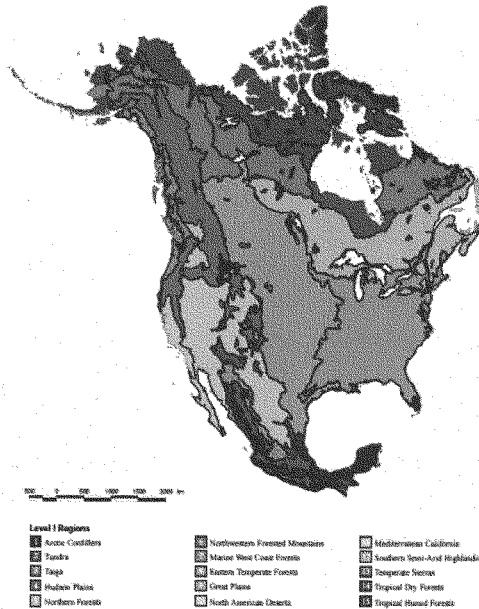
16
17   **Figure 4.5-2 Level I Ecoregions in the North America (source: CEC, 1997)**

1

2   In 2005, the MA released five technical volumes and six synthesis reports, providing a scientific

3 appraisal of the condition and trends in the world's ecosystems and the services they provide. From 2001

4 to 2005, the MA involved the work of more than 1,360 experts worldwide. The MA included the

5 following conclusions regarding the current state of global ecosystems (MA, 2005):

6   ▪   Cultivated systems now cover one quarter of Earth's terrestrial surface. More than two thirds

7   of the area of two of the world's 14 major terrestrial biomes and more than half of the area of

8   four other biomes had been converted by 1990, primarily to agriculture.

9   ▪   Across a range of taxonomic groups, for most species, either the population size or range or

10   both is currently declining.

11   ▪   The distribution of species on Earth is becoming more homogenous; in other words, the set of

12   species in any one region of the world is becoming more similar to the set in other regions

13   primarily as a result of introductions of species, both intentionally and inadvertently in

14   association with increased travel and shipping.

15   ▪   The number of species on the planet is declining. Over the past few hundred years, humans

16   have increased the species extinction rate by as much as 1,000 times over background rates

17   typical over the Earth's history. Some 10 to 30 percent of mammal, bird, and amphibian

18   species are currently threatened with extinction.

19   ▪   Only four of the 24 ecosystem services examined in this assessment have been enhanced,

20   while 15 have been degraded (Hassan, 2005).

21   The MA concluded that biodiversity changes due to human activities were more rapid in the past

22 50 years than at any time in human history. Moreover, the forces causing biodiversity loss and leading to

23 changes in ecosystem services are either steady, show no evidence of declining over time, or are

24 increasing in intensity. The MA examined four plausible future scenarios and projected that the rates of

25 biodiversity change will continue or accelerate (MA, 2005). In one specific example, the United States

26 Fish and Wildlife Service has indicated that the threats to certain endangered species such as the

27 Yosemite toad in Sierra Nevada include disease, cattle grazing, timber harvesting, and climate change

28 (FWS, 2006).

29   The changes in ecosystems identified in the MA can have impacts on ecological processes,

30 species composition, and genetic diversity. Ecological processes, which include water, nitrogen, carbon,

31 and phosphorous cycling, have all changed more rapidly in the second half of the 20th century than at any

32 time in recorded human history (MA, 2005). Human actions have not only changed the structure of

33 ecosystems, but the processes as functions of the ecosystems as well.

34   A change in ecosystem structure also affects the species within the system and vice versa.

35 Historically, the natural processes of evolution and the combination of natural barriers to species

36 migration and local adaptation resulted in significant phenotypic differences in plant and animal species

37 of different ecosystems. These regional differences are now becoming rare.

38   Some ecosystem changes have been the inadvertent result of activities unrelated to the use of

39 ecosystem services, such as the construction of roads, ports, and cities and the discharge of pollutants.

40 But most ecosystem changes were the direct or indirect result of changes made to meet growing demands

41 for food, water, timber, fiber, and fuel (MA, 2005). Ecosystems change can be affected by a variety of

42 human and natural drivers, including climate change, land use, land degradation, urbanization, pollution,

1 natural climate change, geological processes, and invasive species. These drivers can act independently
2 or in concert with each other (Lepers et al., 2004), and are summarized below.

3   Land Use Change

4   Land use change represents the anthropogenic replacement of one land use type by another, e.g.,
5 forest converted to cultivated land (or the reverse), as well as subtle changes of management practices
6 within a given land use type, e.g., intensification of agricultural practices. Both forms of land use change
7 are affecting 40 percent of the terrestrial surface (Foley et al., 2005). Land use change can lead to habitat
8 loss and fragmentation and is an important driver in ecosystem change (Heywood and Watson, 1995;
9 Fahrig, 2003). Overall, land transformation represents the primary driving force in the loss of biological
10 diversity (Vitousek et al., 1997). In nine of the 14 terrestrial biomes studied by the MA, over one half of
11 the area has been transformed, largely by agricultural cultivation (Hassan, 2005). Only the biomes that
12 are less suitable for agriculture, such as deserts, boreal forests, and tundra, have remained largely
13 untransformed by human activity.

14   Virtually all of Earth's ecosystems have now been significantly transformed through human
15 actions (MA, 2005). Roughly 70 percent of original temperate grasslands and forests and Mediterranean
16 forests were lost by 1950, chiefly from conversion to agricultural lands. More land was converted to
17 cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850 (MA, 2005a; Hassan,
18 2005).

19   Historically, terrestrial ecosystems that have been most significantly altered by human activity
20 include temperate broadleaf forests, temperate grasslands, Mediterranean forests, and tropical dry forests
21 (Hassan, 2005). Of these, more than two thirds of the temperate grasslands and Mediterranean forests,
22 and more than half of tropical dry forests, temperate broadleaf forests, and tropical grasslands have been
23 converted to agriculture (Hassan, 2005). Forest systems in general have been reduced by half over the
24 past three centuries, and have effectively disappeared in 25 countries. Another 29 countries have lost 90
25 percent or more of their forest cover (Hassan, 2005).

26   Globally, the rate of ecosystem conversion has begun to decelerate, mainly because the rate of
27 expansion of cultivated land has declined. Ecosystems are beginning to return to conditions and species
28 compositions similar to their pre-conversion states. However, rates of ecosystem conversion remain high
29 or are increasing for specific ecosystems and ecoregions (MA, 2005). Land use changes and land
30 degradation are significant drivers of ecosystem change globally and in the United States. For example,
31 between1982 and 1997, 11 million acres of nonfederal grasslands and shrublands were converted to other
32 uses (SNE, 2002).

33   The increase in cultivated land, especially for the purpose of grazing, has led to an increase in
34 desertification. Desertification involves the expansion of deserts into semi-arid and subhumid regions,
35 and the loss of productivity in arid zones. Desertification is characterized by loss of groundcover and
36 soils, replacement of palatable, mesophytic grasses by unpalatable xerophytic shrubs, or both (Ryan et al.,
37 2008). Desertification affects the livelihoods of millions of people, including a large portion of the poor
38 residents of drylands (Hassan, 2005). While desertification can certainly be exacerbated by changes in
39 climate, there has been long-standing controversy over the relative contributions of climatic and
40 anthropogenic factors as drivers of desertification (National Science and Technology Council, 2008).

41   Fire

42   Fire influences ecosystem structure by promoting species that tolerate fire or even enhance fire
43 spread, resulting in a relationship between the relative flammability of a species and its relative

1   abundance in a particular community (Bond and Keeley, 2005). Intensified and increasing wildfire
2   occurrences appear to be changing vegetation structure and composition in some ecoregions. In the
3   forest-tundra transition in eastern Canada, this transition is observed in a shift from Picea- to Pinus-
4   dominated communities and 75 to 95 percent reductions in tree densities (Lavoie and Sirois, 1998).
5   Across the boreal forests of North America, total burned areas increased by a factor of 2.5 between the
6   1960s and the 1990s (Kasischke and Turetsky, 2006).

7   Insect Outbreaks

8   Invasive alien species represent a major threat to endemic or native biodiversity in terrestrial and
9   aquatic systems. Alien species invasions also interact with other drivers, sometimes resulting in
10   unexpected outcomes. The impact of insect damage is significant and can exceed the impacts of fire in
11   some ecosystems, but especially in boreal forests (Logan et al., 2003). For example, spruce budworm
12   defoliated over 20 times the area burned in eastern Ontario between 1941 and 1996 (Fleming et al., 2002).
13   Fires tended to occur 3 to 9 years after a spruce budworm outbreak (Fleming et al., 2002), suggesting that
14   insect outbreaks can be a driver of increased fire events. Forest impacts by the forest tent caterpillar have
15   also increased in western Canada over the past 25 years (Timoney, 2003).

16   Species Decline and Extinction

17   Although extinction is a natural part of Earth's history, observed modern rates of extinction are
18   not part of natural cycles. Over the past few hundred years, humans have increased the extinction rate by
19   as much as 1,000 times over the rate expected based on natural history (Hassan, 2005). A decrease in
20   global genetic diversity is linked to extinction. The loss of unique populations has resulted in the loss of
21   genetic diversity. The loss of genetic diversity has also declined among cultivated species as farmers
22   have shifted from locally adapted crop populations to more widely adapted varieties produced through
23   formal breeding practices. Currently, for most species across a wide range of taxonomic groups, either
24   the population size, population range, or both is in decline (MA, 2005).

25   Pollution

26   Pollution is another significant threat to terrestrial ecosystems. Over the past four decades,
27   excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in
28   terrestrial, freshwater, and marine systems. A significant cause is the use of increasing amounts of
29   synthetic nitrogen and phosphorous fertilizers, which may be lost to the environment after application.
30   Consumption of nitrogen fertilizer grew nearly 800 percent between 1960 and 2003 (MA, 2005). In
31   terrestrial ecosystems, excessive nitrogen flows contribute to acidification. Nitrogen also plays a role in
32   ground-level ozone, which can lead to a loss of forest productivity (MA, 2005).

33   **4.5.4.2 Consequences**

34   This section discusses current climate change impacts that have already been observed and
35   projected impacts (including the potential for adaptation to climate changes). Climate change impacts are
36   discussed generally, and with specific attention to impacts in the United States. The IPCC WKGI Fourth
37   Assessment Report (Fischlin et al., 2007) was released in 2007, and in 2008 the USCCSP report on
38   climate sensitive ecosystems was released (USCCSP, 2008). The 2007 IPCC report is the most
39   comprehensive, recent summary of projected impacts of global climate change. Many of the impacts
40   discussed in this section were gathered from the 2007 IPCC report, which provides an analysis and
41   discussion on a global scale. Information about impacts specific to ecosystems in the United States was
42   obtained primarily from the 2008 USCCSP report. The projected impacts reported below were forecast

1   with varying degrees of certainty. The level of certainty, as defined by IPCC, is noted in this report where
2   relevant.

3   **4.5.4.2.1 Observed Climate Change Impacts**

4   Because terrestrial ecosystems are defined by the interactions of biotic (plants, animals, and
5   microorganisms) and abiotic factors (geology, hydrology, weather), climate is a key factor in determining
6   the different characteristics and distributions of natural systems.

7   <u>Observed Impacts on Terrestrial Ecosystems Globally</u>

8   Studies have noted the response of biological and chemical characteristics of ecosystems to
9   climate conditions, especially temperature change. Substantial research has examined the effects of
10   climate change on vegetation and wildlife, leading to the conclusion that the changing climate is already
11   having a real and demonstrable effect on a variety of ecosystem types (Janetos et al., 2008). As noted in
12   the IPCC report, plants and animals can reproduce, grow, and survive only within specific ranges of
13   climate and environmental conditions (Fischlin et al., 2008). Changes in climate can affect terrestrial
14   ecosystems in the following ways (Rosenzweig et al., 2007):

15   ▪   shifting the timing of life cycle events such as blooming or migration;
16   ▪   shifting range boundaries or densities of individuals within their ranges;
17   ▪   changing species morphology (body size, egg size), reproduction, or genetics; or
18   ▪   causing extirpation or extinction.

19   These changes are a result of many factors. Phenology – the timing of seasonal activities of
20   animals and plants – is perhaps the simplest process by which to track changes in the ecology of species
21   in response to climate change (Rosenzweig et al., 2007). Observed phenological events include leaf
22   unfolding, flowering, fruit ripening, leaf coloring, leaf fall of plants, bird migration, chorusing of
23   amphibians, and appearance or emergence of butterflies. Global daily satellite data, available since 1981,
24   indicate an earlier onset of spring by 10 to 14 days over 19 years, particularly across temperate latitudes
25   of the northern hemisphere (Zhou et al., 2001; Lucht et al., 2002). Leaf unfolding and flowering in spring
26   and summer have, on average, advanced by 1 to 3 days per decade in Europe, North America, and Japan
27   over the last 30 to 50 years (Fischlin et al., 2007). The seasonal timing of bird migration and egg laying
28   has also changed, associated with the increase of temperature in breeding grounds and migration routes.
29   Many small mammals have been observed to come out of hibernation and to breed earlier in the spring
30   than they did a decade ago (Inouye et al., 2000; Franken and Hik, 2004) and even larger mammals such as
31   reindeer are showing phenological changes (Post and Forchhammer, 2002), as are butterflies, crickets,
32   aphids, and hoverflies (Forister and Shapiro, 2003; Stefanescu et al., 2003; Hickling et al., 2005;
33   Newman, 2005). Increasing regional temperatures are also associated with earlier calling and mating and
34   shorter time to maturity of amphibians (Gibbs and Breisch, 2001; Reading, 2003; Tryjanowski et al.,
35   2003).

36   Rapid global warming can directly affect the size of a species' range, the density of individuals
37   within the range, and the abundance of preferred habitat within the range. Climate changes have affected
38   the location of suitable habitat for several species of plants and animals. Changes in the distribution of
39   species have occurred across a wide range of taxonomic groups and geographical locations (Rosenzweig
40   et al., 2007). Several different bird species no longer migrate out of Europe in the winter as the
41   temperature continues to warm (Rosenzweig et al., 2007). Over the past decades, a poleward extension of
42   various species has been observed, which is probably attributable to increases in temperature (Parmesan
43   and Yohe, 2003). Many Arctic and tundra communities are affected and have been replaced by trees and
44   dwarf shrubs (Kullman, 2002; ACIA, 2005). In several northern hemisphere mountain systems, tree lines

1 have markedly shifted to higher elevations during the 20th century, including those of Alaska (Sturm et
2 al., 2001).

3   Decreases in the size of a species' range, the density of individuals within the range, and the
4 abundance of its preferred habitat factors can lower species population size (Wilson et al., 2004) and
5 increases the risk of extinction. Examples of declines in populations and subsequent extinction or
6 extirpation are found in amphibians around the world (Alexander and Eischeid, 2001; Middleton et al.,
7 2001; Ron et al., 2003; Burrowes et al., 2004).

8   Changes in morphology and reproduction rates have been attributed to climate change. For
9 example, the egg sizes of many bird species are changing with increasing regional temperatures (Jarvinen,
10 1994, 1996; Tryjanowski et al., 2004). Studies from eastern Poland, Asia, Europe, and Japan have found
11 that various birds and mammals exhibit trends toward larger body size with regionally increasing
12 temperatures, probably due to increasing food availability (Nowakowski, 2002; Yom-Tov, 2003;
13 Kanuscak et al., 2004; Yom-Tov and Yom-Tov, 2004). Many northern insects have a 2-year life cycle,
14 and warmer winter temperatures allow a larger fraction of overwintering larvae to survive. The mountain
15 pine beetle has expanded its range in British Columbia into areas previously considered too cold (Carroll
16 et al., 2003).

17   <u>Observed Changes on Terrestrial Ecosystems in the United States</u>

18   Changes and impacts on United States ecosystems are similar to those occurring globally. During
19 the 20th century, the United States already began to experience the effects of climate change.
20 Precipitation over the contiguous United States increased 6.1 percent over long-term averages (USCCSP,
21 2008) while a sea level rise of 0.06 to 0.12 inch per year has occurred at most of the country's coastlines;
22 the Gulf coast has experienced an even greater rise in sea level at a rate of 0.2 to 0.4 inch per year
23 (USCCSP, 2008).

24   Examples of observed changes to terrestrial ecosystems in the United States attributable to
25 anthropogenic climate change include the following:

26   ▪ Many plant species are expanding leaves or flowering earlier - e.g., earlier flowering in lilac:
27   1.8 days per decade (Schwartz and Reiter, 2000), honeysuckle: 3.8 days per decade (Cayan et
28   al., 2001), earlier leaf expansion in apple and grape: 2 days per decade (Wolfe et al., 2005),
29   and trembling aspen: 2.6 days per decade (Wolfe et al., 2005).

30   ▪ Warmer springs have led to earlier nesting for 28 migrating bird species on the east coast of
31   the United States (Butler, 2003) and to earlier egg laying for Mexican jays (Brown et al.,
32   1999) and tree swallows (Dunn and Winkler, 1999).

33   ▪ Several frog species now initiate breeding calls 10 to 13 days earlier than a century ago
34   (Gibbs and Breisch, 2001).

35   ▪ In lowland California, 70 percent of 23 butterfly species advanced the date of first spring
36   flights by an average of 24 days over 31 years (Forister and Shapiro, 2003).

37   ▪ Many North American plant and animal species have shifted their ranges, typically to the
38   north or to higher elevations (Parmesan and Yohe, 2003).

39   ▪ Edith's checkerspot butterfly has become locally extinct in the southern, low-elevation
40   portion of its western North American range but has extended its range 56 miles north and

1   394 feet higher in elevation (Parmesan, 1996; Crozier, 2003; Parmesan and Galbraith, 2004).
2   Edith's checkerspot butterfly is important to the survival of its grassland and rocky outcrop
3   habitat, and also provides essential ecosystem services because the adult butterflies pollinate
4   various flowers (Scott, 1986 in Kayanickupuram, 2002).

5   ■   The frequency of large forest fires and the length of the fire season in the western United
6   States have increased substantially since 1985. These phenomena are related to the advances
7   in the timing of spring snowmelt and increases in spring and summer air temperatures
8   (Westerling et al., 2006).

9   ■   In the Great Basin region, the onset of snow runoff is currently 10 to 15 days earlier than it
10   was 50 years ago (Cayan et al., 2001).

11   ■   The vegetation growing season has increased on average by about 2 days per decade since
12   1948, with the largest increase happening in the west (Easterling, 2002; Feng and Hu, 2004).

13   ■   Recently, spruce budworm in Alaska has completed its lifecycle in 1 year, rather than the
14   previous 2 years (Volney and Fleming, 2000). This allows many more individuals to survive
15   the overwintering period with impacts on the boreal forests of North America.

16   ■   Over the past three to five decades, all the major continental mountain chains exhibited
17   upward shifts in the height of the freezing level (Diaz et al., 2003).

18   ■   Populations of the American pika, a mountain-dwelling relative of the rabbit, are in decline
19   (Beever et al., 2003). The pika may be the first North American mammal to become extinct
20   as a result of anthropogenic climate change.

21   ■   Reproductive success in polar bears has declined as a result of melting Arctic Sea ice.
22   Without ice, polar bears cannot hunt seals, their favorite prey (Derocher et al., 2004). On
23   May 15, 2008, the U.S. Fish and Wildlife Service listed the polar bear as a threatened species,
24   reflecting the loss of sea ice habitat that once encompassed over 90 percent of the polar bear's
25   habitat range (FR 73:95,; May 15, 2009).

26   **4.5.4.2.2 Projected Impacts of Climate Change in the United States**

27   The United States is projected to experience changes in average temperature and precipitation
28 over the 21st century of an even greater magnitude than those experienced in the 20th century. Although
29 the entire country is projected to experience some degree of change, particular regions of the United
30 States could experience changes of a greater-than-average magnitude. For example, the greatest changes
31 in temperature are projected for Alaska and the western continental United States (USCCSP, 2008). In
32 northern Alaska, the average temperatures are projected to increase 5°C by the end of the 21st century.
33 Areas near coasts are projected to witness an increase of approximately 2°C over the same period;
34 summer temperatures nationwide could increase 3 to 5°C; and winter temperatures are projected to
35 increase 7 to 10°C (USCCSP, 2008).

36   Additional expected changes in United States climate include:

37   ■   more frequent hot days and hot nights (USCCSP, 2008);

1   ▪   heavier precipitation events, primarily in the form of rain rather than snow (USCCSP, 2008).
2   Annual precipitation in the northeastern United States is projected to increase while
3   precipitation in the Southwest is expected to decrease (Christensen et al., 2007); and

4   ▪   a decline in spring snow cover, leading to decreased availability of water in reservoirs
5   (USCCSP, 2008).

6   Ecosystems across the United States are projected to experience both positive and negative
7 impacts from climate change over the next century. The degree of impacts will vary by region. Wildlife
8 species have already responded to climate change and its effects on migration patterns, reproduction, and
9 geographic ranges (Field et al., 2007 in National Science and Technology Council, 2008). Future, more
10 substantial changes in climate are projected to affect many ecosystem services negatively (USCCSP,
11 2008). The Working Group II of IPCC has projected, with a high level of confidence, "that recent
12 regional changes in temperature have had discernible impacts on many physical and biological systems"
13 (National Science and Technology Council, 2008, p. 103).

14   The IPCC has determined that areas of the United States that experience temperature increases of
15 1.5 to 2.5 degrees Celsius are at highest risk for modifications to ecosystem structure and composition
16 (IPCC, 2007 in USCCSP, 2008). Over the next century, it is projected that species could move northward
17 and to higher elevations (Field et al., 2007 in National Science and Technology Council, 2008). In one
18 example of possible future threats to ecosystem vegetation, the upward move in elevation of species as
19 the snow and tree line advances suggests that alpine ecosystems could be endangered by the introduction
20 of invasive species (National Science and Technology Council, 2008).

21   Rather than experiencing impacts of climate change directly, most animals could experience the
22 effects of climate change indirectly via changes to their habitat, food sources, and predators (Schneider
23 and Root, 1996 in National Science and Technology Council, 2008). A changing climate facilitates
24 migration of certain species into non-native habitats, potentially affecting current goods and services
25 (USCCSP, 2008).

26   Animals in ecosystems in the United States are projected to experience a variety of climate
27 change impacts. For example:

28   ▪   Changes in hydrology as a result of changes in precipitation patterns could interrupt the
29   breeding cycles of amphibians, which depend on the ability to migrate to breeding ponds.
30   The production of their eggs is also highly dependent on temperature and moisture
31   availability (Fischlin et al., 2007 as cited in National Science and Technology Council, 2008).

32   ▪   Changes in climate that occur over at least several years are likely to affect the reproductive
33   success of migratory birds, as well as their ability to survive. A mismatch in timing between
34   the migration and reproduction periods and peak food availability is the potential pathway for
35   such impacts (Stenseth and Mysterud, 2002; Visser et al., 2004, 2006; Visser and Both, 2005
36   in National Science and Technology Council, 2008).

37   ▪   The migration of butterflies is highly dependent on spring temperatures and anthropogenic
38   climate change is likely to lead to earlier spring arrivals. As with migratory birds, an earlier
39   butterfly migration may result in a mismatch with food supply, thus threatening reproduction
40   and survival (Forister and Shapiro, 2003 in National Science and Technology Council, 2008).

41   ▪   Shifts in migration ranges could result in disease entering new areas; e.g., avian malaria in
42   Hawaii could move upslope as climate changes (USCCSP, 2008).

1   In one prominent example of mammals experiencing the effects of a warming climate, the polar
2   bear is specifically adapted to conditions in a narrow ecological slot (an environment with cold
3   temperatures and access to snow, ice, and open water), and spends much of its time on the frozen sea
4   (Gunderson, 2008). As the climate warms and sea ice melts, the polar bear loses much of its natural
5   habitat. If current trends in sea ice loss continue, the polar bear could become extirpated from most of
6   their range within 100 years (IUCN, 2008). Polar bears were listed as threatened under the Endangered
7   Species Act on May 15, 2008 due to the ongoing and projected loss of their sea-ice habitat from global
8   warming (FR 73: 95; May 15, 2009, p 28212-28303).

9   The vegetation of terrestrial ecosystems in the United States is projected to experience a variety
10   of direct impacts from climate change. For example, national forests, which harbor much of the United
11   States' biodiversity, and national grasslands are expected to experience an exacerbation of pre-existing
12   stressors, such as wildfires, invasive species, extreme weather events, and air pollution (USCCSP, 2008).

13   Warmer, dryer climates weaken trees' resistance to insect infestation, as they are more likely to
14   be wilted and weakened under those conditions. In a healthy state, trees can typically fight off beetle
15   infestation by drowning them with resin as they bore through the bark. Drought reduces the flow of resin
16   and beetles that are able to penetrate the bark introduce decay-causing fungus. This problem has already
17   been documented. Since 1994, winter mortality of beetle larvae in Wyoming has been cut due to mild
18   winters (from 80 percent to less than 10 percent mortality). As a result, the beetles have been able to strip
19   4 million acres of forests (Egan, 2002 in Center for Health & the Global Environment, 2005). In the
20   southwestern United States, high temperatures, drought, and the piñon ips bark beetle have had the
21   cumulative effect of causing a mass die-back of piñon trees. From 2002-2003 alone, piñon mortality in
22   Mesa Verde National Park in Colorado, and Bandelier National Monument in New Mexico exceeded 90
23   percent. Researchers determined that climate factors drove the die-off (Rocky Mountain Climate
24   Organization, 2008). The United States Forest Service indicates that, by 2012, almost all of the mature
25   lodgepole trees in northern Colorado and southern Wyoming will have been killed by bark beetles. This
26   will affect watersheds, timber production, and wildlife habitats, along with other human activities (USFS
27   website, accessed June 20, 2008).

28   Additional impacts on vegetation in ecosystems in the United States could include the following:

29   ■   Water management in the west would be complicated by increases in temperatures and
30   changes in precipitation patterns, which lead to reduced snow pack, earlier snowmelt, and
31   modified hydrology (USCCSP, 2008).

32   ■   High latitudes would experience increased vegetation productivity. Regions in the mid-
33   latitudes would experience either increased or decreased productivity, depending on whether
34   the primary impact is more precipitation or higher temperatures (increasing evaporation and
35   dryness) (Bachelet et al., 2001; Berthelot et al., 2002; Gerber et al., 2004; Woodward and
36   Lomas, 2004 in National Science and Technology Council, 2008).

37   ■   Ecosystems in the east would be statistically "likely to become carbon sources, while those in
38   the west would be likely to remain carbon sinks" (Bachelet et al., 2004 in National Science
39   and Technology Council, 2008).

40   ■   The jet stream would move northward with increasing atmospheric temperatures. The
41   consequence of this shift is a drying of the southeast. Closed-canopy forest ecosystems could
42   be converted to savanna ecosystems, woodlands, or grasslands, significantly increasing the
43   threat of fire occurrence (USCCSP, 2008).

1   ▪   Growing seasons would lengthen, according to several predictive models; this would
2   beneficially act to sustain carbon sinks (Cox et al., 2000; Berthelot et al., 2002; Fung et al.,
3   2005 in National Science and Technology Council, 2008).

4   ▪   In the Olympic Range, a temperature increase of 2°C would move tree species upwards 0.20
5   to 0.38 mile. Temperate species would replace subalpine species over 300 to 500 years
6   (Zolbrod and Peterson, 1999).

7   <u>Adaptation to Climate Change by Terrestrial Ecosystems</u>

8   The ability or inability of ecosystems to adapt to change is referred to as adaptive capacity. There
9 may be notable regional differences in the adaptive capacity of ecosystems, and adaptive capacity is
10 moderated by anthropogenic influences and capabilities. The ultimate impact of climate change on
11 ecosystems depends on the speed and extent to which these systems can adapt to a changing climate.
12 Adaptation occurs naturally in a biological system to varying degrees, but it can also be a planned human
13 response to anticipated challenges (USCCSP, 2008). Ecosystem managers could "proactively alter the
14 context in which ecosystems develop… they can improve the resilience, i.e., the coping capacity, of
15 ecosystems. Such ecosystem management involves anticipatory adaptation options" (Fischlin et al.,
16 2007, p. 246).

17   Because the effectiveness of specific adaptation strategies is uncertain, a "no regrets" path
18 consisting of practical adaptation options that account for current, known stressors along with the more
19 uncertain future stressors (USCCSP, 2008) is typically sought by ecosystem managers. For example,
20 invasive species pose a known threat to many ecosystems. Future climate change is likely to exacerbate
21 this stressor, so an adaptation strategy to tackle current invasive species problems could also address
22 projected impacts of more serious, future invasive species challenges (USCCSP, 2008). Another example
23 of dual-purpose adaptation strategies lies with the construction of riparian buffer strips. These not only
24 reduce agricultural runoff into freshwater systems, but also establish protective barriers against potential
25 increases in both pollution and sediment loadings due to climate change in the future (USCCSP, 2008).

26   **4.5.4.2.3 Projected Impacts of Climate Change on Global Terrestrial Ecosystems**

27   The IPCC concludes (*very high confidence*) that anthropogenic temperature rises have visibly
28 altered ecosystems (Parry et al., 2007). The exact impacts of climate changes are difficult to discern,
29 however, as they are mediated by other stressors and the capabilities of natural systems to adapt to
30 changing climates to some degree (Parry et al., 2007).

31   Some regions of the world are more vulnerable to changes in climate than others. Regions of
32 snow, ice, and tundra have been visibly altered by changes in global temperature. Observations of frozen
33 regions already show larger glacial lakes and the destabilization of glacial debris that dam these lakes;
34 changes in ecosystems at both poles; and increased melting of ice sheets, glaciers, and ice caps (Parry et
35 al., 2007).

36   Ecosystems in all regions of the world are expected to respond to climate changes impacts with:

37   ▪   poleward and upward shifts of plants and animals;
38   ▪   earlier onset of migration of terrestrial species such as birds and butterflies; and
39   ▪   localized disappearance of particular species (Parry et al., 2007).

40   Additional factors, such as projected growth in human populations, are expected to exacerbate the
41 effects of climate change. For example, river basin ecosystems that are already experiencing high levels

1   of stress are projected, with *medium confidence*, to witness growth in human populations from
2   approximately 1.4 to 1.6 billion in 1995 to roughly 4.3 to 6.9 billion by 2050 (Parry et al., 2007). River
3   basins experience the stress of increasing human populations as manifested in increasing demands for
4   water, (USCCSP, 2008b) and more inputs of pollutants. A warmer, dryer climate could increase these
5   stressors and reduce access to other water sources (USCCSP, 2008b).

6   Other projected global impacts of climate change include the following:

7   ■ The hardiness of the world's ecosystems is expected (*high confidence*) to be challenged over
8   the 21st century with "an unprecedented combination of climate change, associated
9   disturbances (e.g., flooding, drought, wildfire, insects, and ocean acidification), and other
10   global change drivers (especially land use, pollution, and over-exploitation of resources)
11   (Fischlin et al., 2007, p. 213).

12   ■ Carbon dioxide (CO_2) levels are projected to be much higher than any in the past 650,000
13   years, and temperatures are projected to be as high as any in the last 740,000 years. Both
14   increases are very likely to impact ecosystems (*very likely*) (Fischlin et al., 2007).

15   ■ Global average temperature increases in excess of 1.5 to 2.5°C are statistically likely to
16   threaten 20 to 30 percent of plant and animal species with extinction (Fischlin et al., 2007 in
17   National Science and Technology Council, 2008).

18   ■ Carbon uptake by ecosystems such as forests and grasslands is statistically likely to peak
19   during the 21st century and might ultimately even reverse (forests and grasslands would emit
20   carbon, rather than taking it in), which would amplify climate change due to increased
21   atmospheric CO_2 (Fischlin et al., 2007 in National Science and Technology Council, 2008).

22   In addition to other anthropogenic stressors, "such as extractive use of goods, and increasing
23   fragmentation and degradation of natural habitats" (Bush et al., 2004 in Fischlin et al., 2007, p. 215),
24   climate change poses a threat to the wellbeing of ecosystems. Although many ecosystems have been
25   resilient to historical changes in climate, it is not clear whether their resilience is enough to withstand the
26   more rapid and profound changes that are projected given the buildup of GHGs in the atmosphere
27   (Chapin et al., 2004; Jump and Peñuelas, 2005 in Fischlin et al., 2007). Predicted climate change and
28   other anthropogenic stressors are "virtually certain to be unprecedented" (Forster et al., 2007 in Fischlin
29   et al., 2007, p. 215). While some of the impacts expected with climate change serve to exacerbate
30   existing stressors on ecosystems, other expected impacts could be altogether new. For example,
31   increasing temperatures could cause some current sinks for GHGs, such as forest vegetation, to actually
32   become sources for these gases (including CO_2 and methane) (Fischlin et al., 2007).

33   Effects of anthropogenic climate change on ecosystems are anticipated at different levels of
34   severity and over varying time scales (decades to centuries) (Lischke et al., 2002 in Fischlin et al., 2007).
35   Some of the broad impacts on ecosystems associated with climate change are expected to include species
36   extinctions, loss of habitat due to more severe tropical storms (Wiley and Wunderle, 1994 in Fischlin et
37   al., 2007), changes in the types and abundance of vegetation present in an ecosystem (Schröter et al.,
38   2005; Metzger et al., 2006 in Fischlin et al., 2007), and increased susceptibility of land to desertification
39   (Burke et al., 2006 in Fischlin et al., 2007).

40   Foreseeable pathways of climate change-induced impacts on ecosystems include the following:

41   ■ CO_2 fertilization effects on vegetation (Baker et al., 2004; Lewis et al., 2004b; Malhi and
42   Phillips, 2004 in Fischlin et al., 2007);

1   ▪   higher atmospheric temperatures that could lead to more frequent insect and disease
2   outbreaks (USCCSP, 2008); and

3   ▪   increased radiation due to a projected decrease in tropical cloud cover (Nemani et al., 2003 in
4   Fischlin et al., 2007). This is linked to warming, which can directly affect ecosystems, and
5   increase the frequency and severity of storms originating in the tropics.

6 **4.5.5   Coastal Systems and Low-lying Areas**

7   This section addresses climate-related impacts on coastal ecosystems. Coastal zones are unique
8 environments where land and water meet. There is no single definition for coastal zones, but what is
9 certain is that all coastal zones include an area of land and an area that is covered by saltwater. Burke et
10 al., (2001, p. 11f) defines coastal zones as the "intertidal and subtidal areas on and above the continental
11 shelf (to a depth of about 650 feet)—areas routinely inundated by saltwater—and immediately adjacent
12 lands."

13 **4.5.5.1   Affected Environment**

14   Important ecosystems found in coastal zones can include estuaries, coral reefs, coastal lagoons,
15 mangroves, seagrass meadows, upwelling areas, salt marshes, beaches, bays, deltas, kelp forests and
16 barrier islands. A variety of terminology exists describing coastal zone ecosystems. Table 4.5-1 lists
17 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.

a/   California Environmental Resources Evaluation Systems, 2000
b/   EPA, 2006

18
19   The world's coastal length is estimated to be 1,015,756 miles, with North America having the
20 longest coastal length of all continents (Pruett and Cimino, 2000). Canada has the longest coastal length
21 of any country in the world and the United States has the second longest, at 164,988 miles and
22 82,836 miles, respectively (Pruett and Cimino, 2000).

1   Coastal zones are areas of significant biological productivity that provide food, shelter, spawning
2   grounds and nurseries for fish, shellfish, birds, and other wildlife. The interaction between aquatic and
3   terrestrial components of coastal ecosystems creates a unique environment that is critical to the life cycles
4   of many plant and animal species. In the United States, 85 percent of commercially harvested fish depend
5   on estuaries and coastal waters at some state in their life cycle (Summers et al., 2004), while as much as
6   95 percent of the world's marine fish harvest are caught or reared in coastal waters (Sherman, 1993).
7   Most historical information available on coastal ecosystems focuses on data related to fisheries. As more
8   research is conducted on other increasingly important coastal ecosystems, new data and information are
9   becoming available. For example, coral reefs alone, while representing only 0.2 percent of the total area
10   of oceans, harbor more than 25 percent of all known marine fish (Bryant et al., 1998). In addition, some
11   coral reefs can reach densities of 1,000 species per square meter (Tibbets, 2004). In the United States,
12   85 percent of the country's essential nesting, feeding, and breeding habitat for waterfowl and migratory
13   birds is found in coastal ecosystems (Summers et al., 2004). Coastal zones have also been found to
14   support a much higher percentage of the world's threatened and endangered species.

15   Because a disproportionate percentage of the world's population lives in coastal zones, the
16   activities of humans have created environmental pressures that threaten the very resources that make the
17   coastal zones desirable (Summers et al., 2004). The impact of these activities varies from place to place
18   and depends on the types and sensitivity of coastal ecosystems involved. A wide range of pressures have
19   been identified as causing adverse changes in coastal ecosystems, but the leading causes of coastal
20   ecosystem degradation include physical alteration, habitat degradation and destruction, water withdrawal,
21   overexploitation, pollution, and the introduction of non-native species (UNESCO and WWAP, 2006). In
22   addition, climate change may compound these pressures through the effects of higher sea levels, warmer
23   seawater, altered ocean circulation patterns, increased and extreme storm events, and increased carbon
24   dioxide concentrations (UNESCO and WWAP, 2006; Burke et al., 2001).

25   **4.5.5.1.1 Coastal Conditions Globally and in the United States**

26   The conditions of coastal ecosystems vary from place to place and depend on many factors.
27   Attempts have been made to assess the global extent and distribution of aquatic habitats, but estimates
28   vary considerably depending on the type and source of data (UNESCO and WWAP, 2006). While
29   inventories of coastal zones exist, there are no high-quality data sets or indicators at the global level that
30   track changes in condition over time (UNESCO and WWAP, 2006). Despite the lack of high-quality
31   data, it is safe to assume that coastal zones with significant human populations are vulnerable to a range
32   of human activities that can increase pressure and cause adverse changes to coastal ecosystems. As
33   mentioned above, typical coastal ecosystem degradation would include physical alteration, habitat
34   degradation and destruction, water withdrawal, overexploitation, pollution, and the introduction of non-
35   native species. The effects of sea level rise from climate change could compound these potential impacts.

36   The current overall coastal condition of the United States is considered fair by the EPA (Summers
37   et al., 2004). Six geographic coastal regions (Great Lakes Coastal Area, Northeast Coastal Area,
38   Southeast Coastal Area, Gulf Coast Coastal Area, West Coastal Area and Alaska, Hawaii, and Island
39   Territories) were evaluated by the EPA using five ecological health indicators to assess estuarine coastal
40   conditions as good, fair, or poor. The five indicators include water quality, sediment quality, benthic,
41   coastal habitat, and fish tissue contaminants. Of the five indicators, only the coastal habitat index
42   received an overall poor rating. The benthic and sediment quality indices rated fair to poor, while the
43   water quality and fish tissue contaminants indices received fair ratings. Of the six coastal regions, the
44   Southeast Coastal Area ranked highest with all indicators rating fair to good. The region with the worst
45   coastal condition was the Northeast Coastal Area, with four of the five indicators rating poor or fair to
46   poor. In terms of human and/or aquatic life use, 21 percent of the assessed coastal resources of the

1 country are considered unimpaired (good condition), whereas 35 percent are impaired (poor condition)
2 and 44 percent threatened (fair condition).

3 ### 4.5.5.1.2 Observed Trends in Coastal Zones Conditions

4   Impacts to coastal ecosystems are expected to continue as coastal populations increase and
5 demand more coastal space and resources. Many coastal ecosystems around the globe have been
6 significantly degraded, and many have been lost altogether. It is difficult to quantify the changes in
7 coastal ecosystems because historical data describing the previous extent of coastal ecosystems is very
8 limited. There is a need for more and higher-quality data characterizing the world's coastal zones. Burke
9 et al., (2001) found the following trends in the conditions of coastal ecosystems:

10   ▪ Many coastal habitats are disappearing at a fast pace, with extensive losses occurring in the
11   last 50 years.

12   ▪ Although some industrial countries have improved coastal water quality, chemical pollutant
13   discharges are increasing overall as agriculture intensifies and new synthetic compounds are
14   developed.

15   ▪ Pollution filtering capacities are lost as coastal ecosystems are lost.

16   ▪ Nutrient inputs to coastal waters appear to be increasing because of population increase and
17   agricultural intensification.

18   ▪ The frequency of harmful algal blooms resulting in mass mortality of marine organisms has
19   increased significantly over the past few decades.

20   ▪ Increased occurrences of hypoxia (shortage of oxygen in water) have been reported.

21   ▪ More than 25 different coral reef diseases have been recorded since 1970, and reports of coral
22   bleaching have increased significantly in recent years.

23   ▪ Many commercial fish species and other marine wildlife have become threatened.

24   ▪ Large-scale marine oil spills have been declining, but oil discharges from land-based sources
25   are believed to be increasing.

26   ▪ An increased number of invasive species is being reported throughout the world coastal
27   ecosystems.

28   ▪ There has been an increase in the number of protected marine and coastal areas, indicating
29   greater awareness of the need to protect these environments.

30   ▪ Global marine fish production has increased six fold since 1950.

31   ▪ The capacity of coastal ecosystems to produce fish for human harvest has been highly
32   degraded by overfishing, destructive trawling techniques, and loss of coastal nursery areas.

33   ▪ Notable ecosystem changes have occurred over the last half-century in some fishery areas,
34   such as the North Atlantic and Northeast Pacific.

1   There are a number of marine wildlife species that have been or may be adversely affected by
2   environmental changes in temperature, availability of water and nutrients, runoff from land, wind
3   patterns, and storminess that are associated with climate change (Kennedy et al., 2002). Marshes and
4   mangroves are particularly susceptible to sea level rise affecting the feeding or nesting grounds of Black
5   Rail, Clapper Rail, some terns and plovers (Kennedy et al., 2002). Over the short term, however, shrimp,
6   menhaden, dabbling ducks and some shorebirds would benefit from the release of nutrients from the
7   breakup of marshes (Kennedy et al., 2002). The southern sea otter, a keystone species, is listed as
8   threatened by the Endangered Species Act where the population has declined as a result of the increased
9   contaminants associated with high runoff produced by El Niño Southern Oscillation (ENSO)-induced
10   Pacific Ocean storms (Environmental and Energy Study Institute, 2001). Marine turtles are affected by
11   unusual changes in high/low temperatures, pollutants, infectious agents, and marine biotoxins, and have
12   become threatened by an epidemic of fibropapollomatosis linked to polluted coastal areas, agricultural
13   runoff, and biotoxins from algae (Environmental and Energy Study Institute, 2001). The full effect of
14   marine birds and species inhaling or ingesting biotoxins produced by algal blooms is of concern and not
15   fully understood (Environmental and Energy Study Institute, 2001).

16   There is strong evidence that temperature increases caused a rise in the global sea level during the
17   20th century (IPCC, 2007). Since each coastal area has its own unique geographic and environmental
18   characteristics, consequences from adaptations to climate change are expected to differ for each
19   community. Areas of critical sensitivity on the global scale include the major cities of Tokyo, Shanghai,
20   and London, and the countries of Thailand, India, and Vietnam (USCCSP, 2008a quoting IPCC). These
21   areas all share the characteristics of a coastal location, low elevation, large population, and currently
22   stressed resources. Because of their proximity to the water's edge and the high level of infrastructure
23   typical of many coastal communities, these urban centers are sensitive to changes in sea level rise
24   (USCCSP, 2008a).

25   Recent data suggest that the rise in global sea level has had an effect on some coastal zones of the
26   United States. Sea level data has shown a rise of 0.8 to 1.2 inches per decade since the beginning of the
27   20th century along most of the Atlantic and Gulf Coasts in the United States (USCCSP, 2008a). The
28   majority of the Atlantic Ocean demonstrated a sea level rise over the past decade at a rate greater than
29   0.1 inch per year in an east-northeast band from the United States east coast (USCCSP, 2008a). Coastal
30   wetland loss is occurring where these ecosystems are squeezed between natural and artificial landward
31   boundaries and rising sea levels (Field et al., 2007 as cited in USCCSP, 2008a). Rises in sea levels may
32   be contributing to coastal erosion across the eastern United States (USCCSP, 2008a). Sea level rise in the
33   Chesapeake Bay has accelerated erosion rates resulting in wetland destruction (USCCSP, 2008a). In
34   Mississippi and Texas, more than half of the shorelines have eroded at average rates of 8.5 to 10.2 feet per
35   year since the 1970s, while 90 percent of the Louisiana shoreline has eroded at a rate of 39.4 feet per year
36   (Nicholls et al., as cited in USCCSP, 2008a). Areas in Louisiana are experiencing barrier island erosion
37   resulting in an increased height of waves (USCCSP, 2008a). Furthermore, regional sea level rise has
38   contributed to increase storm surge impacts along the North American Eastern Coast (USCCSP, 2008a).
39   Particularly since subsidence is occurring in parts of this area, areas such as the Louisiana and Gulf coasts
40   are considered at high risk from erosion and storm surges, and any area along the coast with low
41   elevations, large populations, and currently stressed resources could be expected to be at risk from any
42   future sea level rises.

43   **4.5.5.2 Consequences**

44   This section discusses the potential cumulative effects of climate change on coastal zones both in
45   the United States and globally.

1   **4.5.5.2.1 Projected Impacts of Climate Change for the United States**

2   According to the USCCSP Scientific Assessment, 50 percent of Americans live in coastal
3   communities (National Science and Technology Council, 2008). Coastal urban centers are expected to
4   experience a surge in population growth of an additional 25 million people over the next 25 years. This
5   change in population is expected to compound the anticipated adverse effects of climate change on
6   coastal communities, placing heavier demand on already-stressed resources (National Science and
7   Technology Council, 2008). Data have confirmed an average rise in sea level of 0.8 to 1.2 inches per
8   decade since the beginning of the 20th century along most coasts in the United States, with the Gulf Coast
9   experiencing a rise of a few inches per decade (primarily due to land subsidence) and Alaskan coasts
10   experiencing *decreases* in sea level of a few inches per decade (National Science and Technology
11   Council, 2008). In one example, the Union of Concerned Scientists' report (Frumhoff et al., 2007)
12   discusses the impacts of surging waters during a coastal storm in December 1992, when strong winds and
13   rising water levels disrupted the New York City public transit system and required the evacuation of
14   communities in New Jersey and Long Island. Sea level rise in the Chesapeake Bay has accelerated
15   erosion rates, resulting in wetland destruction (National Science and Technology Council, 2008). Sea
16   level rise in the 21st century is expected to exceed that of past years, causing great alarm for coastal
17   communities and the infrastructures they support.

18   Although a range of adverse effects from climate change is expected in the United States, one of
19   the most damaging is expected to be that of sea level rise. The IPCC predicts a sea level rise of 7 to
20   23 inches by 2090-2099 (Parry, 2007 in National Science and Technology Council, 2008). These figures
21   do not include the anticipated sea level rise from melting ice sheets and glaciers in Greenland and
22   Antarctica where scientists have already noted a decrease in the thickness and depth of sea ice (National
23   Science and Technology Council, 2008) or the potential for rapid acceleration in ice loss (Alley et al,
24   2005; Gregory and Huybrechts, 2006; Hansen, 2005 in Pew, 2007). Recent studies have found the
25   IPCC's estimates of ice loss from the Greenland and Antarctic ice sheets and from mountain glaciers may
26   be underestimated (Shepherd and Wignham, 2007; Csatho et al., 2008; Meier et al., 2007). Further,
27   IPCC may underestimate sea level rise that would be gained through changes in global precipitation
28   (Wentz et al., 2007; Zhang et al., 2007). Rahmstorf (2007) used a semi-empirical approach to project
29   future sea level rise. The approach yielded a proportionality coefficient of 3.4 mm per year per degree
30   Celsius of warming, and a projected sea level rise of 0.5 to 1.4 meters above 1990 levels in 2100 when
31   applying IPCC Third Assessment Report warming scenarios. Rahmstorf (2007) concludes that "[a] rise
32   over 1 meter by 2100 for strong warming scenarios cannot be ruled out."

33   Some general effects associated with rising sea levels include:

34   ▪   Loss of land area due to submergence and erosion of lands in the coastal zone;
35   ▪   Changes to coastal environments;
36   ▪   More flooding due to storm surges; and
37   ▪   Salinization of estuaries and groundwater (National Science and Technology Council, 2008).

38   For islands such as those located in Hawaii and other United States territories in the Pacific,
39   outcomes could include a reduction in island size and the abandonment of inundated areas (National
40   Science and Technology Council, 2008). Approximately one-sixth of United States land that is close to
41   sea level is located in the Mid-Atlantic region and, consequently, much of the reporting on effects focuses
42   on this region (National Science and Technology Council, 2008).

43   Over the past century, the highest rate of sea level rise has been observed in the mid-Atlantic
44   region, in part resulting from subsidence of the land surface (Gutierrez et al., 2007). For example,
45   Virginia has observed sea level rise at 4.4 millimeters per year compared to 1.8 millimeters per year in

1   Maine (Zervas, 2001 cited in Gutierrez et al., 2007). New Jersey, with 60 percent of its population living
2   along the 127 miles of coastline, has experienced coastline subsidence and beach erosion threatening
3   communities and coastal wetlands (Union of Concerned Scientists, 2007; Aucott and Caldarelli, 2006;
4   Metro East Coast Regional Assessment, 2000).

5   The effects of sea level rise on some coastal communities could be devastating with increased
6   erosion and flooding. Extensive erosion has already been documented across the East Coast, as have
7   notable decreases in the coastal wetlands of Louisiana, the mid-Atlantic region, New England, and New
8   York (Rosenzweig et al., 2007 in National Science and Technology Council, 2008). Erosion is expected
9   to be worse in sandy environments along the mid-Atlantic coast, Mississippi, and Texas (National
10   Science and Technology Council, 2008; Nicholls et al., 2007 in National Science and Technology
11   Council, 2008). The IPCC notes that sandy shorelines are already retreating. Furthermore, areas in
12   Louisiana are experiencing barrier island erosion, resulting in increases in the height of waves that make
13   it to shore (Nicholls et al., 2007 in National Science and Technology Council, 2008). A large storm can
14   affect the shoreline position for weeks to a decade or longer (Morton et al., 1994; Zhang et al., 2004; List
15   et al., 2006; Riggs and Ames, 2007 in Gutierrez et al., 2007). Tidal wetlands, estuarine beaches, marshes
16   and deltas are expected to be inundated with water in areas such as the Mississippi River, Louisiana
17   Delta, and the Blackwater River marshes in Maryland (Titus et al., 2008 in National Science and
18   Technology Council, 2008). The "coastal squeeze" phenomenon where wetlands are trapped between
19   natural and human-made land boundaries is causing wetland loss and habitat destruction (Field et al.,
20   2007 in National Science and Technology Council, 2008). Freshwater resources are also at risk given the
21   *likely* intrusion of saltwater into groundwater supplies, adversely affecting water quality and salinization
22   rates (Kundzewicz et al., 2007 in National Science and Technology Council, 2008).

23   The height of storm surges will increase if sea level rises regardless of storm frequency and
24   intensity increases; thus, a storm of similar behavior will cause greater damage with rising sea level
25   (Fisher et al., 2000). One study suggests the 100-year flood may in fact occur every 25 to 30 years
26   (Najjar et al., 2000 in Fisher et al., 2000). By mid-century, Boston and Atlantic City could experience a
27   100-year flood event every 2 to 4 years and annually by the end of the century (Frumhoff et al., 2007).

28   Cayan et al., (2006) projected future sea level rise and its implications for California. The study
29   projected sea level rise, relative to 2000, to range from 11 to 54 centimeters (4.3 to 21 inches); 14 to 61
30   centimeters (5.5 to 24 inches); and 17 to 72 centimeters (6.7 to 28 inches) by 2070 to 2099 for B1, A2,
31   and A1 GHG modeling scenarios, respectively. The mean sea level rise from a survey of several climate
32   models was also determined to range from approximately 10 to 80 centimeters (3.9 to 3.15 inches)
33   between 2000 and 2100. The historic rate of sea level rise observed at San Francisco and San Diego
34   during the last 100 years was 15 to 20 centimeters (5.9 to 7.9 inches). Parts of the California coast are at
35   risk for flood damage, which may further jeopardize levees in the City of Santa Cruz (California
36   Environmental Protection Agency, 2006). Santa Cruz is 20 feet above sea level with levees built to
37   contain the 100-year flood. If sea levels were to increase above 12 inches as predicted for the medium
38   warming range of temperatures, then a flood associated with a storm surge event at the 100-year level
39   may happen once every 10 years (California Climate Change Center, 2006a). The ENSO events of 1982-
40   1983 and 1997-1998 corresponded to high sea level episodes (Flick, 1998 in California Climate Change
41   Center, 2006b). These high sea level episodes may intensify in future ENSO events if rising sea level
42   increases.
43
44   The frequency and intensity of storms are expected to become more prevalent at the same time as
45   sea levels rise and sea surface temperatures increase. Some societal effects include the following:

46   ▪   Infrastructure such as bulkheads, dams, and levees could be damaged by flooding and strong
47   storms (Nicholls et al., 2007 in National Science and Technology Council, 2008).

1   • Coastal ports, roads, railways, and airports are at risk of disruption due to power outages,
2   flooded routes, and poor travel conditions (Nicholls et al., 2007 in National Science and
3   Technology Council, 2008).

4   • Industries reliant on coastal stability such as travel and recreation, fishing and hunting, and
5   trade are expected to become increasingly sensitive to these temperature and precipitation
6   changes in the coming decades (Nicholls et al., 2007 in National Science and Technology
7   Council, 2008).

8   • The most at-risk State in the United States is expected to be Alaska because the indigenous
9   communities residing there depend upon wildlife for hunting and fishing practices, living
10   within floodplains and currently face water shortages (IPCC, 2007 in National Science and
11   Technology Council, 2008).

12   Loss of coastal wetlands due to intense storms has been documented on many occasions. A
13 prominent recent example is the loss of coastal lands as a result of Hurricane Katrina in 2005. In
14 Louisiana alone, the loss of land during Hurricane Katrina was approximately 217 square miles. The
15 Chandeleur Islands, which New Orleans relied on as a tropical storm buffer, lost 85 percent of their
16 surface area (USCCSP, 2008b).

17   Increases in storm frequency and severity, as well as sea rise itself, have detrimental effects on
18 coastal areas with sandy beaches. Many species are reliant on the wellbeing of, and accessibility to,
19 beaches. Some examples:

20   • Diamondback terrapins and horseshoe crabs rely on beach sands to bury their eggs. The eggs
21   not only act to propagate the species, but some shorebirds, such as the piping plover, rely on
22   these eggs as a food source (USFWS, 1988 in Titus et al., 2008).

23   • Horseshoe crabs rarely spawn unless sand is at least deep enough to nearly cover their bodies,
24   about 10 cm (4 inches) (Weber, 2001). Shoreline protection structures designed to slow
25   beach loss can also block horseshoe crab access to beaches and can entrap or strand spawning
26   crabs when wave energy is high (Doctor and Wazniak, 2005). (Titus et al., 2008). So, in this
27   case, the loss of beach, as well as the adaptation strategy selected by the community, can
28   result in harm to local species.

29   • A rare firefly, *Photuris bethaniensis*, is found only in areas between dunes on Delaware's
30   barrier beaches. Its habitat is at risk due to beach stabilization and hardening of shorelines;
31   this limits migration of dunes and the formation of the interdunal swales where the firefly is
32   found (Titus et al., 2008).

33   **4.5.5.2.2 Adaptation to Climate Change**

34   There are uncertainties regarding which effects of climate change could affect individual coastal
35 and low-lying areas. However, because these areas are particularly sensitive to climate and hazardous
36 weather events, adaptation to projected climate change remains a potentially attractive option.
37 Adaptations can be preventative, taken before the arrival of an anticipated impact or reactive, taken in
38 response to the actual changes. Many of the adaptations for coastal and low-lying areas can overlap
39 between these two categories and might differ only by the timing in which they are implemented. The
40 USCCSP (2008, in National Science and Technology Council, 2008) outlines seven approaches to
41 adaptation:

1   ▪   Protecting key ecosystem features;
2   ▪   Reducing anthropogenic stresses;
3   ▪   Representation (maintaining species diversity);
4   ▪   Replication of ecosystems to maintain species diversity and habitable lands;
5   ▪   Restoration of disturbed ecosystems;
6   ▪   Refugia (using less affected areas to "seed" new areas); and
7   ▪   Relocation.

8   Some examples of possible adaptation strategies in the United States include shifting populations
9 and infrastructure from coastal communities along the East and Gulf Coasts and Mid-Atlantic region
10 further inland (IPCC, 2007 in National Science and Technology Council, 2008). Other possible strategies
11 include elevating infrastructure, introducing barriers such as levees and dams to hold off storm surges,
12 reducing fertilizer and pesticide use in nearshore coastal communities (Epstein, P. and E. Mills, 2006),
13 preserving contiguous interconnected water systems (including mangrove stands, spawning lagoons,
14 upland forest and watershed systems, coastal wetlands) (Epstein, P. and E. Mills, 2006), and constructing
15 watertight containment for essential equipment (NY DEP, 2008). While the options for adaptation in
16 coastal and low-lying areas are many, the key is to consider the time frame in which these adaptations are
17 proposed and implemented to best prepare communities. The IPCC in their 2007 Technical Summary has
18 predicted that the costs of adaptation are *virtually certain* to be less than those of inaction (Parry et al.,
19 2007).

20   Current government programs are in effect that assist in subsidizing protection for coastline
21 development including shoreline protection and beach replenishment, Federal disaster assistance, and the
22 National Flood Insurance Program (Fisher et al., 2000). In 2006, Maine developed and implemented
23 shoreline regulations to address projected sea level rise due to climate change (Frumhoff et al., 2007).
24 Maine is currently the only State in the nation with such a program.

25   **4.5.5.2.3 Projected Global Impacts of Climate Change**

26   Globally, coastal systems and low-lying areas are experiencing adverse effects related to climate
27 change and sea level rise such as coastal inundation, erosion, ecosystem loss, coral bleaching and
28 mortality at low latitudes, thawing of permafrost and associated coastal retreat at high latitudes (*very high*
29 *confidence*) (IPCC, 2007). To further exacerbate the stressors, human settlement and encroachment on
30 coastal systems and low-lying areas have been increasing with an estimated 23 percent of the world's
31 population living within about 60 to 65 miles of the coast and no more than about 330 feet above sea
32 level (Small and Nichols, 2003 in National Science and Technology Council, 2008).

33   Though non-uniform around the world, it is estimated global sea level has risen by 0.07
34 ±0.02 inch per year over the past century with western Pacific and eastern Indian Ocean experiencing the
35 greatest rise (IPCC, 2007). Sea level is anticipated to continue to increase 0.7 to 2.0 feet or more by the
36 end of the 21st century (IPCC, 2007). This sea level rise coupled with both projected sea surface
37 temperatures increasing 1 to 3°C and intensified cyclonic activity could lead to larger waves and storms
38 surges impacting coastal systems and low-lying areas across the globe (IPCC, 2007). The loss or
39 degradation of coastal ecosystems has a direct impact on societies that are dependent on coastal-related
40 goods and services such as freshwater and fisheries with the potential to impact hundreds of millions of
41 people (Parry et al., 2007).

42   There is variability in the projected effects from climate change and sea level rise on an
43 international scale. For instance, if the global mean annual temperature increases above 1980 to 1999
44 levels, it is anticipated that coastal systems and low-lying areas will sustain increased damage due to
45 floods and storms; an additional 2 degrees Celsius increase would lead to an increase of millions of

1   people that could experience coastal flooding each year; and an increase by 3 degrees Celsius is estimated
2   to lose 30 percent of the global coastal wetlands (*high confidence*; IPCC, 2007, Figure SPM.2). Coastal
3   wetland ecosystems are at significant risk from sea level rise if they are sediment-starved or unable to
4   migrate further inland. As sea water temperatures increase, it is *likely* that coral bleaching and mortality
5   will rise unless corals demonstrate thermal adaptation (IPCC, 2007). These adverse impacts are expected
6   to increase in severity as the global mean annual temperature increases.

7   Tide gauges have measured the average rate of sea level rise to be 0.07 ±0.02 inch per year from
8   1961 to 2003 and 0.07 ±0.02 inches per year (National Science and Technology Council, 2008) over the
9   past century. These changes are attributed to thermal expansion associated with rising global
10   temperature, thawing of permafrost, and loss of sea ice (IPCC, 2007). The global ocean temperature
11   averaged from the surface to a depth of approximately 2,300 feet has increased by 0.10 degrees Celsius
12   over the period from 1961 to 2003 contributing to an average increase in sea level of 0.02 ±0.004 inch per
13   year (National Science and Technology Council, 2008). This contribution has increased for the period
14   1993 to 2003 with a rate of sea level rise of 0.06 ±0.02 inch per year. Melting of mountain glaciers, ice
15   caps, and land ice have also contributed to the measured sea level rise. From 1961 to 2003, the melting of
16   land ice has contributed approximately 0.03 ± 0.02 inch per year to sea level rise with an accelerated rate
17   of 0.05 ±0.02 inch per year between 1993 and 2003 (Lemke et al., 2007 in National Science and
18   Technology Council, 2008).

19   Sea level rise is non-uniform around the world. In some regions, rates of rise have been as much
20   as several times the global mean, while other regions have experienced falling sea level. This might be
21   the result of variations in thermal expansion and exchanges of water between oceans and other reservoirs,
22   ocean and atmospheric circulation, and geologic processes (Bindoff et al., 2007 in National Science
23   Technology Council, 2008). Satellite measurements provide unambiguous evidence of regional
24   variability of sea level change for the period 1993 to 2003 with the largest sea level rise occurring in the
25   western Pacific and eastern Indian oceans (National Science and Technology Council, 2007).

26   Sea level is projected to increase from 0.7 to 2.0 feet or more by the end of the 21st century
27   (IPCC, 2007) with the possibility of additional significant sea level rise occurring resulting from the
28   breakdown of West Antarctic and/or Greenland ice sheets. A temperature increase of 1.1 to 3.8 degrees
29   Celsius would trigger the breakdown of the Greenland ice sheet, and is *likely* to occur by 2100 (Parry et
30   al., 2007). An additional sea level rise of about 21 to 24 feet would result in the complete disappearance
31   of the Greenland ice sheet (IPCC, 2007, Table 4.1; Epstein, P. and E. Mills, 2006). This scenario raises
32   concern regarding the viability of coastal communities, salt marshes, corals, and mangroves. A sea level
33   rise of about 14 inches from 2000 to 2080 is projected to reduce coastal wetlands by 33 percent with the
34   largest impact on the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean, the Baltic,
35   and small-islands (IPCC, 2007).

36   IPCC SRES estimated that the coastal population could grow from 1.2 billion people in 1990 to
37   between 1.8 billion and 5.2 billion people by the 2080s with this range dependent on coastal migration.
38   Though the impact of sea level rise on a specific region can be difficult to quantify given regional and
39   local variations (Parry et al. 2007), the IPCC describes the following coastal regions as the most
40   vulnerable to the impact of climate change: South Asia, Southeast Asia, East Asia, Africa, and small
41   islands (IPCC, 2007).

42   Many of the coastal cities that are most vulnerable to adverse impacts of climate change are at
43   further risk due to human activities such as agriculture, aquaculture, silviculture, industrial uses, and
44   residential uses that have degraded the natural protective qualities of the coastal systems (IPCC, 2007).
45   Coastal countries at risk for shoreline retreat and flooding due to degradation associated with human
46   activity include Thailand (Durongdej, 2001; Saito, 2001 in National Science and Technology Council,

1   2008), India (Mohanti, 2000 in National Science and Technology Council, 2008), Vietnam (Thanh et al.,
2   2004 in National Science and Technology Council) and the United States (Scavia et al., 2002 in National
3   Science and Technology Council, 2008) with emphasis on the seven Asian megadeltas with a combined
4   population greater than 200 million (IPCC, 2007). Of particular concern are those highly coastal
5   populated regions within countries with limited financial resources to protect or relocate its populations
6   (IPCC, 2007).

7   Small islands are particularly vulnerable to climate change and sea level rise, especially those
8   islands prone to subsidence (Parry et al., 2007). Beach erosion is projected to increase as sea level rises
9   and sea water temperature increases. Arctic islands may experience increased erosion and volume loss as
10 permafrost and ground ice warms in response to rising global temperatures (IPCC, 2007).

11   Positive impacts anticipated to be experienced in high latitudes include a longer tourist season
12 and better navigability (IPCC, 2007). Without adaptation, IPCC model results suggest more than
13 100 million people could endure coastal flooding due to sea level rise every year by 2080 (IPCC, 2007).

14 ### 4.5.5.2.4 Adaptation to Climate Change

15   In some circumstances, the potential effects from climate change and sea level rise on coastal
16 systems and low-lying areas can be reduced through widespread adaptation (IPCC, 2007). The IPCC
17 modeled results of flood risk associated with rising sea level and storm surges projected to 2080 found
18 significant benefit associated with upgrading coastline defenses (Nicholls et al., 2007). In addition,
19 curtailing the current degradation in coastal systems by anthropogenic activities such as deforestation,
20 fertilizer use, sewage dredging, sand mining, fish harvesting, and sea wall construction would provide a
21 more robust coastal system resistant to extreme water levels during storms.

22   Small islands in the Indian Pacific Oceans and the Caribbean have much of their infrastructure
23 in coastal locations (Parry et al., 2007). Under projected sea level rise levels, some infrastructure is *likely*
24 to be at risk from inundation and flooding (IPCC, 2007). Small islands have limited adaptation choices to
25 sea level rise and climate change impact on coastal sections.

26 ### 4.5.6 Food, Fiber, and Forest Products

27   This section defines these resources and describes the existing conditions and potential
28 vulnerability of each to climate change impacts. The primary resource used in this section is the IPCC
29 Fourth Assessment Report (IPCC, 2007a); specifically, Chapter 5 for food, fiber, and forest products.

30   The food, fiber, and forest sector is a significant source of livelihood and food for large numbers
31 of the world's population and a major land cover type at a global level. Cropland, pasture, or natural
32 forests account for approximately 70 percent of the world's land cover. The United Nations Food and
33 Agriculture Organization (FAO) estimates that approximately 450 million of the world's poorest people
34 are entirely dependent on this sector for their livelihood (IPCC, 2007a).

35   According to IPCC, this sector includes agriculture, forestry, and fisheries. It also includes
36 subsistence and smallholder agriculture, defined as rural producers who farm or fish primarily with family
37 labor and for whom this activity provides the primary source of income (IPCC, 2007a).

38 ### 4.5.6.1 Affected Environment

39   It is estimated that 40 percent of the Earth's land surface is used for cropland and pasture (Foley
40 et al., 2005, in IPCC, 2007a). The FAO estimates that natural forests cover another 30 percent of the land

1   surface, and that 5 percent of that natural forest area generates 35 percent of global timber production
2   (FAO, 2000, in IPCC, 2007a). Nearly 70 percent of people in lower-income countries around the world
3   live in rural areas where agriculture is the primary source of livelihoods. Growth in agricultural incomes
4   in developing countries fuels the demand for non-basic goods and services fundamental to human
5   development. The FAO estimates that the livelihoods of roughly 450 million of the world's poorest
6   people are entirely dependent on managed ecosystem services. Fish provide more than 2.6 billion people
7   with at least 20 percent of their average per-capita animal protein intake, but 75 percent of global fisheries
8   are currently fully exploited, overexploited, or depleted (FAO, 2004 in IPCC, 2007a).

9   ## Terrestrial Systems

10   The distribution of crop, pasture, and forest species between the polar and equatorial latitudes is a
11   function of current climatic and atmospheric conditions, as well as photoperiod. Agricultural, pastoral,
12   and forestry systems are dependent on total seasonal precipitation and its pattern of variability, as well as
13   wind and humidity. Crops exhibit threshold responses to their climatic environment, which affect their
14   growth, development and yield (Porter and Semenov, 2005 in IPCC, 2007a). Short-term natural
15   extremes, such as storms and floods, interannual and decadal climate variations, and large-scale
16   circulation changes, such as ENSO, all have important effects on crop, pasture and forest production
17   (Tubiello 2005 in IPCC 2007a).

18   For example, Europe experienced a particularly extreme climate event during the summer of
19   2003, with temperatures up to 6 degrees Celsius above long-term means, and precipitation deficits up to
20   12 inches (Trenberth et al., 2007 in IPCC, 2007a). Associated with this extreme climate event was a
21   decline in corn yield of 36 percent in the Po River valley in Italy and 30 percent in France. In addition,
22   French fruit harvests declined by 25 percent, winter wheat yields declined by 21 percent, and hay and
23   other forage production declined on average by 30 percent (Ciais et al., 2005 in IPCC, 2007a). Moreover,
24   African droughts between 1981 and 1999 caused livestock mortality from 20 percent to more than 60
25   percent in countries such as Botswana, Niger, Ethiopia, and Kenya (IPCC, 2007a).

26   Overall, climate change may benefit crop and pasture yields in mid- to high-latitude regions,
27   while decreasing yields in dry and low-latitude regions. Total forest productivity may rise modestly, with
28   considerable global variation. Local extinctions of fish species are expected, particularly at the edges of
29   habitat ranges (IPCC, 2007a).

30   Agricultural and forest lands are experiencing multiple stresses that increase their vulnerability to
31   climate change impacts. Examples include soil erosion, salinization of irrigated areas, overgrazing, over-
32   extraction of groundwater, loss of biodiversity, and erosion of the genetic resource base in agricultural,
33   forest and pasture areas. Overfishing, loss of biodiversity, and water pollution in aquatic areas serve as
34   stresses that increase vulnerability to climate change to fishery resources (IPCC, 2007a).

35   The vulnerability of these resources is dependent on both the exposure to climate conditions and
36   capacity to cope with changing conditions. Exposure to conditions is highly dependent on local
37   geography and environment. Adaptive capacity is dynamic and dependent on wealth, human capital,
38   information and technology, material resources and infrastructure, and institutions and entitlements
39   (IPCC, 2007a).

40   Sub-Saharan Africa offers one example of a region that is currently highly vulnerable to food
41   insecurity (Vogel, 2005 in IPCC, 2007a). Drought conditions, flooding, and pest outbreaks are some of
42   the current stressors on food security that may be influenced by future climate change. Options for
43   addressing food insecurity in this region (as well as overall development initiatives related to agriculture,
44   fisheries, and forestry) may be constrained by health status, lack of information, and ineffective

1 institutional structures. These constraints have the potential for limiting future adaptations to periods of
2 heightened climate stress (Reid and Vogel, 2006 in IPCC, 2007a).

3 ## Aquatic Systems

4 Spatial adaptation of marine ecosystems to climate change is in some ways less geographically
5 constrained than for terrestrial systems. The rates at which planktonic ecosystems have shifted their
6 distribution have been very rapid over the past three decades, which can be regarded as natural adaptation
7 to a changing physical environment (Beaugrand et al., 2002, in IPCC, 2007a). Most fishing communities
8 use stocks that fluctuate due to interannual and decadal climate variability, and consequently have
9 developed considerable coping capacity (King 2005, in IPCC, 2007a).

10 Research on the relationship between water temperature and the health of freshwater fishes
11 indicates different impacts in summer and winter. While temperature increases may cause seasonal
12 increases in growth in the winter, mortality risks to fish populations occur at the upper end of their
13 thermal tolerance zone in the summer.

14 World capture production of finfish and shellfish in 2004 was more than twice that of
15 aquaculture, but since 1997 capture production decreased by 1 percent, whereas aquaculture increased by
16 59 percent (IPCC, 2007a). The increasingly important aquaculture sector allows for the application of
17 similar types of management adaptations to climate change suggested for crop, livestock, and forestry
18 sectors. This is not the case, however, for marine capture fisheries, which are shared resources subject to
19 varying degrees of effective governance. Adaptation options for marine capture fisheries include altering
20 catch size and effort. Three-quarters of world marine fish stocks are currently exploited at levels close to
21 or above their productive capacity (Bruinsma, 2003 in IPCC, 2007a). Reductions in the level of effort
22 and harvest are required to sustain yields. Such a course of action may also benefit fish stocks that are
23 sensitive to climate variability when their population age-structure and geographic sub-structure is
24 reduced (Brander 2005 in IPCC, 2007a).

25 ### 4.5.6.2 Consequences

26 The Earth's land surface is composed mostly of managed cropland and pasture (40 percent) and
27 natural forests (30 percent) (Foley et al., 2005 in Easterling et al., 2007). These sectors provide important
28 commodities that are produced in a variety of geographic and climatic regions (USCCSP, 2008). The
29 continued growth and productivity of the world's agriculture and forests is necessary to sustain human
30 economic and social development.

31 The discussion below is focused on impacts on food and industrial crops, fisheries, agricultural
32 pastures, commercial forestry, and subsistence farming (Easterling et al., 2007). The key drivers for
33 climate impacts in this sector are higher temperatures, changed precipitation and transpiration dynamics,
34 the effects of increased CO_2 concentrations on vegetative growth and yield, greater frequency in extreme
35 weather events, and increased stressors to forests and agriculture in the form of pests and weeds
36 (Easterling et al., 2007).

37 The world's food crops, forests, and fisheries have evolved to be in tune with the present climatic
38 environment. The productivity of these systems ultimately relies on the interaction of various climate
39 factors including temperature, radiation, precipitation, wind speed, and water vapor pressure (Easterling et
40 al., 2007). There are threshold climatic conditions for crops and forests that affect their growth and yield,
41 and climatic conditions and their interaction influence the global distribution of agricultural and forest
42 species (Porter and Semenov, 2005 in Easterling et al., 2007).

1   The sensitivity to climate change and exposure to various other stressors increases the
2   vulnerability of the forest, food, and fiber systems (Easterling et al., 2007). Non-climate stressors such as
3   soil erosion, overgrazing, loss of biodiversity, decreased availability of water resources, increased
4   economic competition among regions, and the adaptive capacity of various species increase overall
5   sensitivity to the climate and thus exacerbate the adverse effects of climate change (USCCSP, 2008).

6   Climate change could also benefit agriculture and silviculture through the CO_2 fertilization effect.
7   CO_2 is essential for plant growth; some research suggests that higher atmospheric concentrations translate
8   to higher productivity of some food, fiber, and forest crops. Milder winters and longer growing seasons
9   could also increase productivity in some regions.

10   Important examples that highlight the link between large-scale climate changes and the sensitivity
11   of the food, fiber, and forest systems include the effects of ENSO, a relatively well-known phenomenon,
12   on crop yield. In Australia, during ENSO years there is increased probability of a decline in farmers'
13   incomes by as much as 75 percent below the median income as compared to non-ENSO years (Tubiello,
14   2005 in Easterling et al., 2007). Another example is the extreme heat wave that occurred in Europe in
15   2003, which lowered maize yield by 36 percent in Italy and 30 percent in France (Cais et al., 2005 in
16   Easterling et al., 2007). Uninsured losses for the entire European Union agriculture sector were estimated
17   at 13 billion euros; 4 billion euros were lost in France alone (Senat, 2004 in Easterling et al., 2007). (This
18   is discussed earlier in the chapter)

19   The most recent comprehensive and peer-reviewed literature on global climate impacts on the
20   food and forestry sectors is from the IPCC Fourth Assessment Report. The SAP 4.3 report by USCCSP
21   and the Subcommittee on Global Change Research provides an additional source of authoritative
22   information on the impacts of climate change on agriculture, land resources, and biodiversity in the
23   United States. Most of the evidence cited in this chapter focuses on the results of the IPCC report and the
24   SAP 4.3. However, since new evidence is continuously emerging on the subject of climate change
25   impacts on the agriculture and forest systems, the discussion below also draws on results reported in more
26   recent studies.

27   **4.5.6.2.1 Projected Impacts of Climate Change for the United States**

28   <u>Forests</u>

29   In the United States, the combination of human management and temperate climate has resulted
30   in a productive and healthy forest system, as exemplified by the southern pine plantations (USCCSP,
31   2000). Forests are generally considered the most productive of the terrestrial ecosystems and provide
32   important commodities like timber products. They are also key biodiversity sanctuaries and providers of
33   ecosystem services. Presently, forests cover roughly one third of the land in the United States. Net
34   growth of these forests (growth minus removals minus decomposition) accounts for removing about
35   883.7 MMTCO$_2$ per year, about 12.5 percent of gross national GHG emissions (EPA, 2008). Globally,
36   forests account for the largest fraction of terrestrial ecosystem sequestered carbon, estimated to be
37   roughly 1,640 petagrams of carbon (Sabine et. al, 2004 in USCCSP, 2008). Climate change may directly
38   affect the ability of forests to provide these key services and commodities in a number of ways.

39   One key impact of climate change is the extended risk and increased burn area of forest fires
40   coupled with pathogenic stressors that damage fragile forest systems (IPCC, 2007a). These impacts (i.e.,
41   forest fires, diseases, and pathogens) might potentially be greatest between 2050 and 2100. It is projected
42   that the forest fire season (summer) could be extended by 10 to 30 percent as a result of warmer
43   temperatures (Parry et al., 2007). In the western states, the anticipated warmer spring and summer
44   temperatures are expected to reinforce longer fire seasons and increased frequency of large wildfires. In

1 turn, the carbon pools within forests are expected to be affected by changes in forest composition and
2 reduced tree densities (Westerling, 2006). More specifically, the Hadley and Canadian climate and
3 ecological models project an increase in the fire season hazard by 10 percent in the 21st century in the
4 United States, with small regional decreases in the Great Plains and a 30 percent increase in Alaska and
5 the southeast (USCCSP, 2000). Highlighting the geographic differences even within a state, two climate
6 models including the Geophysical Fluid Dynamics Laboratory and the Parallel Climate Model were run
7 using "business as usual" (A2) and "transition to a low GHG emissions" (B1) IPCC SRES emissions
8 scenarios. The results showed increases in fire risk in Northern California (15 to 90 percent), increasing
9 with temperature whereas in Southern California, the change in fire risks ranged from a decrease of 29
10 percent to an increase of 28 percent. These results were largely driven by differences in precipitation
11 between the different scenarios. In Southern California the drier conditions simulated in both the
12 Geophysical Fluid Dynamics Laboratory model scenarios led to reduced fire risks in large parts of
13 southern California, with fire risks increased in parts of the San Bernardino mountains (Westerling and
14 Bryant, 2006).

15   Historical evidence indicates that the warmer periods in the past millennium correlated with
16 increased frequency in wildfires, particularly in the western forests (USCCSP, 2008). General circulation
17 models project increased wildfire activity in the western states, particularly from 2010 through 2029
18 (Flannigan et al., 2000; Brown et al., 2004 in USCCSP, 2008). In 2060, models have projected forest fire
19 severity increases of 10 to 30 percent in the southeastern states and 10 to 20 percent in the northeastern
20 states (Flannigan et al., 2000 in USCCSP, 2008). Some models have projected even larger increases in
21 wildfire activity, particularly in the southeastern region of the United States (Bachelet et al., 2001 in
22 USCCSP, 2008). Potential losses to North American producers from increased disturbances (including
23 wildfires, insects, and diseases) coupled with climate change impacts have been estimated to range from
24 $1 to $2 billion per year averaged throughout the 21st century (Sohngen and Sedjo, 2005 as cited in Field
25 et al., 2007).

26   Ancillary consequences of the projected increase in wildfire frequency across the United States
27 include an increase in emissions expected to affect air quality and continue to be a source of GHGs.
28 Although the GHGs that are released through wildfires could eventually be sequestered by forest
29 regrowth, this carbon release might not be fully recovered in the short term and thus might be an
30 important source of CO_2 in the atmosphere (Kashian et al., 2006 in USCCSP, 2008). Particularly in
31 forests in the western United States, "If wildfire trends continue, at least initially this biomass burning
32 will result in carbon release, suggesting that the forests of the western United States may become a source
33 of increased atmospheric carbon dioxide rather than a sink, even under a relatively modest temperature
34 increase scenario" (Westerling et al., 2006, p. 943).

35 Invasive Species

36   The increasing occurrence of forest fires, which is likely to continue with projected warming
37 temperatures, would impact ecosystem services, reduce the potential for carbon storage via forest
38 management, and provide increased potential habitat for invasive species and insect outbreaks (Parry et
39 al., 2007).

40   Since invasive species and pests are not constrained by the need for pollinators or seed spreaders,
41 these species are more adaptable to the warming climate (Vila et al., 2007 in USCCSP, 2008). The
42 northward movement of weed species, especially invasive weeds, is likely to be a result of higher
43 projected temperatures and increased CO_2 concentration. This movement northward could further be
44 accelerated, as some studies that have shown that the responsiveness of weeds to glyphosate, an important
45 herbicide used in the United States, diminishes with increases in CO_2 concentration levels (Ziska et. al,
46 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

1   range"), such as wine grapes in California, are expected to decrease in yield or quality based on moderate
2   climate change scenarios (IPCC, 2007a, p. 631).

3   Grain crops in the United States are likely to initially benefit from the increased temperature and
4   CO_2 levels. However, as temperatures continue to rise, sensitivity of these grain crops could increase.
5   This sensitivity is expected to an even greater extent for horticultural crops such as tomatoes and onions,
6   compromising their productive yield (USCCSP, 2008). Various studies have found differing thresholds
7   for maize production in the United States, with one in particular showing a 17 percent reduction of maize
8   yield per 1 degree Celsius increase in temperature (Lobel and Asner, 2003, in USCCSP, 2008). Other
9   crops such as wheat are regionally and temporally dependent. Studies show that wheat yield in the Great
10 Plains "is estimated to decline 7 percent per 1 degree Celsius increase in air temperature between 18 and
11 21 degrees Celsius and about 4 percent per 1 degree Celsius increase in air temperature above 21 degrees
12 C" (Lobell and Field, 2007, in USCCSP, 2008, p. 124). Similarly, rice yields are projected to decline
13 about 10 percent per 1 degree Celsius increase for temperature profiles that are above current summer
14 mean air temperatures (USCCSP, 2008).

15   In the Great Lakes region, fruit production might benefit from climate change although there
16 might be increased risk of winter thaws and spring frost (Belanger et al., 2002; Winkler et al., 2002 as
17 cited in Field et al., 2007). In New Jersey, higher summer temperatures are expected to depress the yields
18 of a number of other economically important crops adapted to cooler conditions (e.g., spinach, lettuce) by
19 mid-century, while rising winter temperatures are expected to drive the continued northward expansion of
20 agricultural pests and weeds (such as kudzu) (NECIA, 2007). Cranberries are especially susceptible
21 because of their requirement to be subjected to long periods of cold winter temperatures for development
22 (NECIA, 2007).

23   Extreme Weather Events

24   The negative impacts of increased frequency of extreme weather events on crop yield might
25 temper the beneficial effects of increased CO_2 concentrations with associated temperature increases and
26 longer growing seasons on crop growth (USCCSP, 2008).

27   In the United States, particularly in the north, the average increase in temperature is expected to
28 lead to a longer growing season. However, temperature increases may also lead to increased climate
29 sensitivity in the southeast and the Corn Belt (Carbone et. al, 2003 in USCCSP, 2008). The Great Plains
30 region is not expected to experience increased climate sensitivity (Mearns et al., 2003 in USCCSP, 2008).
31 In terms of species migration as a result of climate change, the United States has experienced an incursion
32 of perennial herbaceous species that limit the soil moisture available for other crops throughout the
33 growing season (USCCSP, 2008). The invasion of these nonnative species could impact how these
34 regions adapt to climate change and could lead to the potential for more frequent wildfires by increasing
35 vegetation density (Fenn et al., 2003; Wisdom et al., 2005 in USCCSP, 2008).

36   Multiyear droughts, which might have been a result of increased temperature conditions in lower-
37 elevation forests in the southwestern region, have had a large impact on forest mortality rates (Breshears
38 et al., 2005 in USCCSP, 2008). The morality rate continued to increase even though growth at the forest
39 tree line had been increasing previously (Swetnam and Betancourt, 1998 in USCCSP, 2008). Forest
40 productivity has decreased from climate change-induced warming in drought-prone regions (McKenzie et
41 al., 2001 as cited in USCCSP, 2008) and in subalpine regions (e.g., Monson et al., 2005; Sacks et al.,
42 2007, as cited in USCCSP, 2008).

1   Livestock

2   The livestock production infrastructure in the United States is likely to be influenced by the
3   climate change-induced distributional and productivity changes to plant species. Livestock production
4   during the summer season may *very likely* be reduced due to higher temperatures, but livestock
5   production during the winter months may increase, again due to the projected increase in temperatures
6   (USCCSP, 2008).

7   The expected elevated CO_2 concentrations may diminish the grass feed quality. An increase in the
8   carbon to nitrogen ratio would decrease the nutritional value of feed. In turn, grazing livestock that feed
9   on lower quality grasses might be affected in terms of decreased weight and health (USCCSP, 2008). The
10   average climate change conditions that are expected to occur in the future may have less effect on
11   livestock productivity and potential livestock loss than the effects of increased climate variability (e.g.,
12   droughts and heat waves) (USCCSP, 2008).

13   Climate models have projected decreases in livestock productivity in the United States simply
14   due to projected temperature increases. In 2050, climate models project an average decrease in swine,
15   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
16   (Frank et. al, 2001, as cited in USCCSP, 2008). Indeed, higher temperatures directly affect animals'
17   ability to maintain homeostasis and consequently livestock must engage in altered metabolic
18   thermoregulatory processes (Mader et. al., 1997; Davis et al., 2003, as cited in USCCSP, 2008). The
19   induced thermal stress on livestock often results in a reduction in physical activity and ultimately
20   diminishes feed intake. Livestock production losses and associated economic losses may be attributed to
21   increasing temperatures that are "beyond the ability of the animal to dissipate [and] result in reduced
22   performance (i.e., production and reproduction), health, and well-being" (Hahn et al., 1992; Mader, 2003,
23   as cited in USCCSP, 2008, p. 131).

24   The increased temperature expected as a result of climate change could allow for easier migration
25   of animal pathogens and diseases, especially in the northward transition from the low to mid-latitudes,
26   which would adversely affect livestock well-being in the United States (White et al., 2003; Anon, 2006;
27   van Wuijckhuise et al., 2006, as cited in USCCSP, 2008).

28   Fisheries

29   Although fisheries in cold freshwater regions are expected to be adversely affected, fisheries in
30   warm freshwater regions could benefit from climate change. The effects of temperature increases have
31   caused northward shifts of fisheries systems and this is expected to continue in the future (USCCSP,
32   2008). According to IPCC, "many warm-water and cool-water species will shift their ranges northward
33   or to higher altitudes" (Clark et al., 2001 and Mohseni et al., 2003, as cited in Field et al., 2007, p. 631).

34   An example of negative impacts that result from large-scale species migration is the recent
35   migration of two protozoan parasites from the Gulf of Mexico northward into the Delaware Bay. This
36   parasitic incursion, possibly as a result of climate change, has led to a significantly increased mortality
37   rate of oysters in the region (Hofmann et al., 2001, USCCSP, 2008).

38   According to IPCC, the survival of brook trout in the United States is directly correlated to its
39   preferred cold groundwater seeps habitat. As temperatures increase, mortality rates also increase for
40   certain species of trout (USCCSP, 2008). The salmonid species are likely also to be negatively affected
41   by rising temperatures as they, too, are cold-water species (Gallagher and Wood, 2003, in Field et al.,
42   2007). It is *likely* that other coldwater marine species may "disappear from all but the deeper lakes; cool-
43   water species will be lost mainly from shallow lakes; and warm-water species will thrive, except in the far

1   south, where temperatures in shallow lakes will exceed survival thresholds" (USCCSP, 2008, p. 134).
2   Stocks of the river-spawning walleye will likely decline due to lower lake levels and climate change
3   impacts in Lake Erie (Jones et al., 2006, as cited in Field et al., 2007). Coastal fisheries are also expected
4   to experience the negative impacts of climate change, including coral reef bleaching, due to increased
5   ocean temperatures (USCCSP, 2008). In Alaska, the spawning and migration behaviors of commercially
6   fished species may be affected and increasing temperatures might cause an increase in the cooling needs
7   for storage and processing of catch (CIER, 2007).

8   Adaptation

9   Motivation to engage in specific adaptation strategies because of the impacts of climate change
10   on the forest, fiber, and food systems of the United States is expected. Adaptive practices in the forestry
11   sector include cultivar selection, replanting tree species that are appropriate for the new climate regime,
12   and utilizing dying timber (USCCSP, 2000). These and other potential strategies should be taken in the
13   context of overall demand, population, and economic growth. Adaptive measures could be especially
14   important to ensure the survival of forest, fisheries, and agriculture systems that are rich in biodiversity
15   and productive value (USCCSP, 2000). It is possible that the current pace of climate change will make it
16   difficult for many tree species to adapt as readily via migration as they have in previous periods of climate
17   changes (Davis, 2001). It has been documented via pollen records that tree migration rates in the past
18   have been roughly 20 to 40 km per century. In order to keep up with the projected climate changes in the
19   future, tree migration rates would require migration patterns of roughly 300 to 500 km per century. Due to
20   the projected pace of climate change, it is possible that "taxa that fail to adapt rapidly enough to tolerate
21   these new and rapidly changing climate regimes will go extinct" (Davis, 2001, p. 678). It is also possible
22   that climate change could result in extinctions of many tree species (Davis, 2001).

23   **4.5.6.2.2 Projected Global Impacts of Climate Change**

24   Although the preceding section highlights anticipated climate change impacts in the United
25   States, there are additional impacts that could affect forest and agriculture systems elsewhere in the world.

26   Crops

27   Globally, the agriculture and forest infrastructure will be affected by climate change. A recent
28   Harvard report on Climate Change Futures states that a "changing climate will alter the hydrological
29   regime, the timing of seasons, the arrival of pollinators and the prevalence, extent, and type of crop
30   diseases and pests" (CCF, 2005, p. 77). Throughout the mid- to high-latitudinal regions, crop-specific
31   productivity increases are projected for global mean temperature increases of 1 to 3 degrees Celsius.
32   Beyond a 3-degrees Celsius increase in global mean temperature, crop productivity is expected to
33   decrease in some regions (IPCC, 2007a). Depending on the crop type, experiments on the effects of
34   increased CO_2 concentrations, namely 550 parts per million as opposed to current levels of roughly 380
35   parts per million, suggest that crop yields may increase by 0 to 20 percent (Parry et al., 2007).

36   In a modest warming climate scenario, adaptive practices such as using various cultivars and
37   altering planting and harvesting times might maintain cereal crop yields and possibly allow for an
38   increase in productivity in the high latitudinal and temperate regions (IPCC, 2007). The adaptive practice
39   in regions with 1 to 2 degrees Celsius increases in temperatures corresponds to an avoidance of a 10 to 15
40   percent reduction in yield for cereal crops (Parry et al., 2007). However, in the lower latitude dry regions,
41   cereal crop productivity is projected to decrease for 1 to 2 degrees Celsius temperature increases, thereby
42   exacerbating hunger issues for the population living in these regions (Parry et al., 2007).

1   According to IPCC the, "projected changes in the frequency and severity of extreme climate
2   events will have more serious consequences for food and forestry production, and food insecurity, than
3   will changes in projected means of temperature and precipitation" (Easterling et al., 2007, p. 275). The
4   low latitudinal regions may experience an increase in the frequency of extreme weather events like floods
5   and droughts, which may adversely affect crop production, especially in the subsistence farming regions
6   (IPCC, 2007a). Extreme weather events, "reduce crop yield and livestock productivity beyond the
7   impacts due to changes in mean variables alone, creating the possibility for surprises" (Parry et al., 2007,
8   p. 38). The reduced adaptive capacity of small-scale farmers such as subsistence and artisanal fisherfolk
9   may result in increased vulnerability to extreme weather events, sea level rise, and the spread of human
10   disease, which may negatively affect agricultural and fish yields (Parry et al., 2007). Current climate
11   change models do not yet include recent findings on precipitation extremes that are expected to impact
12   agricultural production in areas such as southern Asia, northern Europe, and eastern Australia. These
13   areas are expected to experience an impact on agricultural productivity as a result of projected increased
14   precipitation extremes such as floods and droughts (Christensen et al., 2007, in Easterling et al., 2007).
15   Certain crops, such as wheat, are impacted by high precipitation events because wheat is, "susceptible to
16   insects and diseases (especially fungal diseases) under rainy conditions" (Rosenzweig and Hillel, 2005, as
17   cited in CCF, 2005). On the other hand, during droughts, certain fungi, such as *Aspergillus flavus*, are
18   stimulated and will feed on drought-weakened crops (Anderson et. al, 2005 in CCF, 2005).

19   Decreases in crop and forest yields in moderate warming scenarios for the low latitudes will
20   likely result in increased dependence on food imports in these typically the developing countries. As
21   such, agricultural exports to lower latitude countries are likely to increase in the short term (Parry et al.,
22   2007).

23   There may be a marginal increase in the population that is at risk of hunger due to climate
24   change, but this will occur in the context of an overall decrease in the global population at risk of hunger,
25   as a result of anticipated economic development (Parry et al., 2007).

26   <u>Forests</u>

27   Globally, commercially grown forests for use in timber production are expected to increase
28   modestly in the short term, depending on geographic region (IPCC, 2007). Large regional and local
29   differences are anticipated as is a shift in terms of production increase from the lower latitudes to the
30   higher latitudes (Parry et al., 2007). This poleward shift of forests and vegetation is estimated at roughly
31   500 km or more for the boreal zones for climate scenarios with CO_2 concentrations of double the current
32   levels (Kirilenko, 2007). In terms of distributional production, net benefits will accrue to regions
33   experiencing increased forest production, whereas regions with declining activity will likely face net
34   losses (Kirilenko, 2007).

35   Due to increases in CO_2 concentration, there is potential for a carbon fertilization effect on the
36   growth of trees with some experiments showing up to an 80 percent increase in wood production for
37   orange trees (Kirilenko, 2007). There is evidence to support elevated growth for young, immature forests
38   in response to higher CO_2 concentration levels (Parry et al., 2007). However, free-air CO_2 enrichment
39   experiments indicate that mature forests show no appreciable response to elevated CO_2 concentrations.
40   However, young, immature forests show elevated growth in response to higher CO_2 concentrations (Parry
41   et al., 2007). It should be noted that there has been only one feasibility study regarding forest free air CO_2
42   enrichment (FACE) of 100-year-old tree stands in which little to no stem growth was recorded, but that
43   this lack of growth might be explained by the relative difficulty of controlling for constant CO_2 levels
44   (Kirilenko, 2007). Many GCMs have projected increases in forest production in certain geographic
45   regions with notable exceptions. For example, the Terrestrial Ecosystem Model and the Center for
46   International Trade in Forest Products Global Trade Model have simulated a future harvest increase of 2

1   to 11 percent in western North America, a 10 to 12 percent increase in New Zealand, a 10 to 13 percent
2   increase in South America and a harvest decrease in Canada (Kirilenko, 2007).

3   It is important to contrast these possible short term benefits with the negative implications of a
4   warming climate since, "continued warming favors more fungal and insect of forests, and more harsh
5   weather will further weaken tree defenses against pests" (CCF, 2005, p. 68) The ability of forests to
6   continue to function as providers of agriculture and energy as well as sequester carbon will be affected by
7   climate change (CCF, 2005, p. 69). Overall, the "effects of future drought and decreased soil moisture on
8   agriculture and natural vegetation (such as forests) are uncertain and may, at least in part, be temporarily
9   offset by fertilization effects of higher atmospheric concentrations of CO_2" (Triggs et al., 2004 as cited in
10   CIER, 2007, p. 10). These extreme weather events, in concert with increased damage from insect and
11   pathogen outbreaks and wildfires, may result in large scale deforestation as evidenced by recent trends in
12   the Amazon basin (Kirilenko, 2007). Climate-vegetation models have indicated that at CO_2 concentration
13   levels of roughly three times current levels, the Amazon rainforests will eventually be lost due to climate
14   change (Cox et al., 2004, in Kirilenko, 2007).

15   Fisheries

16   The aquaculture and fisheries sector are expected to incur negative development impacts as a
17   result of the regional changes in the distribution and proliferation of various marine species (IPCC,
18   2007a). As the distribution of certain fish species continues to be regionally rearranged, there is the
19   potential for notable extinctions in the fisheries system, especially in freshwater species, in temperature
20   ranges at the margin (Parry et al., 2007). Recent evidence indicates that the Meridional Overturning
21   Circulation, which supplies nutrients to the upper layers of the Pacific and Atlantic Oceans, is slowing
22   and thus adversely affecting regional production of primary food supply for fisheries systems (McPhaden
23   and Zhang, 2002; Curry and Mauritzen, 2005; Gregg et al., 2003; Lehodey et al., 2003, in Easterling et
24   al., 2007). In the North Sea, a shift in the distribution of warm water species such as zooplankton has
25   resulted in a shift of fish species from whiting to sprat (Beaugrand, 2004, in USCCSP, 2008).

26   The largest economic impacts associated with the fisheries sector as a result of climate change are
27   expected to occur in coastal regions of Asia and South America (Allison et al., 2005 as cited in USCCSP,
28   2008). Specifically, species such as tuna and Peruvian anchovy may be the most affected by regional
29   climate change (Barber, 2001; Lehodey et al., 2003 as cited in USCCSP, 2008).

30   Earlier spring ice melts in the Arctic and diminishing sea ice are affecting the distribution and
31   productivity of marine species, particularly the upper-level sea organisms. In turn, fish harvests in the
32   Arctic region are expected to change in the warming future. The freshwater species in the Arctic region
33   are expected to be most affected by the increasing temperatures (Wrona et al., 2005, as cited in Field et
34   al., 2007).

35   **4.5.7   Industries, Settlements, and Society**

36   This section defines these resources and describes the existing conditions and potential
37   vulnerability of each to climate change impacts. In addition, this section briefly describes the potential
38   vulnerability of cultural resources, including archaeological resources and buildings of historic
39   significance to climate change impacts. The primary resource used in this section is the IPCC Fourth
40   Assessment Report (IPCC, 2007a); specifically, Chapter 7 for industry, settlement, and society.

41   The industries, settlements, and society sector encompasses resources and activities that describe
42   how people produce and consume goods and services, deliver and receive public services, and live and
43   relate to each other in society.

1   As defined by IPCC, this sector includes the following:

2   ▪ Industry: manufacturing, transport, energy supply and demand, mining, construction, and
3   related informal production activities (IPCC, 2007a).

4   ▪ Services: trade, retail, and commercial services, tourism, risk financing/insurance (IPCC,
5   2007a).

6   ▪ Utilities/Infrastructure: systems designed to meet relatively general human needs, often
7   through largely or entirely public utility-type institutions (IPCC, 2007a).

8   ▪ Human Settlement: urbanization, urban design, planning, rural settlements (IPCC, 2007b).

9   ▪ Social Issues: demography, migration, employment, livelihood, and culture (IPCC, 2007b).

10   **4.5.7.1 Affected Environment**

11   The industry, settlements, and society sector covers a very broad range of human institutions and
12   systems, including the industrial and services sectors, large and small urban areas and rural communities,
13   transportation systems, energy production, and financial, cultural, and social institutions.

14   A principal objective of human societies is to reduce their sensitivity to weather and climate.
15   Recent experience with storms such as Hurricane Katrina reveals the limits to human control over
16   climate-related impacts on industries, settlements, and society. Systems that are sensitive to climate
17   change include air and water quality, linkage systems (transportation and transmission networks),
18   building structures, resource supplies, social networks, and economic systems (IPCC, 2007a).

19   This sector normally experiences and is generally resilient to variability in environmental
20   conditions. Industries, settlements, and human society, however, can be vulnerable to extreme or
21   persistent changes. Vulnerability increases when changes are unexpected or if resources or other factors
22   inhibit the ability of this sector to respond to changes (IPCC, 2007a).

23   Together, industry and economic services account for more than 95 percent of gross domestic
24   product in highly developed economies and between 50 and 80 percent of gross domestic product in less
25   developed economies (World Bank 2006, cited in IPCC, 2007a). Industrial activities are vulnerable to
26   temperature and precipitation changes. For example, in Canada weather-related road accidents translate
27   into annual losses of at least $1 billion Canadian annually, while more than a quarter of air travel delays
28   in the United States are weather related (Andrey and Mills, 2003, cited in IPCC 2007a). Buildings,
29   linking systems, and other infrastructure are often located in areas vulnerable to extreme weather events
30   (flooding, drought, high winds). Trapp et al. (2007) found a net increase in the number of days in which
31   severe thunderstorm environmental conditions could occur during the late 21st century using global and
32   high-resolution regional climate models. The analysis suggests a future increase in these conditions of
33   100 percent or more in Atlanta, Georgia, and New York, New York. Such extreme events that can
34   threaten linkage infrastructures such as bridges, roads, pipelines or transportation networks may cause
35   industry to experience substantial economic losses (IPCC, 2007a).

36   Institutional infrastructure is generally considered to be less vulnerable to weather and climate
37   variation, as it embodies less fixed investment and is more readily adapted within the time scale of
38   climate change. In some cases, experience with climatic variability can enhance the resilience of
39   institutional infrastructure by triggering adaptive responses (IPCC, 2007 a).

1   Vulnerability to climate change impacts is determined by local geography and social context
2 rather than large scale or aggregate factors (IPCC, 2007a). Risk factors associated with local geography
3 and social context are briefly described below.

4   Geography

5   Extreme weather events are more likely to pose risks to industry, settlements, and society than
6 gradual climate change (IPCC, 2007a). Resources and activities that are located in areas with higher
7 susceptibility to extreme weather events (high temperatures, high winds, and flooding) are more
8 vulnerable to the impacts of climate change. Extreme weather events can damage transportation routes
9 and other infrastructure, damage property, dislocate settlement patterns, and disrupt economic activity.
10 Gradual climate change can change patterns of consumption, decrease or increase the availability of
11 inputs for production, and affect public health needs. Such impacts are experienced locally, but can be
12 linked to impacts on national and global systems (IPCC, 2007a).

13   Archaeological resources and buildings of historic significance are fixed in location and are
14 therefore vulnerable to the effects of extreme weather events and gradual changes associated with local
15 geography. Extreme weather events can expose archaeological resources and damage significant
16 structures. Over time, gradual changes to weather patterns can also erode protective cover around
17 archaeological resources and increase the rate of deterioration of historic buildings. Vulnerability of these
18 resources to climate change impacts is tied to the susceptibility of location and local geography to
19 extreme and gradual changes to weather.

20   Social Context

21   Worldwide, many of the places where people live are under pressure from a combination of
22 growth, social inequity, jurisdictional fragmentation, fiscal shortfalls, and aging infrastructure. These
23 stresses can include scarcity of water, poor sanitation, inadequate governance structures, unmet resource
24 requirements, economic inequities, and political instability. While these types of stresses vary greatly
25 across localities, they can combine with climate change impacts to result in significant additional stress at
26 local, national, and global levels (IPCC, 2007a).

27   The social impacts associated with climate change will be mainly determined by how the changes
28 interact with economic, social, and institutional processes to minimize or magnify the stresses. From an
29 environmental justice perspective, the most vulnerable populations include the poor, the very old and very
30 young, the disabled, and other populations that have limited resources and ability to adapt to changes
31 (IPCC, 2007a).

32   Urbanization

33   It is estimated that one third of the world's urban population (nearly 1 billion people) lives in
34 overcrowded and unserviced slums, and 43 percent of the urban population is in developing countries.
35 More generally, human settlements are often situated in risk-prone regions such as steep slopes, ravines,
36 and coastal areas. These risk-prone settlements are expected to experience an increase in population,
37 urbanized area, and economic activity. The population in the near-coastal zone (i.e., within 330 feet
38 elevation and 60 to 65 miles distance from the coast) has been estimated to be between 600 million and
39 1.2 billion, or 10 to 23 percent of the world's population (Adger et al., 2005; McGranahan et al., 2006
40 cited in IPCC, 2007a). Migration from rural to urban areas is a common response to calamities such as
41 floods and famines (IPCC, 2007a).

1   **4.5.7.2 Consequences**

2   Key climate change impacts on this set of human systems are likely to vary widely and depend on
3   a range of location-specific characteristics and circumstances. Moreover, potential climate change
4   impacts on this sector could be particularly challenging to determine because effects tend to be indirect
5   rather than direct, for example changes in temperature—a direct effect of climate change—affect air
6   pollution concentrations in urban areas thereby affecting human health and health care systems, which are
7   all indirect effects (Wilbanks et al., 2007).

8   The human institutions and systems that comprise the industry, settlements, and society sector
9   tend to be quite resilient to fluctuations in environmental conditions that are within the range of normal
10   occurrence. However, when environmental changes are more extreme or persistent, these systems can
11   exhibit a range of vulnerabilities "especially if the changes are not foreseen and/or if capacities for
12   adaptation are limited" (Wilbanks et al., 2007, p. 359). For this reason industry, settlements, and society
13   in developing countries are expected to be more vulnerable to direct and indirect climate change impacts
14   than they are in industrialized countries (Wilbanks et al., 2007).

15   Climate change is expected to affect industry, settlements, and society via a range of physical
16   effects, including the frequency and intensity of tropical cyclones and storms, extreme rainfall and floods,
17   heat and cold waves, drought, temperature extremes, precipitation, and sea level rise. Following the
18   approach in Wilbanks et al., 2007, the categories of human systems addressed in this section include
19   industry, services, utilities and infrastructure, settlements, and social issues. Each category is described
20   below, and potential climate impacts on each category are discussed. Key systems within these categories
21   that are expected to experience impacts associated with climate change are then discussed in greater detail
22   in subsequent sections.

23   **Industry.** Industry includes manufacturing, transport, energy supply and demand, mining,
24   construction, and related informal production activities (Wilbanks et al., 2007). These activities can be
25   vulnerable to climate change when (a) facilities are located in climate-sensitive areas such as coasts and
26   floodplains, (b) the sector is dependent on climate-sensitive inputs such as food processing, or (c) the
27   sector has long-lived capital assets (Ruth et al., 2004 in Wilbanks et al., 2007). For the energy sector, in
28   addition to possible infrastructure damage or destruction from the effects of climate change (e.g., as could
29   happen due to extreme weather events) effects could also include climate-driven changes in demands for
30   energy. For example, demand for heating could decline in winter months while demand for cooling could
31   rise in summer months (USCCSP, 2008).

32   **Services.** Services include trade, retail and commercial services, tourism, and risk financing or
33   insurance (Wilbanks et al., 2007). Possible climate change impacts on trade include impacts on
34   transportation from extreme weather events like snow and ice storms that could impede the ability to
35   transport goods, or impacts on comparative advantage of a region or country due to temperature shifts that
36   affect production. Climate change impacts on transportation could also affect retail and commercial
37   services. Retail and commercial services could also be affected by climatic conditions that affect prices
38   of raw materials and by potential damage to infrastructure such as facilities existing in climate sensitive
39   areas like coastal regions. Extreme events such as hurricanes can also affect tourism infrastructure.
40   Tourism services could also be affected by climate change impacts through temperature shifts and
41   changes that affect the natural landscape of tourist destinations. Potential indirect effects of climate
42   change on tourism include changes in availability of water and energy prices. With respect to the
43   insurance sector, climate change impacts could lead to increasing risk, which could trigger higher
44   premiums and more conservative coverage. A reduction in availability of or ability to afford insurance
45   could in turn lead to impacts on local and regional economies.

1   **Utilities and Infrastructure.** Utilities and infrastructure includes systems that are "designed to
2   meet relatively general human needs, often through largely or entirely public utility-type institutions"
3   (Wilbanks et al., 2007, p. 370). This includes physical infrastructure such as water, transportation,
4   energy, and communication systems, as well as institutional infrastructure such as shelters, public health
5   care systems, and police, fire, and emergency services. "These infrastructures are vulnerable to climate
6   change in different ways and to different degrees depending on their state of development, their
7   resilience, and their adaptability" (Wilbanks et al., 2007, p. 370). In general, institutional infrastructure
8   tends to be less vulnerable to climate change than physical infrastructure because it typically involves less
9   investment in fixed assets and is more flexible over timeframes that are relevant to climate change. There
10 are numerous points where impacts on different infrastructures interact and the failure of one system can
11 put pressure on others. At the same time, however, "this means that measures to protect one sector can
12 also help to safeguard the others" (Wilbanks et al., 2007, p. 370).

13   **Human Settlement.** Climate change interacts with other stresses in its impact on human
14 settlements (Wilbanks et al., 2007). Potential impacts on human settlements could be experienced
15 through several pathways. Sea level rise threatens populations in coastal areas by accelerating the
16 inundation of coastal wetlands, threatening vital infrastructure and water supplies, augmenting
17 summertime energy demand, and affecting public health (Wilbanks et al., 2007). Changes in precipitation
18 patterns could alter the availability of potable water while changes in temperature could affect air quality
19 and contribute to an increase in incidents of heat stress and respiratory illnesses (Wilbanks et al., 2007).
20 In urban areas, the Urban Heat Island effect (Wilbanks et al., 2007), which relates to the "degree to which
21 built and paved areas are associated with higher temperatures than surrounding rural areas" (USCCSP,
22 2008, p. 159) might affect the manner in which climate change affects these areas.

23   **Social Issues.** Within human settlements, society could also experience a variety of effects
24 associated with climate change. For example, communities could experience increasing stress on
25 management and budget requirements for public services, if demands on public health care and disaster
26 risk reduction grow (USCCSP, 2008). There could be a loss of cultural and traditional groups of people,
27 e.g. "indigenous societies in polar regions" (Wilbanks et al., 2007, p. 373). Societal concerns that might
28 be affected by the impacts of climate change include socioeconomic issues relating to developed versus
29 developing areas and rich versus poor. Because the developing countries and poorer populations tend to
30 have weaker infrastructure in place to begin with, their vulnerability to climate change effects is expected
31 to be higher and their capacity to cope or adapt are expected to be lower than developed countries and
32 wealthier populations (Wilbanks et al., 2007).

33   **4.5.7.2.1 Projected Impacts of Climate Change for the United States**

34   The research literature on climate impacts on United States industry, settlements, and society is
35 relatively sparse. "At the current state of knowledge, vulnerabilities to possible impacts are easier to
36 project than actual impacts because they estimate risks or opportunities associated with possible
37 consequences rather than estimating the consequences themselves" (Gamble et al., 2008, Ch. 3, p. 4). In
38 general, "climate change effects on human settlements in the United States are expected to occur as a
39 result of interaction with other processes" (USCCSP, 2008, p. 159). These effects include those on
40 health, water resources, physical infrastructure (notably transportation systems), energy systems, human
41 settlements, and economic opportunities.

42   Impacts on human health and human health care systems are expected to arise because of
43 temperature-related stress. Increases in cases of respiratory illness associated with high concentrations of
44 ground-level ozone; water-, food-, and vector-borne diseases; and allergies related to higher
45 concentrations of plant species are expected.

1   Effects on water are expected to include reductions in snowpack, river flows, and groundwater
2 levels, saline intrusion in rivers and groundwater, an increase in water demand due to increasing
3 temperatures, and impacts on sanitation, transportation, food and energy, and communication
4 infrastructures from severe weather events.

5   The United States coastline, deltas, and coastal cities such as the Mississippi Delta and
6 surrounding cities, are vulnerable to sea level rise. "Rapid development, including an additional 25
7 million people in the coastal United States over the next 25 years will further reduce the resilience of
8 coastal areas to rising sea levels and increase the economic resources and infrastructure vulnerable to
9 impacts" (Field et al., 2007 in USCCSP, 2008, p. 162).

10   Effects on other key human systems are discussed in greater detail below. Because this section
11 deals with such a broad set of human systems, the potential impacts of climate change and potential
12 adaptations available to key human systems are discussed together. Given the enormous range of human
13 systems that could be affected by climate change, the discussion here is focused on a few key systems
14 where impacts can best be characterized or supported by sufficient information.

15 Impacts on Transportation Infrastructure

16   Climate affects the design, construction, operation, safety, reliability, and maintenance of
17 transportation infrastructure, services, and systems. The potential for climate change raises critical
18 questions about how changes in temperature, precipitation, storm events, sea level rise, and other climate
19 variables could affect the system of roads, airports, rail, public transit, pipelines, ports, waterways, and
20 other elements of the nation's and the world's complex transportation systems.

21   Climate changes anticipated during the next 50 to 100 years include higher temperatures, changes
22 in precipitation patterns, increased storm frequency and intensity, and rising sea levels globally, resulting
23 from the warming of the world's oceans and decline in polar ice sheets. These changes may affect the
24 transportation system in a wide variety of ways. Those of greatest relevance for the United States are
25 summarized below.

26   • **Increases in very hot days and heat waves.** It is *very likely* that heat extremes and heat
27   waves will continue to become more frequent, more intense, and last longer in most regions
28   during the 21st century. This may increase the cost of transportation construction, operations,
29   and maintenance.

30   • **Increases in Arctic temperatures.** Arctic warming is *virtually certain* as temperature
31   increases are expected to be greatest over land and at most high northern latitudes. As much
32   as 90 percent of the upper layer of permafrost could thaw under more pessimistic emission
33   scenarios.

34   • **Rising sea levels.** It is *virtually certain* that sea levels will continue to rise in the 21st century
35   as a result of thermal expansion and loss of mass from ice sheets. This may make much of
36   the existing transportation infrastructure in coastal areas prone to frequent, severe, and/or
37   permanent inundation.

38   • **Increases in intense precipitation events.** It is *very likely* that intense precipitation events
39   will continue to become more frequent in widespread areas of the United States.
40   Transportation networks, safety, and reliability may be disrupted by visibility problems for
41   drivers, and by flooding, which may result in significant damage to the transportation system.

1   ▪   **Increases in hurricane intensity.** Increased tropical storm intensities, with larger peak wind
2   speeds and more intense precipitation are *likely*, which may result in increased travel
3   disruption, impacts on the safety and reliability of transportation services and facilities, and
4   increased costs for construction, maintenance, and repair (Transportation Research Board,
5   2008).

6   Numerous studies have examined ways of mitigating the transportation sector's contribution to
7 global warming from GHG emissions. However, far less attention has been paid to the potential impacts
8 of climate change on United States transportation and on how transportation professionals can best adapt
9 to climate changes that are already occurring, and will continue to occur into the foreseeable future even
10 if drastic mitigation measures were taken today. Since GHGs have long life spans they continue to
11 impact global climate change for decades (Transportation Research Board, 2008).

12   Scientific evidence confirms that climate change is occurring, and that it will trigger new,
13 extreme weather events and could possibly lead to surprises, such as more rapid than expected rises in sea
14 levels or temperature changes. Every mode of transportation will be affected as climate change poses
15 new and often unfamiliar challenges to infrastructure providers (Transportation Research Board, 2008).

16   Consideration of climate change-related factors in transportation planning and investment
17 decisions should lead to a more resilient, reliable, and cost-effective transportation system in the coming
18 decades. When decision makers better understand the risks associated with climate change, they can
19 make better decisions about potential adaptation strategies and the tradeoffs involved in planning,
20 designing, constructing, operating, and maintaining transportation systems (Transportation Research
21 Board, 2008).

22   Projected climate changes have profound implications for transportation in the United States
23 (Transportation Research Board, 2008). Climate change is likely to increase costs for the construction
24 and maintenance of transportation infrastructure, impact safety through reduced visibility during storms
25 and destruction of elements of the transportation system during extreme weather events, disrupt
26 transportation networks with flooding and visibility problems, inundate significant portions of the
27 transportation system in low lying coastal areas, increase the length and frequency of disruptions in
28 transportation service, cause significant damage and incur costly repairs to transportation infrastructure,
29 and impact the overall safety and reliability of the nation's transportation system (Transportation
30 Research Board, 2008).

31   Transportation systems across the United States are projected to experience both positive and
32 negative impacts from climate change over the next century; the degree of impacts will be determined, in
33 part, by the geographic region (Transportation Research Board, 2008). Coastal communities are
34 especially vulnerable to impacts associated with sea level rise, increased frequency or intensity of storms,
35 and damage to the transportation system due to storm surges and flooding. The literature indicates that
36 the intensity of major storms could increase by 10 percent or more, which could result in more frequent
37 Category 3 (or higher) storms in the Gulf Coast and along the Atlantic coast (Transportation Research
38 Board, 2008).Warming temperatures might require changes in the kinds of materials used for construction
39 of transportation facilities, and in the operation and maintenance of transportation facilities and services.
40 Higher temperatures could require the development and use of more heat-tolerant materials
41 (Transportation Research Board, 2008). Restrictions on work rules could increase the time and costs for
42 labor for construction and maintenance of transportation facilities. Rail lines could be affected by higher
43 temperatures and more frequent rail buckling, which would affect service reliability, safety and overall
44 system costs and performance. Costs could increase for ports, maintenance facilities, and transportation
45 terminals if higher temperatures require an increase in refrigeration and cooling (Transportation Research
46 Board, 2008); and higher temperatures could affect aircraft performance and the runway lengths required

1   for safe operation (Transportation Research Board, 2008). On the positive side, higher temperatures
2   might open up northern transportation routes for longer periods of time and allow more direct routing for
3   marine transportation (Transportation Research Board, 2008).

4   　　　Changes in precipitation patterns may increase short-term flooding, resulting in decreased safety,
5   disruptions in transportation services, and costly damage to transportation infrastructure. Hotter climates
6   may exhibit reduced soil moisture and average run-off, which might require changes in the management
7   and maintenance of publicly owned right-of-way. The potential increase in heavy rainfall may exceed the
8   capacity of existing drainage systems, resulting in more frequent flooding and associated disruptions in
9   transportation system reliability and service, increased costs for maintenance of existing facilities, and
10   increased costs for construction of new facilities (Transportation Research Board, 2008).

11   　　　Relative sea level rise may inundate existing transportation infrastructure and significantly
12   increase the cost of provision of new transportation facilities and services. Some portions of the
13   transportation infrastructure in coastal areas, or in areas prone to flooding, may have to be protected with
14   dikes or levees – increasing the cost for construction and maintenance, and the potential for more serious
15   flooding incidents associated with the failure of such dikes and levees (Transportation Research Board,
16   2008).

17   　　　Increased storm frequency and intensity may lead to greater transportation service disruption, and
18   damage to transportation infrastructure in coastal and inland areas. Model results for the study of the Gulf
19   Coast conservatively estimated a 22- to 24-foot potential surge for major hurricanes (Transportation
20   Research Board, 2008). During Hurricane Katrina (a Category 3 storm at landfall) surges exceeded these
21   heights in some locations (Transportation Research Board, 2008). While the specific location and
22   strength of storm surges are difficult to predict due to the variation of the scale and trajectory of
23   individual tropical storms, substantial portions of the coastal infrastructure across the United States are
24   vulnerable to increased damage resulting from the impacts of climate change (Transportation Research
25   Board, 2008).

26   　　　Disruptions in transportation system availability could result in substantial economic impacts
27   associated with increased costs to construct or repair transportation infrastructure, and costs associated
28   with disruptions in transportation for goods and services. Increasing fuel costs and delays in
29   transportation service result in increased transport costs, which are then passed on to consumers. A
30   significant disruption in transportation (e.g. destruction of major transportation facility by hurricane,
31   flood, or other extreme weather event) may affect the regional economy in many different ways.
32   Communities are likely to require long periods of time to recover from these events, and some
33   communities could be permanently affected (Transportation Research Board, 2008).

34   　　　The analysis to date raises clear cause for concern regarding the vulnerability of transportation
35   infrastructure and services in coastal areas, and across the United States. Addressing the risks associated
36   with a changing climate in the planning and design of transportation facilities and services can help public
37   agencies and private investors to minimize disruptions to the smooth and safe provision of transportation
38   services; and can protect the substantial investments made in the nation's transportation infrastructure
39   now and in the future (Transportation Research Board, 2008).

40   　　　According to the USCCSP's *Impacts of Climate Change and Variability on Transportation*
41   *Systems and Infrastructure Report* (Transportation Research Board, 2008), four key factors are critical to
42   understanding how climate change might affect transportation:

1   ▪ **Exposure.** What is the magnitude of stress associated with a climate factor (sea level rise,
2   temperature change, severe storms, and precipitation) and the probability that this stress will
3   affect a transportation segment or facility?

4   ▪ **Vulnerability.** Based on the structural strength and integrity of the infrastructure, what is the
5   potential for damage and disruption in transportation services from this exposure?

6   ▪ **Resilience.** What is the current capacity of a system to absorb disturbances and retain
7   transportation performance?

8   ▪ **Adaptation.** What response(s) can be taken to increase resilience at both the facility (e.g., a
9   specific bridge) and system levels?

10   New approaches to address climate change factors in transportation planning and decision making
11 may include:

12   ▪ **Extending planning timeframes.** In order to address the long timeframe over which climate
13   changes and environmental processes occur, planning timeframes may need to be extended
14   beyond the typical 20- to 30-year planning horizon. The fact that transportation infrastructure
15   can last for many decades (or even more than 100 years) argues for planning for much longer
16   timeframes to examine the potential impacts of climate change and other elements of the
17   natural environment on the location, construction techniques, and costs for transportation
18   infrastructure investments that are expected to last for many decades (Transportation
19   Research Board, 2008).

20   ▪ **Conducting risk assessment analysis for transportation investments.** Transportation
21   investments face many uncertainties, including the potential impacts of climate change on
22   construction, operation, and maintenance. Planners and decision makers can use iterative risk
23   management analysis to evaluate potential risks of all types, and to identify potential ways to
24   minimize the risks and increase the resiliency of transportation infrastructure. Transportation
25   structures and facilities can be hardened, raised, or even relocated if needed. Where it is
26   critical to safety, reliability and mobility, redundant systems may need to be provided for the
27   most critical elements of the transportation system (Transportation Research Board, 2008).

28   ## Impacts on Energy Systems

29   Although the energy sector has been seen as a driver of climate change, the energy sector is also
30 subject to the effects of climate change (Wilbanks et al., 2007). All major energy sources are subject to a
31 variety of climate change effects, including temperature, wind, humidity, precipitation, and extreme
32 weather events (Bhatt et al, 2007). The most direct climate change impacts for fossil fuel and nuclear
33 power plants, for example, are related to power plant cooling and water availability (Bhatt et al., 2007).
34 Each kilowatt of electricity generated by thermoelectric generation requires about 25 gallons of water.
35 Power plants rank only slightly behind irrigation in terms of freshwater withdrawals in the United States
36 (USGS, 2004 cited in Bhatt et al., 2007). In addition, about 10 percent of all United States coal shipments
37 were delivered by barge in 2003, and consequently low river flows can create shortfalls in coal supplies at
38 power plants (Bhatt et al., 2007).

39   USCCSP identified potential effects of climate change on energy production and use in the
40 United States, which are stated in terms of likelihood (Wilbanks et al., 2007). Principal impacts and their
41 likelihood are listed below:

1 • Climate change will reduce total energy demand for space heating; effects will differ by
2 region (*virtually certain*).

3 • Climate change will increase total energy demand for space cooling; effects will differ by
4 region (*virtually certain*).

5 • Net effects on energy use will differ by region. Overall impacts will be affected by patterns
6 of interregional migration – which are likely to be in the direction of net cooling load regions
7 – and investments in new building stock (*virtually certain*).

8 • Temperature increases will increase peak demands for electricity (*very likely*).

9 • Changes in the distribution of water availability will affect power plants; in areas with
10 decreased water availability, competition for water supplies between energy and other sectors
11 will increase (*virtually certain*).

12 • Temperature increases will reduce overall thermoelectric power generation efficiency
13 (*virtually certain*).

14 • In some regions, energy resource production and delivery systems will be vulnerable to the
15 effects of sea level rise and extreme weather events, especially the Gulf Coast and the East
16 Coast (*virtually certain*).

17 • Hydropower production will be directly and significantly affected by climate change,
18 especially in the West and Northwest (*very likely*).

19 • Climate change concerns will affect perceptions and practices related to risk management
20 behavior in investment by energy institutions (*very likely*).

21 • Climate change concerns are almost certain to affect public and private sector energy
22 technology research and development investments and energy resource and technology
23 choices by energy institutions, along with associated emissions (*virtually certain*).

24 USCCSP concluded that there is very little literature on adaptation of the energy sector to effects
25 of climate change, and their following discussion is therefore largely speculative (Wilbanks et al., 2007).
26 Both energy users and providers are accustomed to changing conditions that affect their decisions. The
27 energy sector is among the most resilient of all economic sectors in terms of responding to changes within
28 the range of historical experience (Wilbanks et al., 2007). Adaptations to the effects of climate change on
29 energy use may focus on increased demands and rising costs for space cooling; likely responses include
30 investing in more efficient cooling equipment and building envelopes. Increased demands for both peak
31 and average electricity demands may lead to contingency planning for load-leveling, more efficient and
32 expanded generation capacity, expanded inter-ties, and increased storage capacity (Wilbanks et al., 2007).

33 In terms of energy production and supply, the most likely near-term adaptation is expected to be
34 an increase in perceptions of uncertainty and risk in long-term strategic planning and investment; with
35 investors seeking to reduce risks through such approaches as diversifying supply sources and
36 technologies, and risk-sharing arrangements (Wilbanks et al., 2007).

1   Impacts on Human Settlements

2   The impacts of climate change on human settlements are expected to be significant in a number
3   of ways. "Settlements are important because they are where most of the [United States] population lives,
4   often in concentrations that imply vulnerabilities to location-specific events and processes" (Wilbanks et
5   al., 2007, p. 371). Among the general effects of climate change are increased stress on human settlements
6   due to higher summer temperatures and decreased stress associated with warmer winter weather.
7   Changes in precipitation and water availability, rising sea levels in coastal regions, and greater risks from
8   extreme weather events such as storms, flooding, and droughts are also expected to affect human
9   settlements to various degrees. At the same time, stresses due to cold weather extreme events, such as
10   blizzards and ice storms, are expected to decrease (Wilbanks et al, 2007).

11   Predicting climate change impacts on United States settlements is difficult because climate
12   change is not forecast on a scale that is appropriate for local decision making, and because climate is not
13   the only change that settlements are confronting. A key example is the continuing population shift,
14   particularly among persons who have reached retirement, toward the Sun Belt and coastal areas. This
15   means an ever larger elderly population could be at risk especially from extreme weather events such as
16   tropical storms, as well as some types of vector-borne diseases and heat related illnesses (USCCSP,
17   2008).

18   Anticipated human impacts include the following:

19   ▪   Increased respiratory and cardiovascular problems (Patz and Baldus, 2001 in USCCSP 2007).

20   ▪   Changes in mortality rates caused by temperature extremes (Rozenzweig and Solecki, 2001 in
21   USCCSP 2007).

22   ▪   Increased water demands associated with warming accompanied by changes in precipitation
23   that alters access to water (Gleick et al, 2000; Kirshen, 2002; Ruth et al., 2007 in USCCSP
24   2007).

25   ▪   Damages or disruptions to services associated with urban infrastructure such as sanitation
26   systems, electricity transmission networks, communication systems, and the like could occur
27   as a result of storms, floods, and fires (USCCSP, 2008).

28   ▪   Sea level rise could jeopardize many of the 673 coastal counties and threaten population
29   centers (Neumann et al., 2000; Kirshen et al., 2004 in USCCSP 2007).

30   ▪   Vulnerable populations such as the poor, elderly, those in ill health, the disabled, persons
31   living alone, and individuals with limited rights (e.g., recent migrants) are expected to be at
32   greater risk from climate change (USCCSP, 2008).

33   As a specific example with respect to urban infrastructure, the New York City Department of
34   Environmental Protection assessed potential climate change impacts on the city's drainage and
35   wastewater collection systems, noting that if rainfall becomes more intense, sewer system capacities
36   could be exceeded leading to street and basement flooding (NY City DEP 2008). Additionally, extreme
37   precipitation events may lead to an inundation of the Water Pollution Control Plants' (WPCPs) influent
38   wells. Sea level rise could threaten hydraulic capacity of WPCP outfalls by making peak flow discharges
39   more difficult and also increase the salinity of influent to the WPCP which would upset biological
40   treatment processes and lead to corrosion of equipment (NY City DEP 2008).

1   The vulnerability of human settlements and infrastructure in coastal areas to natural disasters such
2 as hurricanes and tropical storms was demonstrated through the damages incurred by Hurricanes Katrina
3 and Rita in the Southeastern region of the United States After Hurricane Katrina struck, a total of 90,000
4 square miles was declared a Federal disaster area, 80 percent of New Orleans was flooded, more than
5 1,700 lives were lost, 850,791 housing units were damaged, 2,100 oil platforms and over 15,000 miles of
6 pipeline were damaged (Petterson et al. 2006 in CIER 2007).

7   There are various possible adaptation strategies for human settlements. Assuring effective
8 governance, increasing the resilience of physical and linkage infrastructures, changing settlement
9 locations over a period of time, changing settlement form, reducing heat-island effects, reducing
10 emissions and industry effluents, improving waste handling, providing financial mechanisms for
11 increasing resiliency, targeting assistance programs for especially impacted segments of the population,
12 and adopting sustainable community development practices are some of them (Wilbanks et al., 2005 in
13 Wilbanks et al., 2007). Land use choices, specifically the discouragement of housing development in
14 flood prone areas including areas below sea level and in deep flow plains, can help protect human
15 settlements and preserve management flexibility for these areas (Isenberg et al., 2008). The choice of
16 strategies and policies for adaptation depend on their relationships with other social and ecological
17 processes and level of economic development (O'Brien and Leichenko, 2000 in Wilbanks et al., 2007).

18 <u>Impacts on Economic Opportunities and Risks</u>

19   Communities or regions that are dependent on climate-sensitive resources or goods or whose
20 comparative advantage could be affected are expected to be particularly vulnerable to climate change.
21 The insurance sector is an example of an industry that could be highly vulnerable to climate impacts. If
22 increasing trends of adverse weather events continue, claims made to private and public insurers are
23 expected to climb (NAST 2001 in CIER 2007). Overall risk exposure of insurers' has grown
24 considerably, e.g., the National Flood Insurance Program's exposure increased four-fold since 1980 to $1
25 trillion in 2005 and the Federal Crop Insurance Corporation's exposure grew up to $44 billion (U.S. GAO
26 2007 in CIER 2007). To the extent that climate change increases costs for insurers or increases the
27 difficulty in forecasting risks, the insurance sector might "withdraw (or make much more expensive)
28 private insurance coverage from areas vulnerable to climate change impacts" (USCCSP, 2008, p. 159).

29   Trade, retail, and commercial services, and tourism are other economic areas that are expected to
30 be affected by climate change impacts, largely as a result of impacts on the transportation and energy
31 sectors. For example, impacts on transportation will affect distribution and receipt of goods for retail
32 services. This could have a particular effect on the Midwest which is a heavy domestic freight and
33 shipping route area. Approximately "$3.4 billion and 60,000 jobs rely on the movement of goods within
34 the Great Lakes-St. Lawrence shipping route annually" (Easterling and Karl 2001 in CIER 2007, p. 22).
35 A decline in water levels could jeopardize this mode of transporting manufacturing. In fact, "[s]ystem
36 connectivity is predicted to be come 25 percent impaired causing a loss of $850 million annually"
37 (Easterling and Karl 2001 in CIER, 2007, p. 23). Dredging 7.5 to 12.5 million cubic yards, costing $85-
38 142 million, may be the only alternative to salvage this system if water levels decline significantly (Great
39 Lakes Regional Assessment Group 2000 in CIER, 2007).

40   Tourism could be affected by "changes in the landscape of areas of tourist interest" as well as by
41 changes in the availability of resources and energy costs (Wilbanks et al., 2007, p. 368). In the United
42 States, climate change impacts could affect winter recreation and tourism in the Northeast. Warmer
43 winters would "shorten the average ski and snowboard seasons, increase snow making requirements, and
44 drive up operating costs", possibly "prompting further closures and consolidation of ski areas northward
45 toward the Canadian border" (Frumhoff et al., 2007, p. 81).

1   Historical and Cultural Resources

2   A variety of cultural and historical resources are at risk from climate change. According to a
3   recent study by UNESCO "The adverse impacts of climate change will have consequences for humanity
4   as a whole including the products of human creativity...these consequences will be manifest in at least
5   two principal ways: (1) the direct physical effects on the buildings or structures and (2) the effects on
6   social structures and habitats" (Colette et al., 2007, p. 64).

7   Alaska is the region expected to be most affected by climate change largely because of location
8   (warming is more pronounced closer to the poles) and way of life (settlement and economic activities
9   based around Arctic conditions) (Gamble *et al.*, 2008, p. 25). Indigenous communities in Alaska are
10   facing major economic and cultural impacts because they depend for subsistence on various climate-
11   sensitive animals such as polar bears, walruses, seals, and caribou (USCCSP Scientific Assessment, 2008,
12   p. 160). "Changes in species' ranges and availability, access to these species, a perceived reduction in
13   weather predictability, and travel safety in changing ice and weather conditions present serious challenges
14   to human health and food security, and possibly even the survival of some cultures" (ACIA, 2004 in
15   USCCSP Scientific Assessment, 2008, p. 160 as cited in ACIA, 2004).

16   In discussing the impacts of climate change on historic cities and settlements around the world, Colette et
17   al. (2007, pp64-65) list the following potential threats associated with climate change:
18
19   ▪   Increased salt mobilization with resulting damage to surfaces and decoration as a result of
20   increasing rate of heavy rainfall;

21   ▪   Changes in the amplitude of temperature and humidity can cause splitting, cracking, flaking
22   and other damage to exposed surfaces;

23   ▪   Organic building materials such as wood could be subject to increase infestation as a result of
24   migration of pests;

25   ▪   An increase in flooding can directly damage structures and promote growth of damaging
26   micro-organisms such as molds and fungi; and

27   ▪   In arid regions, desertification, salt weathering and erosion could threaten cultural and
28   historic sites.

29   Climate change could also create pressures that result in migration of populations, which in turn could
30   result in the breakdown of communities and the loss of "rituals and cultural memory" (Colette, et al.,
31   2007, p. 65)
32
33   **4.5.7.2.2 Projected Global Impacts of Climate Change**

34   As the discussion above suggests, the three major ways in which industry, settlements, and
35   society are vulnerable to climate change are through impacts on economics, infrastructure, and health.
36   The magnitude of impacts on industry, settlements, and society largely depends on location and the level
37   of development of the area or region. The discussion below highlights anticipated impacts on key human
38   systems at the global level.

1   Global Energy Sector Impacts

2   In terms of energy production and use, the expected global impacts will likely be similar to those
3   discussed above for the United States. When the climate warms, less heating will be needed for
4   industrial, commercial, and residential buildings, with changes varying by region and by season
5   (Wilbanks et al., 2007). Electricity is used in areas around the world for cooling; coal, oil, gas, biomass,
6   and electricity provide energy for heating. Regions with substantial requirements for both cooling and
7   heating could see net increases in electricity demands while demands for other energy sources decline
8   (Hadley et al., 2006, in Wilbanks et al., 2007).

9   According to one study, by 2100 the benefits (reduced heating) will be about 0.75 percent of
10   gross domestic product, and impacts (increased cooling) will be approximately 0.45 percent (Tol, 2002a,
11   2002b, in Wilbanks et al., 2007). These percentages could be affected by migration from heating-
12   intensive regions to cooling-intensive regions (Wilbanks et al., 2007).

13   Climate change could also affect global energy production and distribution if extreme weather
14   events become more frequent or intense; and in regions dependent upon water supplies for hydropower or
15   thermoelectric generation if there are significant changes in rainfall/snowfall locations and seasonality.
16   Reduced stream flows are expected to jeopardize hydropower production in some areas, but higher
17   precipitation rates resulting in greater or more sustained stream flows may be beneficial (Casola et al.,
18   2005; Voisin et al., 2006 cited in Wilbanks et al., 2007). More frequent or intense extreme weather
19   events could threaten coastal energy infrastructures including electricity transmission and distribution
20   facilities (Bull et al., 2007).

21   Warming temperatures resulting in melting of permafrost threaten petroleum production facilities
22   and pipelines, electrical transmission towers, and nuclear power plants in the Arctic region (Nelson et al.,
23   2001 cited in Wilbanks et al., 2007). As with Alaska's North Slope facilities, structural failures in
24   transportation and industrial infrastructure are becoming more common in northern Russia due to melting
25   permafrost (Wilbanks et al., 2007).

26   Global Transportation Sector Impacts

27   The IPCC concludes, with *very high confidence*, that data since 1970 have demonstrated
28   anthropogenic temperature rises have visibly altered ecosystems (Parry et al., 2007). Other stressors on
29   the built environment and the ability of cities and countries to adapt to a changing climate make it
30   difficult to discern the exact impacts of climate change on transportation systems around the world.
31   Additional factors, such as projected population growth, are expected to exacerbate the effects of climate
32   change. Development typically occurs in the coastal regions, especially in the newly developing third
33   world countries. These areas are particularly vulnerable to the impacts of projected increases in extreme
34   weather events such as hurricanes, cyclones, unusually heavy precipitation, and flooding. In addition
35   these developing countries are less able to adapt to expected changes due to their limited resources and
36   other pressing needs (Wilbanks, et al., 2007).

37   Transportation system vulnerabilities in more developed countries often focus on physical assets
38   and infrastructures and their economic value and replacement costs, along with linkages to global
39   markets. Vulnerabilities in less developed countries often focus on human populations and institutions
40   that are likely to have very different transportation needs and resources (Wilbanks, et al., 2007). A
41   warmer, dryer climate could exacerbate many of the problems of developing countries, including drought
42   and decreases in food production in areas of Africa and Asia (Wilbanks, et al., 2007).

1   At a national scale, industrialized countries such as the United Kingdom and Norway can cope
2   with most kinds of gradual climate change, but localized differences can show considerable variability in
3   stresses and capacities to adapt (Environment Canada, 1997; Kates and Wilbanks, 2003; London Climate
4   Change Partnership, 2004; O'Brien et al., 2004; Kirshen et al., 2006).

5   The impacts on the United States transportation systems described above apply in other countries
6   as well. Based on information developed by the Transportation Research Board, 2008, the potential
7   impacts of climate change on transportation fall into the two major categories described below.

8   ▪ Climate change will affect transportation primarily through increases in several types of
9   weather and climate extremes, such as very hot days, intense precipitation events, intense
10   hurricanes, drought, and rising sea levels, coupled with storm surges and land subsidence.
11   The impacts will vary by mode of transportation and region, but they will be widespread and
12   costly in both human and economic terms and will require significant changes in the
13   planning, design, construction, operation, and maintenance of transportation systems.

14   ▪ Potentially, the greatest impact of climate change on global transportation systems will be
15   flooding of coastal roads, railways, transit systems, and runways because of rising sea levels
16   coupled with storm surges, and exacerbated in some locations by land subsidence (USCCSP,
17   2008).

18   Given the global nature of the impacts of climate change and the world economy, coordination
19   within and among nations will become increasingly important (Wilbanks, et al., 2007). Strong and
20   complex global linkages and interactions occur throughout the world today and are likely to increase in
21   the future. Climate change effects cascade through interlinked systems for international trade, migration,
22   and communication patterns producing a variety of direct and indirect effects. Some of these impacts
23   may be anticipated. However, many might not, especially if the globalized economy becomes less
24   resilient and more interdependent (Wilbanks, et al., 2007).

25   The impacts of an extreme weather event in one location (e.g., Hurricane Katrina in Louisiana)
26   causes ripple effects throughout the transportation system in the United States and in areas around the
27   world linked to the United States through the ports in the affected area (Transportation Research Board,
28   2008).

29   There are now incidences in Europe, North America, and Japan, of new transportation
30   infrastructure being designed and constructed with potential climate change in mind. For example,
31   bridges and other infrastructure designed at higher elevations in anticipation of sea level rise over the life
32   span of these transportation system elements (Wilbanks, et al., 2007).

33   Global Human Settlements Impacts

34   Human settlements are vulnerable to the effects of climate change in three major ways: (1)
35   through economic sectors affected by changes in input resource productivity or market demands for goods
36   and services; (2) through impacts on certain physical infrastructure; and (3) through impacts of weather
37   and extreme events on the health of populations. The degree of vulnerability tends to be a function of the
38   location (coastal and riverine areas are most at risk), economy (economies most dependent on weather-
39   related sectors are at the highest risk), and size (larger settlements are at a greater aggregate risk, but they
40   likely have greater resources to prevent the impacts of climate change and respond to events that result
41   from climate changes such as hurricanes, floods, or other extreme weather events) (IPCC, 2007a).

1   Shifts in precipitation patterns might affect already stressed environments. For example, mean
2   precipitation in all four seasons of the year has tended to decrease in all main arid and semi-arid regions
3   of the world, e.g., northern Chile and northeast Brazil, West Africa, and Ethiopia, drier parts of southern
4   Africa, and western China (Folland et al., 2001 in Wilbanks et al., 2007). Increasing temperature could
5   aggravate ozone pollution in many cities which may affect quickly growing urban areas that, especially
6   those in developing countries, are experiencing more air pollution problems (Wilbanks et al., 2007).
7   Extreme weather events affect settlements and society in developing countries just as they do developed
8   countries, through damage and destruction of infrastructure and loss of human life, although perhaps in
9   slightly different ways. For example, in some urban areas of developing countries, informal settlements
10 develop. These informal settlements are especially vulnerable as they tend to be built on hazardous sites
11 and susceptible to floods, landslides, and other climate-related disasters (Cross, 2001, UN-Habitat, 2003
12 in Wilbanks et al., 2007). Another example is how "[i]n developing countries, a common cause of death
13 associated with extreme weather events in urban areas is electrocution by fallen power cables" (Few et al.,
14 2004 in Wilbanks et al., 2007, p.371).

15   <u>Global Impacts on Economic Opportunities and Risks</u>

16   Impacts vary by region and locality and cannot be generalized for all nations. Although impacts
17 are expected to vary, a factor that developed countries have in common is that their access to material and
18 financial resources provides them opportunities to adapt to the effects of a changing climate. By contrast,
19 developing countries are expected to be less able to adapt to climate change because they lack both the
20 physical and financial resources needed to bolster their resilience to the same extent that is possible in
21 industrialized countries.

22   In developing countries "industry includes a greater proportion of enterprises that are small-scale,
23 traditional, and informally organized…Impacts of climate change on these businesses are likely to depend
24 on… location in vulnerable areas, dependence on inputs sensitive to climate, and access to resources to
25 support adaptive actions" (Wilbanks et al., 2007, p. 366). One specific industry that may become more
26 vulnerable to direct and indirect impacts of climate change is the tourism industry. Impacts on this
27 industry can be "especially significant for smaller, tourist-oriented countries often in the developing
28 world" (Wilbanks et al., 2007, p. 369). It seems "likely that tourism based on natural environments will
29 see the most substantial changes due to climate change… Tropical island nations and low-lying coastal
30 areas may be especially vulnerable as they may be affected by sea level rise, changes in storm tracks and
31 intensities, changes in perceived climate-related risks, and changes in transport costs…" (Wilbanks et al.,
32 2007, p. 380). The implications are most notable for areas in which tourism is a relatively large share of
33 the local or regional economy, and those for which adaptation would represent a relatively significant
34 need and a relatively significant cost (Wilbanks et al., 2007). Trade is another industry that may be
35 affected by extreme weather events that temporarily close ports or transport routes and damage
36 infrastructure critical to trade, both domestic and international. There could be "linkages between climate
37 change scenarios and international trade scenarios, such as a number of regional and sub-regional free
38 trade agreements" (Wilbanks et al., 2007, p. 368). However, research on this topic is lacking.

39   **4.5.7.2.3 Adaptation**

40   People and societies have adapted to changing conditions in every phase of human history, and
41 human societies have generally been highly adaptable (Ausubel and Landford, 1977). Adaptation can be
42 anticipatory or reactive, self-induced and decentralized, or dependent on centrally initiated policy changes
43 and social collaboration. Adaptation measures can be gradual, occurring over long periods of time; or
44 evolutionary based on reactions to abrupt changes in settlement patterns or economic activity, or in
45 response to extreme weather events (Wilbanks et al., 2007).

1   Adaptation strategies vary widely depending on the exposure of a place or sector to dimensions of
2   climate change, its sensitivity to such changes, and its capacities to cope with the changes. Some of the
3   strategies are multisectoral, such as improving climate and weather forecasting at local and regional
4   levels, emergency preparedness, and public education (Wilbanks et al., 2007). These strategies are likely
5   to be more prominent in more fully developed countries, but are important tools to facilitate adaptation in
6   all countries. Awareness, capabilities, and access to resources that facilitate adaptation to climate change
7   are likely to be much less widely available in less developed countries, where industrial production and
8   residential population often locate in areas vulnerable to flooding, coastal erosion, and extreme weather
9   events (Wilbanks et al., 2007).

10   New warning systems and evacuation procedures are important adaptation strategies. New
11   warning systems in areas prone to extreme weather events such as hurricanes, cyclones, tornados, and
12   flooding can help to prevent weather-related deaths; and minimize damage to community infrastructure,
13   including the transportation system. Adaptation strategies tend to be context-specific, within larger global
14   markets and policy structures, although it generally takes place within the larger context of globalization
15   (Benson and Clay, 2003; Sperling and Szekely, 2005).

16   "Adaptation strategies vary widely depending on the exposure of a place or sector to dimensions
17   of climate change, its sensitivity to such changes, and its capacities to cope with the changes" (Wilbanks
18   et al., 2007, p. 378). In general, uncertainty about the distribution and timing of climate-change impacts
19   at the local level makes judgments about the scale and timing of adaptation actions very difficult
20   (Wilbanks et al., 2007, p. 378).

21 **4.5.8   Human Health**

22 **4.5.8.1 Affected Environment**

23   Climate change has contributed to human mortality and morbidity (*very high* confidence; IPCC,
24   2007) with further projected increases. Climate change may increase the risk of flooding; increase
25   incidence of heat waves; change the severity, duration, and location of extreme weather; increase surface
26   temperature; and alter precipitation intensity and frequency. These events can affect human health either
27   directly through temperature and weather or indirectly though changes in water, air, food quality, vector
28   ecology, ecosystems, agriculture, industry, and settlements. Climate change can also affect health
29   through social and economic disruption. Malnutrition, death, and disease brought on by climate-change
30   are projected to affect millions of people. (IPCC, 2007)

31 **4.5.8.2 Consequences**

32   **4.5.8.2.1 Heat Waves**

33   A heat wave is a period of abnormally high temperatures that may be accompanied by unusual
34   humidity. This weather phenomenon is not formally specified by a time period or temperature reading.
35   Conventionally, a heat wave lasts several days to several weeks, though a one-day event can qualify as a
36   heat wave. The temperature to qualify as a heat wave is dependent upon what is considered unusually hot
37   for that region, as increases in mortality can occur below temperatures considered extremely hot (Ebi et
38   al., 2008). IPCC has found the number of hot days, hot nights, and heat-waves to have increased (IPCC,
39   2007). Global warming has increased intensity of heat waves (Houghton et al., 2001 in Epstein et al.,
40   2006), due in part to the disproportionate warming at night (Easterling et al., 1997, in Epstein et al.,
41   2006). Heat-wave events can trigger poor air quality and forest fires, leading to further increases in
42   human mortality and morbidity (Bates et al., 2005; Goodman et al., 2004; Keatinge and Donaldson 2001;
43   O'Neill et al., 2005; Ren et al., 2006 as cited in Ebi et al., 2008).

1   The impact of a heat wave on the affected population depends on the current health and economic
2   status. In South Asia, those most sensitive to heat waves include the rural population, elderly, outdoor
3   workers, very young, city-dwellers, those with less education, socially isolated, medicated people,
4   mentally ill, and those without available air conditioning (Chaudhury et al, 2000 in IPCC, 2007; Diaz et
5   al., 2002; Klinenberg, 2002; McGeehin and Mirabelli, 2001; Semenza et al., 1996; Whitman et al., 1997;
6   Basu et al., 2005; Gouveia et al., 2003; Greenberg et al., 1983; O'Neill et al., 2003; Schwartz, 2005; Jones
7   et al., 1982; Kovats et al., 2004; Schwartz et al, 2004; Semenza et al., 1999; Watkins et al., 2001, as cited
8   in Ebi, 2008). People in developed areas can be impacted significantly by heat waves as well. Existing
9   electricity grids in the United States would be severely stressed by a major heat wave, leading to
10   brownouts and blackouts further contributing to increased heat-related illnesses (Epstein et al., 2006).

11   The urban heat island effect may increase temperatures experienced in cities by 2 to 10°
12   Fahrenheit compared to neighboring rural and suburban areas (EPA, 2005, in Ebi et al., 2008). This
13   increase in temperature occurs, in part, as the city pavement and buildings absorb a greater amount of
14   incoming solar radiation compared to vegetation and trees; in addition, heat is also emitted from buildings
15   and transportation (EPA, 2005; Pinho and Orgaz, 2000; Vose et al., 2004; Xu and Chen, 2004 in Ebi et
16   al., 2008). However, it has been demonstrated that during a heat wave, not all urban areas experience
17   greater heat-related mortality than the surrounding rural and suburban areas (Sheridan and Dolney, 2003
18   in Ebi et al., 2008).

19   **4.5.8.2.2 Cold Waves**

20   Human mortality and morbidity can also be caused by cold waves. Cold waves affect human
21   health through death, hypothermia, frostbite, damage to organs such as kidney, pancreas, and liver, with
22   greatest risk to infants and the elderly (NOAA, 2001). Cold waves can cause further complications of
23   heavy snow, ice, coastal flooding, and stranded motorists. As with a heat wave, the classification of a
24   cold wave varies by region, with no formal definition for the minimum temperature reached, the rate of
25   temperature fall, or the duration of the event. Populations in temperate countries tend to be more
26   sensitive to cold weather (Honda et al., 1998 in IPCC, 2007). The human health reaction of a population
27   to a cold wave can vary depending on the income, (Healy, 2003 in Ebi et al., 2008), age, topography,
28   climate, (Curriero et al., 2002; Hajat, 2006 in IPCC, 2007), race, (Fallico et al., 2005 as cited in Ebi et al.,
29   2008), sex, (Wilkinson et al., 2004 as cited in Ebi et al., 2008), health, (Wilkinson et al., 2004 as cited in
30   Ebi et al., 2008), dress, (Donaldson et al., 2001 as cited in Ebi et al., 2008), and fuel access (Healy, 2003
31   in Ebi et al., 2008). Cold days, cold nights, and frost days have become less common (IPCC, 2007) with
32   the winter season projected to continue to decrease in duration and intensity (Alley et al., 2007, in Ebi et
33   al., 2008). This may lead to a decrease in cold-related health impacts, notwithstanding external factors,
34   such as influenza outbreaks (Ebi et al., 2008).

35   **4.5.8.2.3 Extreme Weather Events**

36   Climate change is anticipated to affect the number, severity, and duration of extreme weather
37   events (Fowler and Hennessey, 1995 in Sussman et al., 2008). Extreme weather events include floods,
38   tropical and extra-tropical cyclones, tornadoes, windstorms, and drought. Extreme weather can further
39   trigger additional extreme events such as wildfires, negatively affecting infrastructure including
40   sanitation, human mortality and morbidity, and mental health (IPCC, 2007). The loss of shelter, large-
41   scale population displacement, damage to community sanitation and health care, and reduction in food
42   availability can extend the level of mortality and morbidity beyond the actual event (Curriero et al., 2001
43   in Sussman et al., 2008). Factors that influence population vulnerability to extreme weather include
44   location, population density, land use, age, income, education, health, health care response, and disaster
45   preparedness (Blaikie et al., 1994; Menne, 2000; Olmos, 2001; Adger et al., 2005; Few and Matthies,
46   2006; in IPCC, 2007).

315

1	Adverse weather conditions create safety hazards and delays in the Nation's transportation
2	systems, especially on the nation's highways. The Federal Highway Administration (FHWA) estimates
3	that about 25 percent of highway crashes occur during adverse weather resulting in about 17 percent of
4	highway fatalities (AMS, 2004), while the Federal Motor Carrier Safety Administration (FMCSA) found
5	that the factor "environmental conditions" was the critical reason[18] for 3 percent of large truck crashes
6	(FMCSA, 2007). Extreme weather events that increase adverse weather conditions on the nation's
7	highways could potentially affect highway safety.
8	Floods occur with the greatest frequency compared to other extreme weather events (EM-DAT,
9	2006 in IPCC, 2007). The intensity of a flood is dependent on rainfall, surface runoff, evaporation, wind,
10	sea level, and local topography (IPCC, 2007). Health impacts related to flood events include deaths and
11	injuries sustained during a flood event; increased transmission and prevalence of infectious diseases; and
12	toxic contamination of supplies and food (Greenough et al., 2001; Ahren et al., 2005 in IPCC, 2007, and
13	Hajat et al., 2003, Kalashnikov et al., 2003, Tuffs and Bosch, 2002, in Epstein et al., 2006).
14	Drought is an abnormal period of dry weather that has led to significant decrease in water
15	availability for a given location (Huschke, 1959). The health impacts associated with a drought include
16	mortality, malnutrition, infectious diseases, and respiratory diseases (Menne and Bertollini, 2000 in IPCC,
17	2007). Aggravating this situation, malnutrition increases the susceptibility of contracting an infectious
18	disease (IPCC, 2007) and drought-related population displacement can reduce access to adequate and safe
19	water, food, and shelter, leading to increased malnutrition and infectious diseases. Further health impacts
20	can spiral, such as a change in the transmission of mosquito-borne diseases during and after the drought
21	event (IPCC, 2007). Impacts on the agricultural productivity affect health through risk of under- and
22	malnutrition (Epstein et al., 2006), and increased dust storm activity and frequency of forest fires.
23	Drought conditions weaken trees' defenses against pests and can result in increased threats to human
24	health from forest fires (Mattson and Hack, 1987, Boyer 1995, Holsten et al., 2000, in Epstein et al.,
25	2006).

4.5.8.2.4 Air Quality

27	Climate change can affect air quality through altering local weather patterns and/or pollution
28	concentrations. Ground-level ozone, particulate matter, and airborne allergens contribute to poor air
29	quality, leading to respiratory ailments and premature mortality. Increasing exposure to these pollutants
30	would have significant negative health impacts (IPCC, 2007).
31	Ground-level ozone contributes to urban smog, and occurs both naturally and as a secondary
32	pollutant formed through photochemical reactions of nitrogen oxides and volatile organic compounds.[19]
33	These reactions are accelerated with increasing sunlight and temperatures; thus ozone concentrations tend
34	to peak during late afternoon and early evening in the warmer season; however, some locations
35	demonstrate no such seasonality in ozone concentration (Bates, 2005 as cited in IPCC, 2007). The
36	concentration of ground-level ozone for a particular location varies as a function of temperature, wind,

---

[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.

1   solar radiation, atmospheric moisture, atmospheric mixing, and cloud cover. Studies have found
2   increasing levels of ground-level ozone in most regions (Wu and Chan, 2001; Chen et al., 2004 as cited in
3   IPCC, 2007). A recent study found increases in CO_2 concentrations lead to increases in water vapor and
4   temperatures. These lead to higher ozone concentrations in polluted areas, resulting in an increase in
5   ozone-related deaths by 40 percent (Jacobson, 2008). Climate change is anticipated to increase ozone-
6   related diseases (Sussman et al., 2008).

7   Ozone exposure is associated with respiratory ailments such as pneumonia, chronic obstructive
8   pulmonary disease, asthma, allergic rhinitis, chest pain, shortness of breath, and premature mortality
9   (Mudway and Kelly, 2000; Gryparis et al., 2004; Bell et al., 2005, 2006; Ito et al., 2005; Levy et al., 2005
10   in IPCC, 2007; American Lung Association, 2008). Asthmatics are considered a sensitive population
11   (Ebi et al., 2008). Long-term exposure to elevated amounts of ozone has been shown to affect lung
12   efficiency (Ebi et al, 2008; American Lung Association, 2008).

13   Particulate matter comprises solid and liquid particles suspended in the atmosphere varying in
14   both chemical composition and origin. Concentrations of particulate matter are affected by emission rates
15   and local weather conditions such as atmospheric stability, wind, and topography. Some particulates
16   display seasonal variability directly linked to seasonal weather patterns (Alvarez et al., 2000; Kassomenos
17   et al., 2001; Hazenkamp-von Arx et al., 2003; Nagendra and Khare, 2003; Eiguren-Fernandez et al., 2004
18   in IPCC, 2007). In Mexico City and Los Angeles, local weather conditions can create a stagnant air mass,
19   restricting dispersion of pollution. Seasonal weather patterns can further enhance the chemical reactions
20   of emissions, thereby increasing secondary particulate matter (Rappengluck et al., 2000; Kossmann and
21   Sturman, 2004 in IPCC, 2007).

22   Breathing particulate matter can cause respiratory ailments, heart attack, and arrhythmias
23   (Dockery et al., 1993; Samet et al., 2000; Pope et al., 1995, 2002, 2004; Pope and Dockery, 2006;
24   Dominici et al., 2006; Laden et al., 2006 in Ebi et al., 2008). Those populations at greatest risk may
25   include those with heart and lung disease, diabetes, children, the elderly, (Ebi et al., 2008) and high blood
26   pressure (Kunzli et al., 2005 in Ebi et al., 2008). Chronic exposure to PM may decrease lifespan by one
27   to three years (Pope, 2000 in American Lung Association, 2008). Increasing PM concentrations will have
28   a significant adverse impact on human health (IPCC, 2007).

29   Forest fires contribute to poor air quality conditions. During the 5th largest United States wildfire
30   in 1999, medical visits at the Hoopa Valley National Indian Reservation increased by 52 percent with
31   symptoms affecting lower respiratory tract and preexisting cardiopulmonary conditions (Mott et al.,
32   2002). Human health ailments associated with forest fires include burns, smoke inhalation, mortality, eye
33   illnesses, and respiratory illnesses (IPCC, 2007; Ebi et al., 2008). Certain regions are anticipated to
34   experience an increase in frequency and intensity of fire events with projected changes in temperature and
35   precipitation. Pollution from forest fires along with other pollutants, such as carbon monoxide, ozone,
36   desert dust, mould spores and pesticides, can be transported thousands of kilometers on time scales of 4 to
37   6 days affecting populations far from the sources (Gangoiti et al., 2001; Stohl et al., 2001; Buchanan et
38   al., 2002; Chan et al., 2002; Martin et al., 2002; Ryall et al., 2002; Ansmann et al., 2003; He et al., 2003;
39   Helmis et al., 2003; Moore et al., 2003; Shinn et al., 2003; Unsworth et al., 2003; Kato et al., 2004; Liang
40   et al., 2004; Tu et al., 2004 in IPCC, 2007).

41   **4.5.8.2.5 Water-borne and Food-borne Diseases**

42   Significant morbidity and childhood mortality has been linked to water- and food-borne diseases.
43   Climate change is projected to alter temperature and the hydrologic cycle through changes in
44   precipitation, evaporation, transpiration, and water storage. These changes, in turn, potentially affect
45   water-borne and food-borne diseases, such as salmonellosis, campylobacter, leptospirosis, and pathogenic

1   species of vibrio. They also have a direct impact on surface water availability and water quality. It has
2   been estimated that over 1 billion people in 2002 did not have access to adequate clean water (McMichael
3   et al., 2003 in Epstein et al., 2006). Increased temperatures, greater evaporation, and heavy rain events
4   have been associated with adverse impacts on drinking water through increased waterborne diseases, algal
5   blooms, and toxins (Chorus and Bartram, 1999; Levin et al., 2002: Johnson and Murphy, 2004 in Epstein,
6   2006). In the United States, 68 percent of all waterborne diseases between 1948 and 1994 happened after
7   heavy rainfall events (Curriero et al., 2001 in Epstein et al., 2006). Climate change could further impact a
8   pathogen by directly affecting its life cycle (Ebi et al., 2008). The global increase in the frequency,
9   intensity, and duration of red tides may be linked to local impacts already associated with climate change
10   (Harvell et al., 1999 in Epstein et al., 2006); toxins associated with red tide directly affect the nervous
11   system (Epstein et al., 2006).

12   Many people do not report or seek medical attention for their ailments of water-borne or food-
13   borne diseases; hence, the number of actual cases with these diseases is greater than clinical records
14   demonstrate (Mead et al, 1999 in Ebi et al., 2008). Many of the gastrointestinal diseases associated with
15   water-borne and food-borne diseases can be self-limiting; however, vulnerable populations include young
16   children, those with a compromised immune system, and the elderly.

17   **4.5.8.2.6 Vector-borne Diseases**

18   Infections can be spread by the bite of an infected arthropod (termed vector-borne), such as
19   mosquitoes, ticks, sandflies, and blackflies, or through non-human vertebrates such as rodents, canids,
20   and other mammals. Such diseases include typhus, malaria, yellow fever, dengue fever, West Nile virus,
21   Western Equine encephalitis, Eastern Equine encephalitis, Bluetongue virus, and lyme disease. Increased
22   insect density has been correlated with milder seasonal variability (IPCC, 2007) and tick distributions
23   tend to expand with higher minimum temperatures (Ebi et al., 2008). In general, climate and weather are
24   important constraints on the range of transmission for vector-borne diseases. For example, temperature
25   and flooding are key constraints on the range of mosquitoes, which serve as a primary vector for malaria
26   and other diseases (Epstein et al., 2006). Changes in seasonal duration and increases in weather
27   variability reduce/eliminate these constraints (Epstein et al., 2006). In southern Mozambique a the
28   number of malaria cases increased four to five times over long-term averages in the days and weeks
29   following a severe flooding event in 2000 (Epstein et al., 2006). Temperature and the availability of
30   water can both play key roles in regulating population size as well. For the deer tick, the disease vector
31   for Lyme disease, off-host survival is strongly affected by these two variables, and thus climate is the
32   primary factor determining size and distribution of deer tick populations (Needham and Teel, 1991;
33   Bertrand and Wilson, 1996, in Epstein et al., 2006). Changes in land use practice or to the habitat and
34   behavior of wildlife hosts of the insect can also impact latitudinal or altitudinal shifts in the disease
35   carrying species (IPCC, 2007).

36   **4.5.8.3 Projected Health Impacts of Climate Change on the United States**

37   Human health is projected to be adversely affected by rising temperatures, increasing ground-
38   level ozone concentrations, changes in extreme weather events, and increasing food and water-borne
39   pathogens. The impact of the varying health-related event is dependent on location. The United States is
40   anticipated to sustain fewer cases of illness and death associated with climate change compared with the
41   developing world (Gamble et al., 2008). The current health infrastructure along with the United States
42   government's disaster planning and emergency response systems are key assets to enable the United
43   States to meet changing health effect demands associated with climate change. These health impacts will
44   vary in scope across the United States

1   In the United States, there have been 20,000 heat and solar-related deaths from 1936 to 1975,
2   with the heat wave of 1980 accounting for over 1,250 deaths (NOAA, 2005). A rise in heat-related
3   morbidity and mortality may occur in the coming decades (Gamble et al., 2008) due, in part, to an aging
4   population. By 2010, 13 percent of the United States population is projected to be over the age of 65, and
5   20 percent by 2030 (Day, 1996 in Ebi et al., 2008). Studies have shown a decline in heat-related
6   mortality over the past decades, possibly due to increased air conditioning usage and improved health care
7   (Davis et al., 2002; Davis et al., 2003a; Davis et al., 2003b; Carson et al., 2006 in Ebi et al., 2008). Heat
8   waves are anticipated to increase in severity, frequency and duration, particularly in the Midwest and
9   Northeast sections of the country (Gambel et al., 2008; Frumkin, 2008).

10   The northern latitudes of the United States are likely to experience the greatest increases in
11   average temperature and concentrations of many of the airborne pollutants (Gamble et al., 2008). In
12   particular, urban centers in the West, Southwest, Mid-Atlantic and Northeast regions are projected to
13   incur the largest increases in average temperatures (Frumkin, 2008). A regional climate simulation
14   projected air quality to worsen in Texas but to improve in the Midwest in 2045 to 2055 compared with
15   1995 to 2005 (Leung and Gustafson, 2005 in Ebi et al., 2008). In urban areas, ground-level ozone
16   concentrations are anticipated to increase in response to higher temperatures and increases in water vapor
17   concentration (Gamble, 2008; Jacobson, 2008). Climate change may further cause stagnant air masses
18   that increase pollution concentrations of ground-level ozone and PM in populated areas. For example,
19   one study projected an increase in the upper Midwest stagnant air between 2000 and 2052 (Mickley et al.,
20   2004 in Ebi et al., 2008). Further, Frumkin (2008) found that climate change is likely to alter the air
21   pollution contribution from natural sources and increase the creation of secondary pollutants; however, an
22   alternative study found an increase in evaporative losses from nitrate particles reduces PM levels (Aw and
23   Kleeman, 2003 in Ebi et al., 2008). A recent study concluded that continuous local outdoor CO_2
24   emissions can increase the respective CO_2 concentration for that area, thereby increasing ozone levels
25   (Jacobson, 2008).

26   The spring pollen season has been shown to begin earlier than usual in the Northern Hemisphere
27   (D'Amato et al., 2002; Weber, 2002; Beggs, 2004 in IPCC, 2007). There is further evidence suggesting a
28   lengthening of the pollen season for some plant species (IPCC, 2007). A recent study determined that the
29   density of air-borne pollen for some species has increased, however, it is not understood what the
30   allergenic content of this additional pollen is (Huynen and Menne, 2003; Beggs and Bambrick, 2005 in
31   IPCC, 2007). Additionally, climate change could alter the pollen concentration of a given plant species as
32   the species reacts to increased concentration of CO_2. Current findings demonstrate that ragweed pollen
33   production and the length of the ragweed pollen season increase with rising CO_2 concentrations and
34   temperatures (Wan et al., 2002; Wayne et al., 2002; Singer et al., 2005; Ziska et al., 2005; Rogers et al.,
35   2006a in IPCC, 2007). Invasive plant species with high allergenic content such as ragweed and poison
36   ivy have been found to be spreading in particular locations around the world, increasing potential health
37   risks (Rybnicek and Jaeger, 2001; Huynen and Menne, 2003; Taramarcaz et al., 2005; Cecchi et al., 2006
38   in IPCC,).

39   Extreme weather events are likely to be altered by climate change, though there is uncertainty
40   predicting the frequency and severity of events. Some regions in the United States may incur drought
41   conditions due to the reduction in rainfall, while other sections of the country are likely to experience
42   increased frequency of heavy rainfall events leading to potential flood risk (Frumkin, 2008). On the West
43   coast, water quality may be adversely affected as water supplies reduce with decreases in regional
44   precipitation and depletion of mountain snowpacks (Frumkin, 2008). It is considered *very likely* (>90
45   percent certainty) that over the course of this century there will be an increase in the frequency of extreme
46   precipitation (IPCC, 2007b in Ebi et al., 2008). The Southeast, Intermountain West and West are likely to
47   experience an increase in frequency, severity and duration of forest fires (Gamble et al., 2008; Brown et
48   al., 2004; Fried et al., 2004 in Ebi et al., 2008). Impacts to respective vulnerable populations may change

1   in the future as shifts occur in population, suburban development, and community preparedness. It is very
2   likely that a large portion of the projected growth of the United States population will occur in areas
3   considered to be at risk for future extreme weather events (Ebi et al., 2008). Hence, even if the rate of
4   health impacts were to decrease, the growth in population in risk areas will still cause an increase in the
5   total number of people affected.

6   Pathogen transmission is dependent upon many climate-related factors such as temperature,
7   precipitation, humidity, water salinity, extreme weather events, and ecological shifts, and may display
8   seasonal shifts (Ebi et al., 2008). Few studies have projected the health impact of vector-borne diseases.
9   Vector-borne illnesses are likely to shift or expand northward and to higher elevations with the possible
10 introduction of new vector-borne diseases (Gamble et al., 2008; Frumkin, 2008), while decreasing the
11 range of tick-borne encephalitis in low latitudes and elevation (Randolph and Rogers, 2000 in Ebi et al.,
12 2008). Malaria and dengue fever in the United States are unlikely to be affected by climate change
13 variables given the housing quality, land use patterns, and vector control (Frumkin, 2008).

14   Overall, populations within certain United States regions may experience climate change-induced
15 health impacts from a number of pathways simultaneously. For instance, populations in coastal
16 communities may experience an extreme weather event, such as a tropical cyclone and flooding, adding
17 to health burdens associated with sea level rise or coastal erosion.

18 **4.5.8.3.1 Adaptation**

19   The United States has a number of organizations and activities that identify and plan for the
20 prevention of adverse health impacts associated with weather and climate although recent experiences
21 following extreme weather and vector-borne disease outbreaks have demonstrated there is a need for
22 improvement (Confalonieri et al., 2007 in Ebi et al., 2008). The regions where there is an anticipated
23 increase in the health impacts of climate change are very likely to have a greater proportion of poor,
24 elderly, disabled, and uninsured residents. In addition, the American Academy of Pediatrics has
25 determined children are a vulnerable population, recommending the United States government give
26 children particular attention when developing emergency management and disaster response systems
27 (American Academy of Pediatrics, 2007; McMichael et al., 2001; US Department of Health and Human
28 Services, 2007 in American Academy of Pediatrics, 2007).

29   The public health sector has divided the activities associated with preventing diseases into one of
30 three classifications: primary, secondary and tertiary. Primary prevention protects the unaffected
31 population from contracting diseases. Secondary prevention focuses on the response action that starts at
32 the onset of a disease. Tertiary prevention deals with an existing disease and focuses on reducing
33 suffering and long-term health difficulties. Primary prevention tends to be the most effective and least
34 costly compared to secondary or tertiary prevention (Ebi et al., 2008).

35   Adaptation policies and measures to address human health impact due to climate change should
36 be continually managed as climate change is dynamic. Such adaptation may include the:

37   ▪ Support and maintenance of the public health infrastructure (Frumkin, 2008);

38   ▪ Improvement and dissemination of preventive care in the public health infrastructure
39   (Frumkin, 2008);

40   ▪ Continued use of nationwide surveillance as a tool to identify, track and map vector-borne
41   diseases (Frumkin, 2008);

1   ▪   Utilization of preparedness tools to identify and assist vulnerable populations during extreme
2   weather events (Frumkin, 2008); and

3   ▪   Strengthening of infrastructure to withstand extreme weather events.

4   **4.5.8.4 Projected Global Health Impacts of Climate Change**

5   Globally, climate change is anticipated to contribute to both adverse and beneficial health
6   impacts. Projected adverse health impacts include malnutrition leading to disease susceptibility (*high*
7   *confidence*); increased heat-wave, flood, storm and fire-induced mortality (*high confidence*); decrease in
8   cold-related deaths (*high confidence*); increased diarrheal disease burden (*medium confidence*); increased
9   levels of ground-level ozone (*high confidence*); and altered geographic distribution of some infectious
10   disease vectors (*high confidence*) (IPCC, 2007). A decrease in cold-related mortality and some pollutant-
11   related mortality, increased crop yields in certain areas, and restriction of certain diseases in certain areas
12   (if temperatures or precipitation rises above the critical threshold for vector or parasite survival) are
13   examples of projected beneficial health impacts (IPCC, 2007). The adverse impacts, however, greatly
14   outweigh the beneficial impacts, particularly after the mid-century mark (IPCC, 2007).

15   Regionally, the impact on human health will vary. Some Asian countries may experience
16   increasing malnutrition by 2030 with crop yields decreasing later in the century, rendering the population
17   in the region particularly vulnerable to malnutrition-associated diseases and disorders (IPCC, 2007).
18   Certain coastal areas will experience flooding by 2030 impacting human mortality (IPCC, 2007). By
19   2080, lyme disease is projected to have moved northward into Canada, due to a two- to four-fold increase
20   in tick abundance (IPCC, 2007). By 2085, climate change is projected to increase the population at risk
21   to dengue fever to a total of 3.5 billion people (IPCC, 2007).

22   Heat waves have been experienced globally: thousands of deaths incurred in India over the
23   eighteen heat-waves recorded between 1980 and 1998 (De and Mukhopadhyay, 1998; Mohanty and
24   Panda, 2003; De et al., 2004; in IPCC, 2007). In August 2003, approximately 35,000 deaths were linked
25   to a heat-wave experienced in Europe, with France alone incurring over 14,800 deaths (Hemon and
26   Jougla, 2004; Martinez-Navarro et al., 2004; Michelozzi et al., 2004; Vandentorren et al., 2004; Conti et
27   al., 2005; Grize et al., 2005; Johnson et al., 2005; in IPCC, 2007). Around 60 percent of the heat-wave
28   related deaths in France were people at or over 75 years of age (Hemon and Jougla, 2004 in IPCC, 2007).
29   Overall, studies have linked high temperatures to about 0.5-2 percent of annual mortality in the elderly
30   European population (Pattenden et al., 2003; Hajat et al., 2006 in IPCC, 2007).

31   In 2003, floods in China affected 130 million people (EM-DAT, 2006 in IPCC, 2007). In 1999,
32   storms with floods and landslides in Venezuela killed 30,000 people (IPCC, 2007).

33   The World Health Organization (WHO) estimates that a high proportion of those in dry regions
34   (approximately 2 billion) experience malnutrition, infant mortality, and water-related diseases (WHO,
35   2005 in IPCC, 2007). Children in low-income countries are particularly vulnerable to loss of life due to
36   diarrhea. The transmission of the enteric pathogen appears to increase during the rainy season for
37   children in the sub-Saharan Africa (Nchito et al., 1998; Kang et al., 2001 as cited in IPCC, 2007). In
38   Peru, higher temperatures have been linked to periods of increased diarrhea incidence experienced by
39   adults and children (Checkley et al., 2000; Speelmon et al., 2000; Checkley et al., 2004; Lama et al., 2004
40   in IPCC, 2007).

41   Cholera outbreaks associated with floods can occur in areas of poor sanitation. A study in Sea
42   surface temperatures in the Bay of Bengal demonstrated a bimodal seasonal pattern that translated to

1 increased plankton activity leading to increases in cholera in nearby Bangladesh (Colwell, 1996; Bouma
2 and Pascual, 2001 in IPCC, 2007).

3   Dengue is considered the most important vector-borne viral disease (IPCC, 2007). A strong
4 correlation exists between climate-based factors such as temperature, rainfall and cloud cover with the
5 observed disease distribution in Colombia, Haiti, Honduras, Indonesia, Thailand and Vietnam (Hopp and
6 Foley, 2003 in IPCC, 2007). Favorable climate conditions for dengue exist to about one-third of the
7 world's population (Hales et al., 2002; Rogers et al., 2006b in IPCC, 2007).

8   Malaria is a vector-borne disease spread by mosquitoes. Depending upon location, malaria
9 outbreaks may be influenced by rainfall amounts and sea-surface temperatures in southern Asia,
10 Botswana, and South America (Kovats et al., 2003; Thomson et al., 2005; DaSilva et al., 2004 in IPCC,
11 2007). A recent study of malaria in East Africa found that the significant warming trend the area has
12 experienced since the 1970s can be correlated with the potential of disease transmission. (Pascual et al.,
13 2006 in IPCC, 2007) However, southern Africa was not shown to exhibit the same trend (Craig et al.,
14 2004 in IPCC, 2007). External factors are also influencing the number of cases of the disease in Africa,
15 such as drug-resistant malaria, and parasite and HIV infection. Studies did not provide clear evidence that
16 malaria in South America or the continental regions of the Russian Federation have been affected by
17 climate change (Benitez et al., 2004; Semenov et al., 2002 in IPCC). In general, however, higher
18 temperatures and more frequent extreme weather occurrences (such as floods and droughts) are predicted
19 to have a stronger influence on the wider spread of malaria with increasing climate change (McMichael et
20 al. 1996, in Epstein et al., 2006).

21   Temperature has been shown to affect food-borne and water-borne diseases. Several studies have
22 found increases in salmonellosis cases (food poisoning) within 1 to 6 weeks of the high-temperature
23 peaks (controlled by season. This may be due, in part, to the processing of food products and the
24 population varying its eating habits during warmer months (Fleury et al., 2006; Naumova et al., 2006;
25 Kovats et al., 2004a; D'Souza et al., 2004; Naumova et al., 2006 in Ebi et al., 2008). High temperatures
26 have been shown to increase common types of food poisoning (D'Souza et al., 2004; Kovats et al., 2004;
27 Fleury et al., 2006 in IPCC, 2007). Increasing global temperatures could contribute to a rise in
28 salmonellosis cases (Ebi et al., 2008). There is further concern that projected increasing temperatures
29 from climate change will also increase leptospirosis cases, a disease that is resurging in the United States.

30   The effects of climate change on air quality are expected to adversely impact people suffering
31 from asthma and other respiratory ailments. Increases in temperature, humidity, the prevalence and
32 frequency of wildfires, and other factors are expected to result in more smog, dust, and particulates that
33 exacerbate asthma. Widespread respiratory distress throughout many regions of the world is a possible
34 result of climate change. Current asthma treatment and management plans may be overwhelmed, leading
35 to major increases in asthma-related morbidity and mortality (Epstein et al., 2006).

36   Warm climates are more apt to support the growth of the pathogenic species of Vibrio leading to
37 shell-fish related death and morbidity that may affect the United States, Japan and South-East Asia (Janda
38 et al., 1988; Lipp et al., 2002 in Ebi et al., 2008, 2-10; Wittmann and Flick, 1995; Tuyet et al., 2002 in
39 IPCC, 2008). If temperatures increase, the geographic range and concentration of the Vibrio species
40 could expand. For example, as the waters of the northern Atlantic have warmed, the concentration of
41 Vibrio species has also (Thompson et al., 2004 in Ebi et al., 2008). Future ocean warming might also
42 lead to the proliferation of harmful algal blooms, releasing toxins that contaminate shellfish and lead to
43 food-borne diseases (IPCC, 2007). Algal blooms such as red tide can also increase if fecal bacteria
44 concentrations and nutrient loading increases from storm water runoff during heavy precipitation events
45 (Frumkin, 2008).

1   In 2000, WHO estimated that climate change has caused the loss of more than 150,000 lives
2   (Campbell-Lendrum et al., 2003; Ezzati et al., 2004; McMichael, 2004 in IPCC, 2007). The projected
3   risks in 2030 described by the WHO study vary by health outcome and region; most of the increase in
4   disease is due to diarrhea and malnutrition. More cases of malaria are predicted in those countries that are
5   situated at the edge of the current distribution. The projected health impact associated with malaria is
6   mixed, with some regions demonstrating increased burden and others exhibiting decreased burden.

7   ### 4.5.8.4.1 Adaptation

8   Climate change is considered to pose a risk to the health of both the United States and global
9   populations (Ebi et al., 2008). Developed societies such as the United States are more likely to implement
10   effective adaptation measures reducing the magnitude of severe health impacts. For example, the risk and
11   impact of floods on a population can be reduced with changes in water management practices, improved
12   infrastructure, and land use practices (EEA, 2005 in IPCC, 2007). Unblocking drains also helps to reduce
13   the transmission of enteric pathogens (Parkinson and Butler, 2005 in IPCC, 2007). However,
14   improvements world-wide in adaptive capacity are needed (*high confidence*; IPCC, 2007). Many
15   governments have increased their efforts to cope with extreme climate events moving from disaster relief
16   to risk management. Efforts in Portugal, Spain, France, UK, Italy and Hungary focus on short-term
17   events such as heat waves (Pascal et al., 2006; Simon et al., 2005; Nogueira, 2005; Michelozzi et al.,
18   2005; NHS, 2006; Kosatsky and Menne, 2005 in IPCC, 2007) while other efforts have undertaken long-
19   term strategies addressing policies for agriculture, energy, forestry and transport (IPCC, 2007).

20

323

1
2
3

[This page intentionally left blank]

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.

1   All of the six criteria air pollutants regulated by EPA under the CAA and all but one of vehicle
2 emission toxic air pollutants would decrease overall with adoption of any of the action alternatives and
3 the foreseeable MY 2011-2015 standards (see Section 4.3). However, increases in vehicle miles traveled
4 due to the "rebound effect" are still projected to cause increases in criteria pollutants to levels that exceed
5 the EPA NAAQS in certain areas. The exceedance of the NAAQS in these areas would likely result in
6 adverse impacts on environmental justice communities. It is not, however, possible to determine whether
7 these impacts would represent a disproportionate impact on these communities.

8 **4.6.2.2 Effects of Climate Change in the United States**

9   Environmental justice populations in the United States, as defined by EO 12898, would
10 experience the same general impacts as a result of global climate change felt by the United States
11 population as a whole and described in Sections 4.5.6, Food, Fiber, and Forest Products, 4.5.7, Industry,
12 Settlements, and Society, and Section 4.5.8, Human Health. However, the United States Climate Change
13 Science Program notes that the general climate change impacts experienced the United States population
14 may be differentially experienced by environmental justice populations, explaining that, "[e]conomic
15 disadvantage, lower human capital, limited access to social and political resources, and residential choices
16 are social and economic reasons that contribute to observed differences in disaster vulnerability by
17 race/ethnicity and economic status" (Gamble et al 2008, Ch. 4, p. 12). A general description of the
18 potential impacts of climate change on the population of the United States is provided below. These
19 impacts are similar to those that would be experience globally, though the severity of impacts felt by
20 developing countries would likely be disproportional to those experienced in developed nations, such as
21 the United States. The most likely anthroprogenic climate change impacts include:

22   ■ **Human Health** – increased mortality and morbidity due to excessive heat, increases in
23   respiratory conditions due to poor air quality, increases in water and food-borne diseases and
24   changes to the seasonal patterns of vector-borne diseases, and increases in malnutrition (see
25   Section 4.5.7 for details)

26   ■ **Services** – disruption of ability to transport goods and services, shifts in the location of
27   certain crops, disaster related damage to transportation infrastructure (roads, rail, ports),
28   tourism location shifts, insurance premium increases (see Section 4. 5.6 for details)

29   ■ **Utilities and Infrastructure** – more frequent droughts and increases in irrigation/drinking
30   water demand, flooding-related impacts on sewage systems with potential water quality
31   impacts, and disaster related damage to transportation, power and communications systems
32   (see Section 4.5.6 for details)

33   ■ **Human Settlement** – synergistic effects with existing resource scarcities (for example
34   energy and water), inundation of inhabited coastal areas due to sea level rise, urban
35   temperature increases (see Section 4.5.6 for details)

36   ■ **Social Issues** – increased stress on public services and disruptions to traditional cultures (see
37   Section 4.5.6 for details)

38   ■ **Agriculture** – changes in crop yields, more intense droughts and floods, changes in the
39   length of growing seasons (see Section 4.5.6 for details)

40   ■ **Forest and Ecosystem Service** – increased risk of forest fires, redistribution and extinction
41   of economically or culturally significant wildlife species, expanded ranges for pests and
42   invasive species (see Section 4.5.6 for details).

1   Environmental justice populations would likely be disproportionately affected by some of these
2 potential impacts. The remainder of this section discusses, qualitatively, the most significant areas of
3 potential disproportionate impact for these populations in the United States.

4   **4.6.2.2.1 Human Health**

5   Low income and minority communities exposed to the direct effects of extremes in climatic
6 conditions may also experience synergistic effects with pre-existing health risk factors, such as limited
7 availability of preventative medical care and inadequate nutrition (Gamble et al. 2008).

8   As stated in Section 4.5.7, increases in heat related morbidity and mortality as a result of higher
9 overall and extreme temperatures is likely to disproportionately affect minority and low income
10 populations, partially as a result of limited access to air conditioning and high energy costs (Gamble et al.
11 2008; O'Neill et al. 2005). Urban areas, which often have relatively large environmental justice
12 populations, will likely experience the most significant temperature increase due to the urban "heat
13 island" effect and could be particularly vulnerable to this type of health impact (Gamble et al. 2008;
14 Knowlton et al. 2007).

15   Increasing temperatures could also lead to expanded ranges for a number of diseases (Gamble et
16 al. 2008). As described in Section 4.5.8, the number and severity of outbreaks for vector-borne illnesses,
17 such as the West Nile Virus, could become more frequent and severe in the future. Because the vectors of
18 these diseases (such as mosquitoes) are more likely to come into contact with environmental justice
19 populations, disproportionate impacts may occur. For example, an outbreak of the mosquito-borne
20 dengue fever in Texas impacted primarily low income Mexican immigrants living in lower quality
21 housing without air conditioning, leading a team researching the outbreak to conclude that the low
22 prevalence of dengue in the United States is primarily due to economic, rather than climatic, factors
23 (Reiter et al. 2003).

24   **4.6.2.2.2 Land Use**

25   In the United States, two primary types of geographical environmental justice communities are
26 likely to be affected by global climate change: urban areas, because of their relatively high concentrations
27 of low-income and minority residents, and indigenous communities. Environmental justice communities
28 in urban areas, because of previously mentioned heat exposure and health issues, are likely to experience
29 climate change impacts more acutely. Additionally, environmental justice populations in coastal urban
30 areas (vulnerable to increases in flooding as a result of projected sea level rise, larger storm surges, and
31 human settlement in floodplains) are less likely to have the means to quickly evacuate in the event of a
32 natural disaster (Gamble et al. 2008; USCCSP 2007). USCCSP, as an example, notes that flooding in
33 Louisiana following the 2005 Hurricane Katrina primarily killed poor and elderly residents without the
34 means to flee (USCCSP 2008). As stated in Section 4.5.7, Industry, Settlements, and Society, traditional
35 communities in the United States, particularly Alaska, could face major impacts on their subsistence
36 economy from climate change. These impacts result from the indigenous communities' partial reliance
37 on arctic animals, such as seals and caribou, for food and the potential destruction of transportation
38 infrastructure due to ground thaw.

39   In coastal and floodplains areas prone to flooding because of larger storm surges and generally
40 more extreme weather, increases in flood insurance premiums could disproportionately affect
41 environmental justice populations unable to absorb the additional cost. Lack of sufficient insurance
42 coverage could leave these populations more financially vulnerable to severe weather events.

1   Potential food insecurity as a result of global climate change, particularly among low-income
2   populations in the United States and abroad, is an often mentioned concern (Wilbanks et al. 2007; Gamble
3   et al. 2008). Climate change is likely to affect agriculture by changing the growing season, limiting
4   rainfall and water availability, or increasing the prevalence of agricultural pests (see Section 4.5.6 for
5   more information). In the United States, the most vulnerable segment of the population to food insecurity
6   is likely to be low-income children (Cook et al., 2007 as cited in Gamble et al. 2008).

7 **4.6.2.3 Effects of Global Climate Change**

8   EO 12898, which requires Federal agencies to consider high and adverse disproportionate
9   impacts of their actions on environmental justice populations, does not apply to areas outside of the
10   United States or its territories and possessions; however, because of the global impact of climate change,
11   the agency feels that its cumulative impacts assessment should include impacts on vulnerable global
12   populations as well. This global, qualitative environmental justice analysis examines potential climate
13   change impacts on developing nations.

14   Generally, low-income and other vulnerable populations would experience the same impacts from
15   climate change as populations in comparable geographic areas described in the global impacts sections of
16   4.5.6, Food, Fiber, and Forest Products, 4.5.7, Industries, Settlements, and Society, and 4.5.8, Human
17   Health. However, as with environmental justice populations in the United States, climate change impacts
18   would likely be differentially experienced by vulnerable populations. The magnitude of climate change
19   impacts on citizens of developing countries would be expected to be greater. For example, IPCC notes
20   that the continent of Africa's, "major economic sectors are vulnerable to current climate sensitivity, with
21   huge economic impacts, and this vulnerability is exacerbated by existing developmental challenges such
22   as endemic poverty, complex governance and institutional dimensions; limited access to capital, including
23   markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts.
24   These in turn have contributed to Africa's weak adaptive capacity, increasing the continent's vulnerability
25   to projected climate change" (Wilbanks et al., 2007, p. 435).

26 **4.6.2.3.1 Human Health**

27   As discussed in Section 4.5.7, the danger to human health from climate change will differentially
28   affect developing countries. The IPCC states that, "Adverse health impacts will be greatest in low-
29   income countries. Those at greater risk include, in all countries, the urban poor, the elderly and children,
30   traditional societies, subsistence farmers, and coastal populations" (Wilbanks et al. 2007, p. 393). Section
31   4.5.8 describes in detail the potential health effects from climate change on developing countries; these
32   impacts include:

33   ■   increases in malnutrition, and related health impacts, in developing regions of the world due
34   to declining crop yields;

35   ■   potential increases in water-related diseases, such as diarrhea causing pathogens, due to
36   higher temperatures;

37   ■   potential for continuation of upward trends in certain vector-borne diseases, such as malaria
38   in Africa, which have been attributed to temperature increases; and

39   ■   increases in temperature leading to increased ozone and air pollution levels in large cities
40   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).

1
2   *[This page intentionally left blank]*
3
4

1 **4.7   NON-CLIMATE CUMULATIVE IMPACTS OF CO$_2$**

2 **4.7.1   Affected Environment**

3   In addition to its role as a GHG in the atmosphere, CO$_2$ is exchanged from the air to water, plants,
4 and soil. CO$_2$ dissolves easily in water and more easily in salt water such as oceans. In water, CO$_2$
5 combines with water molecules to form carbonic acid. The amount of CO$_2$ dissolved into oceans is
6 related to the concentrations in the air. This process reduces CO$_2$ available in the atmosphere as a GHG,
7 but also increases the acidity of the ocean. Increasing levels of CO$_2$ are having a global effect on our
8 oceans. By 2100, ocean pH could drop 0.5 units from pH levels seen in the 1900s (Hall-Spencer, et al.,
9 2008).

10   Plants take CO$_2$ from the air through photosynthesis, and use the carbon for plant growth. This
11 uptake by plants can influence annual fluctuations of CO$_2$ on the order of 3 percent from growing season
12 to non-growing season (Schneider and Londer 1984 as cited in Perry 1994). Increased levels of CO$_2$
13 essentially act as a fertilizer influencing normal annual plant growth.

14   In addition, CO$_2$ concentrations affect soil microorganisms. Only recently have the relationships
15 between above-ground ecosystems and below-ground components of ecosystems been considered
16 significant; there is increasing awareness of the fact that feedbacks between the above-ground/below-
17 ground components play a fundamental role in controlling ecosystems processes. For example, the
18 organic carbon required for below-ground decomposition is provided by plants. Plants also provide the
19 resources for root-associated microorganisms (Wardle, et al., 2004). The "decomposer subsystem in turn
20 breaks down dead plant material and indirectly regulates plant growth and community composition by
21 determining the supply of available root nutrients" (Wardle, et al., 2004, p. 1).

22   Specific plant species, depending on the quantity and quality of resources provided to below-
23 ground components, may have greater impacts on soil biota and the processes regulated by those biota
24 than do other plants. Variation in the quality of forest litter produced by co-existing species of trees, for
25 instance, "explains the patchy distribution of soil organisms and process rates that result from 'single tree'
26 effects" (Wardle, et al., 2004, p. 2). The composition of plant communities has a consistent and
27 significant impact on the composition of root-associated microbes; however, the effects of plant
28 community composition on decomposer systems are apparently context-dependent. In one example cited,
29 manipulating the composition of plant communities in five sites in Europe produced distinctive effects on
30 decomposer microbes while root-related soil microbes experienced no clear effect (Wardle, et al., 2004).

31   The amount of carbon stored in soils of temperate and boreal forests is about four times greater
32 than the carbon that is stored by vegetation and is "33 percent higher than total carbon storage in tropical
33 forests" (Heath, et al., 2005, p. 1711). Terrestrial communities contain as much carbon as the
34 atmosphere. Forest soils are also the longest-lived carbon pools in terrestrial ecosystems (King, et al.,
35 2004, p. 1027). Several experiments involving increases of atmospheric CO$_2$ resulted in increasing carbon
36 mass in trees, but a reduction of carbon sequestration in soils. This is associated with increasing soil
37 microorganism respiration (Heath, 2005; Black, 2008 (online)); respiration is associated with "root
38 herbivory, predation, consumption of root exudates, and the decomposition of root and leaf litter" (King,
39 et al., 2004, p. 1028). In future real-world scenarios, however, it is possible that the reduction of soil
40 carbon via increased soil respiration could be countered by an increase in litter on the forest floor.

41 **4.7.2 Consequences**

42   One of the large-scale non-climatic effects of an increase in CO$_2$ emissions is the potential for
43 ocean acidification. The ocean exchanges huge quantities of CO$_2$ with the atmosphere, and when

1   atmospheric concentrations rise (due to anthropogenic emissions), there is a net flux from the atmosphere
2   into the oceans. This lowers the pH of the oceans (more acidic water), which reduces the ability of shell-
3   forming organisms to produce their shells. Most shells are made of calcium carbonate, which dissolves
4   under acidic conditions (Hall-Spencer, 2008, et al; Kleypas, et al, 2006). According to Kleypas, et al
5   (2008), under increasing atmospheric CO_2, "A variety of evidence indicates that calcification rates will
6   decrease, and carbonate dissolution rates increase, as $CaCO_3$ (calcium carbonate) saturation state
7   decreases."

8   In conjunction with rapid climate change, ocean acidification could pose severe threats to coral
9   reef ecosystems. Reef building and reef dissolution is always occurring, but dissolution of coral reefs is
10   expected to increase, and surpass reef building, as anthropogenic CO_2 in the atmosphere increases. If the
11   water column above reefs becomes saturated with the CO_2 from the atmosphere, the water could be less
12   able to hold the CO_2 respired by microorganisms in the reef environment. Although the interactions are
13   complex and difficult to project, a possible scenario is that the excess of CO_2 in the reef environment
14   could prevent reef-building. Thresholds for calcium carbonate dissolution exceeding calcification will
15   vary for different reef systems (Kleypas, et al, 2006).

16   In contrast to its potential adverse effect on the productivity of marine ecosystems, higher CO_2
17   concentrations in the atmosphere could increase the productivity of terrestrial systems. Plants use CO_2 as
18   an input to photosynthesis. The IPCC Fourth Assessment Report (WGI, Chapter 7) states that "On
19   physiological grounds, almost all models predict stimulation of carbon assimilation and sequestration in
20   response to rising CO_2, referred to as 'CO_2 fertilization'" (Denman et al. 2007, p. 562).

21   Under bench-scale and field-scale experimental conditions, a number of investigators have found
22   that higher concentrations have a fertilizing effect on plant growth (e.g., Long et al. 2006; Schimel et al.
23   2000). IPCC reviewed and synthesized field and chamber studies, finding that:

24   There is a large range of responses, with woody plants consistently showing net primary
25   productivity (NPP) increases of 23 to 25 percent (Norby et al., 2005), but much smaller increases for
26   grain crops (Ainsworth and Long, 2005) … Overall, about two-thirds of the experiments show positive
27   response to increased CO_2 (Ainsworth and Long, 2005; Luo et al., 2005). Since saturation of CO_2
28   stimulation due to nutrient or other limitations is common (Dukes et al., 2005; Koerner et al., 2005), is the
29   magnitude, and effect of the CO_2 fertilization is not yet clear.

30   The CO_2 fertilization effect could potentially mitigate some of the increase in atmospheric CO_2
31   concentrations by resulting in more storage of carbon in biota.

32   As with the climatic effects of CO_2, the changes in non-climatic impacts associated with the
33   regulatory alternatives is difficult to assess quantitatively. In the base case, atmospheric CO_2
34   concentrations increase from current levels of about 380 ppm to as much as 800 ppm in 2100 (Kleypas, et
35   al, 2006). It is not clear whether the distinction in concentrations is significant across alternatives, as the
36   damage functions and potential existence of thresholds for CO_2 concentration are not known. However, it
37   is clear that a reduction in the rate of increase in atmospheric CO_2 would reduce the ocean acidification
38   effect, as well as the CO_2 fertilization effect.

39   **4.7.2.1 Soil Organisms**

40   The current annual exchange in CO_2 between the atmosphere and terrestrial ecosystems is
41   approximated as being nine to ten times greater than annual emissions produced as a result of burning
42   fossil fuels. Even a small shift in the magnitude of this exchange could have a significant impact on
43   atmospheric CO_2 concentration (Heath, et al., 2005, 1712). The above-ground/below-ground processes

1 and components in terrestrial ecosystems typically act to sequester carbon. Studies are now confirming
2 that variations in atmospheric CO_2 have impacts not only on the above-ground plant components, but also
3 on the below-ground microbial components of these systems.

4   In one study, CO_2 levels were artificially elevated in a forest for the purpose of studying the effect
5 of atmospheric CO_2 on soil communities. An *indirect* impact of the increased CO_2 was that there were
6 distinct changes in the composition of soil microbe communities as a result of increased plant detritus
7 (BNL, 2007; Science Daily, 2007). In another study, an increase in CO_2 *directly* resulted in increased soil
8 microbial respiration. However, after four to five years of increased exposure to CO_2, "the degree of
9 stimulation declined" to only a 10 to 20 percent increased in respiration over the base rate (King, et al.,
10 2004, p. 1033). Additionally, the degree of stimulation was linked to variability in seasonal and
11 interannual weather (King, et al., 2004).

12   The increase in microbe respiration could, therefore, have the effect of diminishing the carbon
13 sequestration role of terrestrial ecosystems. Upon reaching a certain level of CO_2 in the atmosphere,
14 carbon sinks in soils could become net carbon emitters (Heath, et al., 2005; Black, 2008). Because of the
15 number of factors involved in determining soil respiration and carbon sequestration, the threshold for
16 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.

---

[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.

---

[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

Name	Qualifications/Experience
PROJECT MANAGEMENT	
Michael J. Savonis	
	MRP, Cornell University; BS in Chemistry, State University of New York at Buffalo
	25 years of experience in transportation policy, with extensive expertise in air quality and emerging environmental issues.
Carol Hammel-Smith	
	M.P.A., Environmental Management and Policy, University of Colorado; B.A., Political Science, University of Colorado
	20 years of experience in environmental impact assessment.
Michael M. Johnsen	
	M.S., Environmental Science and Policy, Johns Hopkins University; B.S., Natural Resource Management, University of Maryland
	20 years experience in the environmental field with extensive experience in NEPA and climate change.
Don H. Pickrell	
	Ph.D., Urban Planning, University of California, Los Angeles; M.A., Urban Planning, University of California, Los Angeles; B.A. (with high honors), Economics and Mathematics, University of California, San Diego
	30 years of experience in applied transportation economics, including 15 years of experience in analysis of environmental impacts of transportation activity.
REVIEWERS	
Julie Abraham, Director, Office of International Policy, Fuel Economy and Consumer Programs	
	M.S., Bioengineering, University of Michigan, Ann Arbor; M.S., Electrical Engineering, Wayne State University; Director, Office of International Policy Fuel Economy and Consumer Programs
	16 years of experience in domestic and international transportation policy.
Stephen P. Wood	
	J.D., Columbia Law School; B.A., Political Science, Williams College
	39 years of experience in vehicle safety rulemaking and 33 years in fuel economy rulemaking.

Name	Qualifications/Experience
Sarah Alves	
	J.D., Boston University School of Law; B.A., Astronomy and Physics, Boston University
	1 year of legal experience, and 2 years of experience in macroeconomic analysis.
Kevin Green	
	M. Eng., Applied & Engineering Physics, Cornell University; B.S., Applied & Engineering Physics, Cornell University
	17 years of experience in vehicle emissions analysis and regulation.
Kerry E. Rodgers	
	J.D., New York University School of Law; M.E.S., Environmental Studies, Yale University School of Forestry & Environmental Studies; A.B., Biology, Brown University
	12 years of experience in environmental law.
Mark Talty	
	J.D. Candidate, University of Baltimore School of Law; B.S., Political Science, Northeastern University
	1 year of legal experience.
Kevin Wang	
	J.D. Candidate, University of Maryland School of Law; B.S. Civil Engineering, University of California, Davis
	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.

Name/Role	Qualifications/Experience
PROJECT MANAGEMENT	
Alan Summerville, Officer in Charge	
	M.A., City Planning, University of Pennsylvania; B.A., Economics and Political Science, University of Vermont.
	18 years of experience participating in and managing the preparation of NEPA documents.

Name/Role	Qualifications/Experience
Michael Smith, Project Manager	
	Ph.D., Sociology, Utah State University; M.A., Geography, University of Wyoming; B.A., Environmental Studies (Honors), University of California
	15 years of experience in environmental impact assessment.
Neil Sullivan, Deputy Project Manager	
	M.S., Integrated Environmental Management, University of Bath; B.S., Human and Physical Geography, University of Reading
	12 years of experience participating in and managing the preparation of NEPA documents.
Karen Fadely, Deputy Project Manager	
	M.E.M., Conservation Science and Policy, Duke University; B.S., Biology, Bucknell University
	8 years of environmental experience; 3 years participating in and managing the preparation of NEPA documents.

TECHNICAL AND OTHER EXPERTISE (alphabetically)

Linda Amato, AICP, Document Review Lead	
	M.U.R.P., Community Planning & Design, The George Washington University; B.A., Art History, State University of New York at Stony Brook; Certificate, Technical Writing & Communication, Bellevue Community College
	23 years of experience in managing and preparing environmental documentation.
Jeffrey Ang-Olson, Senior Technical Air Quality Advisor	
	M.C.P., City Planning, University of California at Berkeley; M.S., Transportation Engineering, University of California at Berkeley; B.S., Electrical Engineering, Rice University
	12 years of experience analyzing the air quality impacts of transportation programs, plans, and projects.
Leiran Biton, Air Quality Analyst	
	M.S., Environmental Science, University of North Carolina, Chapel Hill, B.A., Environmental Science & Policy and Theater Arts, Clark University
	2 years of experience in environmental analysis.
Brent Bouldin, Editor	
	M.A., Communications, Louisiana State University at Baton Rouge, B.S., Communications, University of Texas at Austin
	30 years of experience in managing document publications, including EIS and Resource Management Plans.

Name/Role	Qualifications/Experience
Adam Brundage, Climate Change Modeling	
	M.E.M., Environmental Management, Duke University; B.S., Atmospheric Science, McGill University
	3 years of experience assessing and analyzing climate change issues, including NEPA.
David Burch, Human Health Analyst	
	M.E.M., Environmental Chemistry and Toxicology, Duke University; B.S., Chemistry, Duke University
	13 years of professional experience in human health risk and exposure assessment and environmental chemistry and toxicology, including 3 years of related experience assisting with NEPA documents.
Edward Carr, Air Quality Analyst	
	M.S., Atmospheric Science, University of Washington at Seattle; B.S., Chemistry, Duke University
	14 years of experience in assessing mobile source air toxic emissions.
Jenny Chen, Energy Analyst	
	M.A., Urban Planning and Policy, University of Southern California; B.A., Economics (Summa Cum Laude), University of California, Irvine
	2 years of experience in researching fuels and technology for NEPA documents.
Laura Cooper, Editor	
	B.A., Psychology, Reed College
	18 years of experience writing and editing technical documents; 3 years of experience managing publications processes and teams.
Charlotte Coultrap-Bagg, Climate Change Analyst	
	B.A., Environmental Studies, with honors, Dartmouth College
	4 years of experience in assessing the impacts of climate impacts.
David Ernst, Team Leader for the Air Quality Team	
	B.C.R.P., Environmental Policy, Harvard University; B.S., Urban Systems Engineering, Brown University; B.A., Ethics and Politics, Brown University
	28 years of experience preparing air quality analysis for NEPA documents.
Cristiano Facanha, Safety Analyst	
	Ph.D., Civil and Environmental Engineering, University of California, Berkeley, M.S., Transportation Engineering, University of California, Berkeley, M.S., Management of Transportation, Chalmers University of Technology, Gothenburg, Sweden, B.S., Industrial Engineering, Federal University of Rio de Janeiro, Brazil
	5 years in transportation analysis.

Name/Role	Qualifications/Experience
Mark Flugge, Climate Change Analyst	
	Ph.D., Atmospheric Chemistry, University of Oxford, United Kingdom; M.C., Chemistry,, University of Oxford, United Kingdom
	10 years of experience analyzing atmospheric chemistry, greenhouse gas, and climate change issues.
Randall J. Freed, Senior Technical Climate Change Advisor	
	M.S., Water Resource Management, University of Maryland at College Park; B.S., Zoology, University of Maryland at College Park
	33 years experience on assessing and managing environmental risk and 14 years assessing climate change issues.
Frank Gallivan, Air Quality Analyst	
	Master of City Planning, University of California, Berkeley, B.A., Economics / Classical Archaeology, Dartmouth College
	2 years of experience preparing economic and environmental analyses for NEPA documents.
Ralph Grismala, P.E., Quality Control	
	M.S., Civil Engineering, Massachusetts Institute of Technology, B.S., Civil Engineering, Massachusetts institute of Technology
	30 years of experience in geothermal and environmental impact analyses.
Philip Groth, Climate Change Analyst	
	Master of Planning, University of Southern California, Los Angeles, B.A., Anthropology, Williams College
	4 years of experience in climate change analysis.
Steven Hackett, Land Use Affected Environment Analyst	
	Ph.D., Economics, Texas A&M University; M.S., Economics, Texas A&M University; B.S., Agricultural Business/Economics, Montana State University
	19 years of experience analyzing economic impacts.
John Hansel, Senior NEPA Advisor	
	J.D., cum laude, American University; B.A., Economics, University of Wisconsin at Madison
	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
	20 years of experience analyzing economics and environmental policy analysis, including 12 years in assessing climate change impacts.

Name/Role	Qualifications/Experience
William Hartley, Air Quality Analyst	
	M.S., Atmospheric Sciences, University of Washington at Seattle; B.S., Physics North Carolina State University
	10 years of experience in air quality analysis.
Joseph Herr, Climate Change Analyst	
	B.S., Natural Resources, University of Vermont, Burlington, B.S., Business Administration, University of Vermont, Burlington
	3 years of experience in air quality analysis.
David Johnson, Ecosystem Analyst	
	B.S., Biology, Minors in Geology and Chemistry, University of Minnesota, Twin Cities
	9 years of experience assessing aquatic resources, resource inventory and classification, impact assessment, permitting assistance, and regulatory compliance.
Robert Lanza, P.E., QA/QC Lead	
	M.Eng., Chemical Engineering, Cornell University; B.S., Chemical Engineering, Cornell University
	20 years of experience in preparing and reviewing NEPA documents.
Andrew Leung, Energy Analyst	
	B.S., Economics, Carnegie Mellon University
	2 years of experience in energy analysis.
Brian Lutenegger, Safety Analyst	
	Master of Urban Planning, University of Michigan, B.S., Sociology & Political Science, University of Wisconsin – Madison
	1 year of experience participating in the preparation of NEPA documents.
Amalia Marenberg, Climate Change Analyst	
	B.S., Environmental Science, University of Maine at Farmington
	1 year of experience assisting NEPA document preparation.
Suzanne Martos, Research Assistant	
	B.S., Science of Earth Systems: Biogeochemistry, Cornell University, B.S., Biology, Cornell University
	1 year of experience in assisting in NEPA document preparation.
Stacy McDowell, Document Coordinator	
	B.S., Environmental Studies, Portland State University
	6 years of experience in project coordination, publication development, and production.

Name/Role	Qualifications/Experience
William Mendez, Jr., QA/QC Analyst	
	Masters, Public Policy Program, John F. Kennedy School of Government, Harvard University, Ph.D., Biochemistry, University of Chicago, B.S., Natural Sciences, Colgate University
	29 years of experience in assessing human health risks.
Rawlings Miller, Human Health Analyst	
	Ph.D., Atmospheric Sciences, University of Arizona; M.S., Aerospace Engineering, Boston University; B.S., Physics, Union College
	5 years of experience modeling the impacts of climate issues.
Chris Moelter, Terrestrial Analyst	
	M.E.M., Environmental Tourism, University of Queensland, Australia; B.S., Zoology, University of Wisconsin
	4 years of experience in environmental impact analysis.
Danielle Monteverde,Research Assistant	
	B.S., Environmental Studies, Bucknell University
	1 year of experience assisting NEPA document production.
Deborah Munkburg, Land Use Analyst	
	M.Plan., University of Minnesota, Humphrey Institute of Public Affairs; BA, Urban Planning, 1980, University of Washington, College of Architecture and Urban Planning
	20 years of experience writing land use analyses and NEPA documents.
Rick Nevin, Alternatives Analyst	
	M.M., Concentration in Finance, Managerial Economics, and Strategy, J.L. Kellogg Graduate School of Management, Northwestern University; M.A., Economics, Boston University; B.A., Economics and Mathematics, Boston University
	25 years of experience managing and preparing environmental, energy, and economic analyses
Melissa Pauley, Fresh Water Analyst	
	M.S., Environmental Science and Management, Duquesne University; B.S., Environmental Studies, Bucknell University
	4 years of consulting on environmental issues and 1 year of experience in preparing NEPA documents.
Bill Pepper, Climate Change Team Leader	
	M.A., Mathematics, Temple University; B.S., Mathematics, University of Maryland
	20 years of experience modeling and evaluating climate change issues.

Name/Role	Qualifications/Experience
Marybeth Riley, Terrestrial Analyst	
	M.S., Atmospheric Science, Cornell University; B.S., Geology, University of New Mexico
	3 years of experience in climate change analysis.
Kathleen Rooney, Transportation Analyst	
	M.P.P. Environmental Policy, University of Maryland-College Park, B.A., Political Science, Tulane University.
	5 years of analyzing environmental and transportation policies, planning, and programs.
Zeta Rosenberg, Energy Analyst	
	M.A. Economics, George Washington University, Ph.D (less dissertation) History, University of Toronto, Canada, B.A. and M.A., History with Honors, University of Toronto, Canada
	3 years of experience in energy analysis.
Karen Savage, Transportation Analyst	
	M.A. Public Systems Planning, Transportation, UCLA; B.A. Urban Planning, University of Washington
	30 years of experience analyzing environmental impacts of transportation programs and planning.
Andy Shapiro, Human Health Analyst	
	B.S.P.H., Environmental Health Science, University of North Carolina at Chapel Hill
	1 year of experience analyzing human health impacts.
Jennifer Singer, Terrestrial Analyst	
	M.A., Urban and Environmental Policy and Planning, Tufts University; B.A., Politics, Honors, Brandeis University
	4 years of experience analyzing ecosystem impacts.
Allison Stork, Scoping Comments Analyst	
	M.S., Geography, University of Tennessee at Knoxville; B.A. Geography, State University of New York at Geneseo, B.A. English, State University of New York at Geneseo
	1 year of experience participating in and managing the preparation of NEPA documents.
Fran Sussman, Climate Change Cumulative Impacts Analysis Lead	
	Ph.D., Economics, University of Maryland; M.A., Economics, University of Maryland; B.A., Economics, State University of New York at Stony Brook
	20 years of experience in climate change analysis.

Name/Role	Qualifications/Experience
John Venezia, Climate Change and Economics Analyst	
	M.S., Environmental Science and Policy, Johns Hopkins University; B.S., Biology and Environmental Science & Policy, Duke University
	10 years of experience analyzing the technical and economic aspects of global climate change issues.
Nate Wagoner, Other Environmental Impacts Lead	
	M.S., Human Dimensions of Ecosystem Science and Management, Utah State University; B.S., Natural Resources Integrated Policy and Planning, Ohio State University
	5 years of experience in environmental impact analysis.

1

CHAPTER 8 REFERENCES

8.1 CHAPTER 1 REFERENCES

Alley, R.B., et al. 2002. Abrupt Climate Change: Inevitable Surprises. US National Research Council Report, National Academy Press, Washington, DC, 230 pp.

Hansen, J., M. Sato, P. Kharecha, G. Russell, D.W. Lea, and M. Siddall. 2007a. Climate change and trace gases. Phil. Trans. R. Soc. A 365: 1925-1954.

MacCracken, F., Moore, and J.C. Topping Jr., eds. 2008. Sudden and Disruptive Climate Change. The Climate Institute. Earthscan, Sterling, VA.

8.2 CHAPTER 3 REFERENCES

Adar, S. D., and Kaufman, J. D. 2007. Cardiovascular disease and air pollutants: Evaluating and improving epidemiological data implicating traffic exposure. *Inhalation Toxicology* 19(Suppl. 1): 135–149.

Ahmad, S. and Greene, D. L. 2005. Effect of Fuel Economy on Automobile Safety: A Reexamination. Transportation Research Record 1941. Washington, DC: Transportation Research Board of the National Academies.

Ainsworth, E. A., and Long, S. P. 2005. What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy. *New Phytol.* 165(2): 351–371. (Cited by Denman et al. 2007.)

Alley, R.B., et al. 2002. Abrupt Climate Change: Inevitable Surprises. US National Research Council Report, National Academy Press, Washington, DC, 230 pp.

Argonne. 2002. The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model. Version 1.8a, Argonne National Laboratories, February 2002. http://www.transportation.anl.gov/software/GREET/index.html.

Baker, T. R., Phillips, O. L., Malhi, Y., Almeida, S., Arroyo, L., DiFiore, A., Erwin, T., Higuchi,N., Killeen, T. J., Laurance, S. G., Laurance, W. F., Lewis, S. L., Monteagudo, A., Neill, D. A., Vargas, P. N., Pitman, N. C. A., Silva, J. N. M., and Martinez, R. V. 2004. Increasing biomass in Amazonian forest plots. *Philos. T. Roy. Soc. Lond. B* 359: 353–365.

Barnett, J., and Adger, W. N. 2003. Climate dangers and atoll countries. Climatic Change 61(3): 321–337.

Baum, E. 2001. Unfinished Business: Why the Acid Rain Problem is Not Solved. http://eastonsd.org/eahs/fileadmin/eahs/academics/science/Clean_air_task_force_on_acid_rain.pdf

Black, H. 2008. The mighty microbe. Some scientists fear CO_2-spewing bacteria will speed global warming. http://www.jsonline.com/story/index.aspx?id=728254.

Bunkley, N. 2008. Highly Rated Auto Plants Set to Close. http://www.nytimes.com/2008/06/06/business/06auto.html?ref=business.

1 CCSP. 2008b. The effects of climate change on agriculture, land resources, water resources, and
2   biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on
3   Global Change Research. Backlund, P., Janetos, A., Schimel, D., Hatfield, J., Boote, K., Fay, P.,
4   Hahn, L., Izaurralde, C., Kimball, B. A., Mader, T., Morgan, J., Ort, D., Polley, W., Thomson, A.,
5   Wolfe, D., Ryan, M., Archer, S., Birdsey, R., Dahm, C., Heath, L., Hicke, J., Hollinger, D.,
6   Huxman, T., Okin, G., Oren, R., Randerson, J., Schlesinger ,W., Lettenmaier, D., Major, D., Poff,
7   L., Running, S., Hansen, L., Inouye, D., Kelly, B. P., Meyerson, L, Peterson, B., and Shaw, R..
8   U.S. Environmental Protection Agency, Washington, DC., USA, 362 pp (SAP 4.3)

9 Chan, C. C., Shie, R-H., Chang, T-Y., and Tsai, D-H. 2005. Workers' exposures and potential health
10   risks to air toxics in a petrochemical complex assessed by improved methodology. *International
11   Archives of Occupational and Environmental Health* 79(2).
12   http://www.springerlink.com/content/v828028146272263/.

13 Chung, H., Zak, D. R., Reich, P. B., and Ellsworth, D. S. 2007. Plant species richness, elevated CO_2, and
14   atmospheric nitrogen deposition alter soil microbial community composition and function.
15   *Global Change Biology* 13(5): 980–989.

16 Claggett, M., and Houk, J. 2006. FHWA Workshop on Project-Level Mobile Source Air Toxics. Third
17   Mobile Source Air Toxics Workshop, Phoenix, Arizona, October 23–25.

18 Coviella, C.E., Trumble, J.T. 1999. Effects of Elevated Atmospheric Carbon Dioxide on Insect-Plant
19   Interactions. http://www.blackwell-synergy.com/doi/abs/10.1046/j.1523-1739.1999.98267.x

20 Cox, P.M., et al. 2000. Acceleration of global warming due to carbon-cycle feedbacks in a coupled
21   climate model. Nature, 408, 184–187.

22 Curtis, P. S., Balduman, L. M., Drake, B. G., and Whigham, D. F. 1990. Elevated Atmospheric CO_2
23   Effects on Belowground Process in C3 and C4 Estuarine Marsh Communities.
24   http://www.jstor.org/pss/1937608.

25 Deeb, R. A., Sharp, J. O., Stocking, S., McDonald, S., West, K. A., Laugier, M., Alvarez, P. J. J.,
26   Kavanaugh, M. C., and Alvarez-Cohen. L. 2002. Impact of ethanol on benzene plume lengths:
27   Microbial and modeling studies. *Journal of Environmental Engineering* 128(9): 868–875.

28 DeHayes, D. H., Schaberg, P. G., Hawley, G. J., and Strimbeck, G. R. 1999. Acid rain impacts on
29   calcium nutrition and forest health. *BioScience* 49(10): 789 – 800.
30   http://nrs.fs.fed.us/pubs/jrnl/1999/ne_1999_dehayes_001.pdf.

31 Delucchi, M., and Hsu, S-L. 1998. The external damage cost of noise emitted from motor vehicles.
32   *Journal of Transportation and Statistics* 1(3): 1–24.

33 Denman, K.L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P.M., Dickinson, R.E., Hauglustaine, D.,
34   Heinze, C., Holland, E., Jacob, D., Lohmann, U., Ramachandran, S., da Silva Dias, P.L., Wofsy,
35   S.C., and Zhang, X. 2007. Couplings Between Changes in the Climate System and
36   Biogeochemistry. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis.
37   Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental
38   Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.
39   B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United
40   Kingdom and New York, NY, USA, pp. 499–588.

347

Domingues, C.M., J. Church, N. White, P. Glecker, S. Wijffels, P. Barker and J. Dunn. 2008. Improved estimates of upper-ocean warming and multi-decadal sea-level rise. Nature 453, 1090-1093. (June 19, 2008)

Driscoll, C. T., Lawrence, G. B., Bulger, A. J., Butler, T. J., Cronan, C. S., Eagar, C., Lambert, K. F., Likens, G. E., Stoddard, J. L., and Weathers, K. C. 2001. Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies. *BioScience* 51(3). http://www.esf.edu/efb/mitchell/Class%20Readings%5CBioSci.51.180.198.pdf.

Dukes, J. S., et al. 2005. Responses of grassland production to single and multiple global environmental changes. *PLoS Biol.* 3(10): 1829–1836. (Cited by Denman et al. 2007.)

EIA. 2008. Annual Energy Outlook 2007. Energy Information Administration, Department of Energy. DOE/EIA-0383(2007). February 2007.

EIA. 2008. International Energy Annual 2005. Energy Information Agency. http://www.eia.doe.gov/iea/carbon.html.

El Maayar, M., Ramankutty, N., and Kucharik, C. J. 2006. Modeling global and regional net primary production under elevated atmospheric CO_2: On a potential source of uncertainty. *Earth Interactions* 10: 1–20.

EPA. n.d. Effects of Acid Rain–Materials. U.S. Environmental Protection Agency. Accessed 06-12-08 at http://www.epa.gov/acidrain/effects/materials.html.

EPA. 1995. U.S. EPA Office of Compliance Sector Notebook: Profile of the Petroleum Refining Industry. EPA/310-R-95-013 SIC Code: 2911. http://www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks/petroleum.html.

EPA. 2000. [ICF-MAP4] EPA's Global Warming Site. U.S. Environmental Protection Agency. http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html.

EPA. 2000a. U.S. EPA Office of Compliance Sector Notebook: Profile of the Oil and Gas Extraction Industry. EPA/310-R-99-006 http://www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks.

EPA. 2000b. U.S. EPA Office of Compliance Sector Notebook: Project Profile of the Agricultural Crop Production Industry. EPA/310-R-00-001 http://www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks/crop.html.

EPA. 2004. Oil Program Update: Special Issue Freshwater Spills Symposium 2004. http://www.epa.gov/emergencies/docs/oil/newsletters/0504update.pdf.

EPA. 2006. Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990 – 2020 (revised). http://www.epa.gov/nonco2/econ-inv/international.html.

EPA. 2007. Effects of Acid Rain – Surface Waters and Aquatic Animals. http://www.epa.gov/acidrain/effects/surface_water.html#a3.

EPA. 2008a. National Ambient Air Quality Standards. U.S. Environmental Protection Agency.
http://epa.gov/air/criteria.html. Web page last updated March 28, 2008. Accessed June 15, 2008.

EPA. 2008b. Green Book, Criteria Pollutants. U.S. Environmental Protection Agency.
http://www.epa.gov/air/oaqps/greenbk/o3co.html. Web page last updated June 3, 2008.
Accessed June 15, 2008.

EPA. 2008. U.S. Environmental Protection Agency. Greenbook. Currently Designated Nonattainment
Areas for All Criteria Pollutants. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed
June 12, 2008.

EPA. 2008. [ICF-MAP3] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006.
Washington, DC: U.S. Environmental Protection Agency. EPA 430-R-08-005. April.
http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

EPA. 2008a. National Water Program Strategy: Response to Climate Change.
http://www.epa.gov/ow/climatechange/docs/3-27-08_ccdraftstrategy_final.pdf.

EPA. 2008b. Spill Location. http://www.epa.gov/emergencies/content/learning/location.htm.

Epstein, P. R., and Selber, J. (Editors). 2002. Oil: A Life Cycle Analysis of its Health and Environmental
Impacts. Boston: The Center for Health and the Global Environment.

FHWA. 2005. Federal Highway Administration Section 4(f) Policy Paper.
http://www.environment.fhwa.dot.gov/projdev/4fpolicy.asp#alternative.

Field, C. B., Mortsch, L. D., Brklacich, M., Forbes, D. L., Kovacs, P., Patz, J. A., Running, S. W., and
Scott, M. J. 2007. North America. IPCC. 2007: Climate Change 2007: Impacts, Adaptation
and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp.
617–652.

Fleming, G. G., Plotkin, K. J., Roof, C. J., Ikelheimer, B. J., and Senzig, D. A. l. 2005. Assessment of
Tools for Modeling Aircraft Noise in the National Parks, for the Federal Interagency Committee
on Aviation Noise, March.

Frumkin, H., Hess, J., and Vindigni, S. 2007. Peak petroleum and public health. *Journal of the
American Medical Association* 298: 1688–1690.

Geary, J. 1998. Mad About The Noise. *Time Magazine* 152(4). July 27.
http://www.time.com/time/magazine/1998/int/980727/cover_story.mad_about_th14.html.

Graham, J. D., Beaulieu, N. D., Sussman, D., Sadowitz, M., and Li, Y. C. 1999. Who lives near coke
plants and oil refineries? An exploration of the evironmental inequity hypothesis. *Risk Analysis*
19(2): 171–186.

Greene, D. L. 2006. On vehicle weight, fuel economy and safety. Expert report of David L. Greene.
Central Valley Chrysler–Jeep v. Whitherspoon: USDC (E.D. Cal.) No. CIV-F-04-6663.

1 Hansen, J., M. Sato, P. Kharecha, G. Russell, D.W. Lea, and M. Siddall. 2007a. Climate change and
2   trace gases. *Phil. Trans. R. Soc. A* 365: 1925-1954.

3 Hansen, J., M. Sato, R. Ruedy, P. Kharecha, A. Lacis, R. Miller, L. Nazarenko, K. Lo, G. A. Schmidt, G.
4   Russell, I. Aleinov, S. Bauer, E. Baum, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen,
5   A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N. Y.
6   Kiang, D. Koch, G. Labow, J. Lerner, S. Menon, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz,
7   D. Rind, A. Romanou1, R. Schmunk, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D.
8   Thresher, N. Unger, M. Yao, and S. Zhang. 2007b. Dangerous human-made interference with
9   climate: a GISS modelE study. Atmos. Chem. Phys. 7: 2287-2312.

10 Heavenrich, R. M. 2005. Light-Duty Automotive Technology and Fuel Economy and Fuel Trends: 1975
11   through 2005. EPA 420-R-05-001, Office of Transportation and Air Quality, U.S.,
12   Environmental Protection Agency, Ann Arbor, Michigan, July.

13 Heinrich, J., and Wichmann, H. 2004. Traffic related pollutants in Europe and their effect on allergic
14   disease. *Current Opinion in Allergy & Clinical Immunology* 4(5): 341–348.

15 Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell,
16   C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R.,
17   Muthiga, N., Bradbury, R.H., Dubi, A., and Hatziolos, M.E. 2007. Coral reefs under rapid
18   climate change and ocean acidification. *Science* 318(5857): 1737 – 1742.

19 Hogan, C. M., and Gregory, A. 2006. Hybrid Vehicle Noise Emission Comparison Study.
20   http://luminatechnologies.org/luminaaco.html.

21 Houghton, R.A. 2003. Emissions (and Sinks) of Carbon from Land-Use Change. (Estimates of national
22   sources and sinks of carbon resulting from changes in land use, 1950 to 2000). Report to the
23   World Resources Institute from the Woods Hole Research Center. http://cait.wri.org.

24 Hymel, M.L. 2007. Globalisation, Environmental Justice, and Sustainable Development: The Case of
25   Oil. *Macquarie Law Journal* Vol. 7.
26   http://www.law.mq.edu.au/html/MqLJ/volume7/07Hyme.pdf.

27 IEA. 2006. CO_2 Emissions from Fuel Combustion (2006 edition). International Energy Agency.
28   http://data.iea.org/ieastore/co2_main.asp.

29 IPCC. 2000. (IPCC. 2000. *Special Report on Emissions Scenarios* (SRES). A Special Report of
30   Working Group III of the Intergovernmental Panel on Climate Change [N. Nakicenovic et al.
31   (Editors)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.).

32 IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to
33   the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. ISBN 978
34   0521 88009-1 Hardback; 978 0521 70596-7 Paperback.

35 IPCC. 2007. WG1. p.820. (IPCC. 2007. Summary for Policymakers. In: IPCC, 2007. Climate
36   Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth
37   Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D.,
38   Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors),
39   Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–18).

1 Kahane, C. J. 2003. Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991 – 99
2   Passenger Cars and Light Trucks. Technical Report No. DOT HS 809 662. Washington, DC:
3   U.S. Department of Transportation, National Highway Traffic Safety Administration.

4 Keenan, G., and Mckenna, B. 2008. GM wakes up and plugs in. Now comes the hard part.
5   http://www.theglobeandmail.com/servlet/story/LAC.20080607.RCOVER07/TPStory/Business

6 Keeney, R. and Hertel, T. 2008. The Indirect Land Use Impacts of U.S. Biofuel Policies: The
7   Importance of Acreage, Yield, and Bilateral Trade Responses, GTAP Working Papers 2810,
8   Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

9 Kharaka, Y. K., and Otton, J. K. 2005. Environmental Impacts of Petroleum Production: Initial Results
10   from the Osage-Skiatook Petroleum Environmental Research Sites, Osage County, Oklahoma.
11   http://pubs.usgs.gov/wri/wri03-4260/pdf/WRIR03-4260.pdf.

12 Koerner, C., et al. 2005. Carbon flux and growth in mature deciduous forest trees exposed to elevated
13   CO_2. *Science* 309(5739): 1360–1362. (Cited by Denman et al. 2007.)

14 Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P, Kabat, P., Jiménez, B., Miller, K. A., Oki, T.,
15   Sen, Z., and Shiklomanov, I. A. 2007. Freshwater resources and their management. In: IPCC,
16   2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working
17   Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,
18   Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors),
19   Cambridge University Press, Cambridge, UK, pp.173–210.

20 Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., Peterson T., and Prather,
21   M. 2007. Historical Overview of Climate Change. In: IPCC, 2007. Climate Change 2007: The
22   Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the
23   Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z.,
24   Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press,
25   Cambridge, United Kingdom and New York, NY, USA, pp. 93–128.

26 Lesaulnier, C., Papamichail, D., McCorkle, S., Ollivier, B., Skiena, S., Taghavi, S., Zak, D., and van der
27   Lelie, D. 2008. Elevated atmospheric CO_2 affects soil microbial diversity associated with
28   trembling aspen. *Environmental Microbiology* 10(4): 926–941.

29 Lindberg, R. L. n.d. Water Encyclopedia; Nutrients in Lakes and Streams.Accessed 6-12-08.
30   http://www.waterencyclopedia.com/Mi-Oc/Nutrients-in-Lakes-and-Streams.html.

31 Lipson, D. A., Wilson, R. F., and Oechel, W. C. 2005. Effects of elevated atmospheric CO_2 on soil
32   microbial biomass, activity, and diversity in a chaparral ecosystem. *Applied and Environmental*
33   *Microbiology* 71(12): 8573–8580.

34 Long, S. P., Ainsworth, E. A., Leakey, A. D. B., Nösberger, J., and Ort, D. B. 2006. Food for thought:
35   Lower-than-expected crop yield stimulation with rising CO_2 concentrations. *Science* 312(5782):
36   1918–1921.

37 Luo, Y., et al. 2005. Progressive nitrogen limitation of ecosystem responses to rising atmospheric carbon
38   dioxide. *Bioscience* 54: 731–739. (Cited by Denman et al. 2007.)

Lynch, M. J., Stretesky, P. B., and Burns, R. G. 2004. Determinants of environmental law violation fines against petroleum refineries: Race, ethnicity, income, and aggregation effects. *Society & Natural Resources* 17(4): 333–347.
http://www.informaworld.com/smpp/content~content=a714491918~db=all.

MacCracken, F., Moore, and J.C. Topping Jr., eds. 2008. Sudden and Disruptive Climate Change. The Climate Institute. Earthscan, Sterling, VA.

Marland, G., Boden, T.A., and Andres, R. J. 2007. Global, Regional, and National Fossil Fuel CO_2 Emissions. In: Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. http://cdiac.ornl.gov/trends/emis/meth_reg.htm.

Meehl, G. A., Stocker, T. F., Collins, W.D., Friedlingstein, P., Gaye, A.T., Gregory, J.,M., Kitoh, A., Knutti, R., Murphy, J. M., Noda, A., Raper, S. C. B., Watterson, I. G., Weaver A.J., and Zhao, Z.-C. 2007. Global Climate Projections. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 747–846.

Morello-Frosch, R. 2002. (Morello-Frosch, R. 2002. The political economy of environmental discrimination. *Environ. Plann. C* 20: 477–496).

Moss, R. H., and Schneider, S. H. 2000. Uncertainties in the IPCC TAR: Recommendations to lead authors for more consistent assessment and reporting. In: Guidance Papers on the Cross Cutting Issues of the Third Assessment Report of the IPCC [eds. R. Pachauri, T. Taniguchi and K. Tanaka], World Meteorological Organization, Geneva, pp. 33-51.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., et al. 2000. Special Report on Emissions Scenarios. Working Group III, Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, 595 pp.
http://www.grida.no/climate/ipcc/emission/index.htm

NAS. 2001. Climate Change Science: An Analysis of Some Key Questions. Committee on the Science of Climate Change, Division of Earth and Life Studies, National Research Council, National Academy of Sciences. National Academy Press, Washington, DC. http://books.nap.edu/html/climatechange/climatechange.pdf.

National Park Service. n.d. Listing a Property: Some Frequently Asked Questions. Accessed 06-12-08. http://www.nps.gov/nr/listing.htm.

National Research Council (NRC). 1984. A Decade of Experience. Special Report 204. Washington, DC: Transportation Research Board.

National Research Council (NRC). 2002. Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. Washington, DC: National Academies Press.

NHTSA. 2008. Preliminary Regulatory Impacts Analysis, Corporate Average Fuel Economy for MY 2011–2015. Passenger Cars and Light Trucks. National Highway Traffic Safety Administration, Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis. April.

352

1   Noland, R. B. 2004. Motor Vehicle Fuel Efficiency and Traffic Fatalities. *The Energy Journal* 25(4): 1–
2   22.

3   Norby, R. J., DeLucia, E. H., Gielen, B., Calfapietra, C., Giardina, C. P., King ,J. S., Ledford, J.,
4   McCarthy, H. R., Moore, D. J. P., Ceulemans, R., De Angelis, P., Finzi, A. C., Karnosky, D. F.,
5   Kubiske, M. E., Lukac, M., Pregitzer, K. S., Scarascia-Mugnozza, G. E., Schlesinger, W. H., and
6   Oren, R. 2005. Forest response to elevated CO2 is conserved across a broad range of
7   productivity. *Proceedings of the National Academy of Sciences of the United States of America*
8   102: 18052–18056.)

9   Norby, R. J., and Iversen, C. M. 2006. Nitrogen uptake, distribution, turnover, and efficiency of use in a
10   CO_2-enriched sweetgum forest. *Ecology* 87: 5–14. (Cited by Denman, et al. 2007.)

11 NRC. 2002. Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.
12   National Research Council. National Acadmies Press. 184 pp.

13 O'Rourke, D., and Connolly, S. 2003. Just oil? The distribution of environmental and social impacts of
14   oil production and consumption. *Annual Review of Environment and Resources* 28: 587–617.
15   http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1485&context=postprints

16 OECD. 1988. Cited in Delucchi and Hsu. 1998. The external damage cost of noise emitted from motor
17   vehicles. *Journal of Transportation and Statistics* 1(3): 1–24.

18 Office of Regulatory Analysis and Evaluation. 2008. Corporate Average Fuel Economy for MY 2011–
19   2015 Passenger Cars and Light Trucks. DOT HW 809 662. Washington, DC: Office of
20   Regulatory Analysis and Evaluation, National Center for Statistics and Analysis.

21 O'Neill, M. S., Zanobetti, A., and Schwartz, J. 2003. Modifiers of the temperature and mortality
22   association in seven US cities. *American Journal of Epidemiology* 157(12): 1074–1082).

23 ORNL/CDIAC. 1990. Carbon Dioxide and Climate, 1990. ORNL/CDIAC-39, Carbon Dioxide
24   Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Third
25   Edition. Edited by: Fred O'Hara Jr. http://cdiac.ornl.gov/pns/convert.html.

26 Orr, J. C., Fabry, V. J., Aumont, O., Bopp, L., Doney, S. C., Feely, R. A., Gnanadesikan, A., Gruber, N.,
27   Ishida, A., Joos, F., Key, R. M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P.
28   Mouchet, A., Najjar, R. G., Plattner, G. K., Rodgers, K. B., Sabine, C. L., Sarmiento, J. L.,
29   Schlitzer, R., Slater, R. D., Totterdell, I. J., Weirig, M-F., Yamanaka, Y., and Yool, A. 2005.
30   Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying
31   organisms. *Nature* 437: 681–686.
32   http://www.nature.com/nature/journal/v437/n7059/abs/nature04095.html.

33 Pastor, M., Sadd, J., and Hipp, J. 2001. Which came first? Toxic facilities, minority move-in, and
34   environmental justice. J *Urban Aff* 23:1–21).

35 Powers, S. E. 2005. Quantifying Cradle-to-Farm Gate Life-Cycle Impacts Associated with Fertilizer
36   Used for Corn, Soybean, and Stover Production. National Renewable Energy Laboratory.
37   Technical Report NREL/TP-510-37500. http://www1.eere.energy.gov/biomass/pdfs/37500.pdf.

Powers, S. E., Hunt, C. S., Heermann, S. E., Corseuil, H. X., Rice, D., Alvarez, P. J. J. 2001. The transport and fate of ethanol and BTEX in groundwater contaminated by gasohol. *Critical Reviews in Environmental Science and Technology* 31(1): 79–123.

Pukkala, E. 1998. Cancer incidence among Finnish oil refinery workers, 1971–1994. *Journal of Occupation and Environmental Medicine* 40: 8.

RGGI. 2006. Preliminary Electricity Sector Modeling Results: Phase III RGGI Reference and Package Scenario. Updated Reference, RGGI Package – 10/11/06, updated 5/22/2007. August 17, 2006. ICF Consulting.

Richardson, A. J. and Poloczanska, E. S. 2008. Ocean science: Under-resourced, under threat. *Science* 320(5881): 1294–1295.

RIVM/TNO. 2003. EDGAR 3.2, Olivier, J.G.J., and Berdowski, J.J.M. 2001. Global emission sources and sinks. In: Berdowski, J., Guicherit, R., and Heij, B.J. (Editors). The Climate System: 33–77. Lisse: Swets & Zeitlinger Publishers). http://www.mnp.nl/edgar/.

Ross, M., Patel, D., and Wenzel, T. 2006. Vehicle Design and the Physics of Traffic Safety. *Physics Today* 49–54. Melville, New York: American Institute of Physics.

Sabine, C. L., Feely, R. A., Gruber, N., Key, R. M., Lee, K., Bullister, J. L., Wanninkhof, R.,Wong, C. S., Wallace, D. W. R., Tilbrook, B., Millero, F. L., Peng, T. H., Kozyr, A., Ono, T., Rios, A. F. 2004. The oceanic sink for anthropogenic CO_2. *Science* 305(5682): 367–371.

Samet, J. M. 2007. Traffic, air pollution, and health. *Inhalation Toxicology* 19: 1021–1027.

Schimel, D., Melillo, J. Tian, H., McGuire, A.D., Kicklighter, D., Kittel, T., Rosenbloom, N., Running, S., Thornton, P., Ojima, D., Parton, W., Kelly, R., Sykes, M., Neilson, R., and Rizzo, B. 2004-2006. *Science* 17(287): 2004–2006.

Schimel, D., Melillo, J., Tian, H., McGuire, A. D., Kicklighter, D., Kittel, T., Rosenbloom, N., Running, S., Thornton, P., Ojima, D., Parton, W., Kelly, R., Sykes, M., Neilson, R., and Rizzo, B. 2004-2006. *Science* 287: 2004–2006.

ScienceDaily. 2007. Elevated Carbon Dioxide Changes Soil Microbe Mix Below Plants, May Help Plants Grow. December 20. http://www.sciencedaily.com/releases/2007/12/071219105808.htm.

Shiklomanov, I. A. and Rodda, J. C. (Editors). 2003. World Water Resources at the Beginning of the 21st Century. Cambridge University Press, Cambridge) and (Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Kabat, P., Jiménez, B., Miller, K. A., Oki, T., Sen, Z., and Shiklomanov, I. A. 2007. Freshwater resources and their management. In: IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 173–210).

Simpson, T. W., Sharpley, A. N., Howarth, R. W., Paerl, H. W., and Mankin, K. R. 2008. The new gold rush: Fueling ethanol production while protecting water quality. *Journal of Environmental Quality* 37: 318–324.

354

Small, K., and van Dender, K. 2005. [ICF - MAP5] The Effect of Improved Fuel Economy on Vehicle Miles Traveled: Estimating the Rebound Effect Using U.S. State Data, 1966-2001. University of California Energy Institute's (UCEI) Energy Policy and Economics Working Paper Series (www.ucei.berkeley.edu/PDF/EPE_014.pdf).

Small, K. A., and Van Dender, K. 2005. A Study to Evaluate the Effect of Reduced Greenhouse Gas Emissions on Vehicle Miles Traveled. State of California Air Resources Board, California Environmental Protection Agency, and the California Energy Commission.

Srinivasan, S., O'Fallon, L. R., and Dearry, A. 2003. Creating Healthy Communities, Healthy Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health. *American Journal of Public Health* 93(9): 1446–1450. http://www.ajph.org/cgi/content/full/93/9/1446#R48.

Stouffer, R. J., and S. Manabe. 2003. Equilibrium response of thermohaline circulation to large changes in atmospheric CO_2 concentration. *Clim. Dyn.* 20: 759–773.

Subramanian, R. 2008. Fatalities and Fatality Rates in Alcohol-Impaired Crashes by State, 2005–2006. NHTSA (National Highway Traffic Safety Administration) Traffic Safety Facts: Research Note. DOT HS 810 920. February. Available online at: http://www-nrd.nhtsa.dot.gov/Pubs/810920.PDF.

Szasz, A. 1994. Ecopopulism: toxic waste and the movement for environmental justice. http://books.google.com/books?hl=en&lr=&id=MBPL_HpmZ8oC&oi=fnd&pg=PP11&dq=oil+e nvironmental+justice+&ots=a7zYJ5NipN&sig=oVzwLYwEbQemBbEMWwWlV23O8jl#PPA2, M1.

Tedesco, K., et al. 2005. Impacts of Anthropogenic CO_2 on Ocean Chemistry and Biology. http://www.oar.noaa.gov/spotlite/spot_gcc.html.

The American Petroleum Institute. 2000. Overview of Exploration and Production Waste Volumes and Waste Management Practices in the United States. http://www.api.org/aboutoilgas/sectors/explore/waste-management.cfm.

USCCSP SAP 3.3. 2008. Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. U.S. Climate Change Science Program and Subcommittee on Global Change Research. [Karl, T. R., Meehl, G. A., Miller, C. D., S. J., Waple, A. M., and Murray, W. L. (Editors)]. Department of Commerce, NOAA's National Climatic Data Center, Washington, DC.

USCCSP. 2008. Scientific Assessment of the Effects of Global Change on the United States. U.S. Climate Change Science Program, Committee on Environment and Natural Resources, National Science and Technology Council, Washington, DC, USA.

van Auken, R. M., and Zellner, J. W. 2003. A Further Assessment of the Effects of Vehicle Weight and Size Parameters on Fatality Risk in Model Year 1985 – 98, Passenger Cars and 1985 – 87 Light Trucks. Volume II: Technical Report. Dynamic Research, Inc.

van Auken, R. M., and Zellner, J. W. 2004a. An Assessment of the Effects of Vehicle Weight and Size on Fatality Risk in 1985 to 1997 Model Year Light Trucks and Vans. SAE Technical Paper Series 05B-244, Warrendale, Pennsylvania: Society of Automotive Engineers.

van Auken, R. M., and Zellner, J. W. 2005. Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track on Fatality Risk in 1985 – 1998 Model Year Passenger Cars and 1985 – 1997 Model Year LTVs. DRI-TR-05-01. Torrance, California: Dynamic Research, Inc.

van Auken, R.M., and Zellner, J. W. 2004b. A Review of the Results in the 1997 Kahane, 2002 DRI, 2003 DRI, and 2003 Kuhane Reports on the Effects of Passenger Car and Light Truck Weight and Size on Fatality Risk. DRI-04-02. Torrance, California: Dynamic Research, Inc.

Van Dam, H. 1996. Partial recovery of moorland pools from acidification: Indications by chemistry and diatoms. *Aquatic Ecology* 30(2–3): 203–218.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., and Melillo, J. M. 1997. Human domination of Earth's ecosystems. *Sceince* 277: 494–499. Cited in: Fischlin, A., Midgley, G. F., Price, J. T., Leemans, R., Gopal, B., Turley, C., Rounsevell, M. D. A., Dube, O. P., Tarazona, J., Velichko, A. A.. 2007. Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, 211–272.

Vitousek, P.M. 1994. Beyond Global Warming: Ecology and Global Change. http://www.jstor.org/pss/1941591.

von Braun, J., and Pachauri, R. K. 2006. The Promises and Challenges of Biofuels for the Poor in Developing Countries. International Food Policy Research Institute 2005–2006 Annual Report Essay. http://www.ifpri.org/pubs/books/ar2005/ar2005_essay.asp#dl.

Walter, K. M., L. C. Smith, and F. S. Chapin, III. 2007. Methane bubbling from northern lakes: present and future contributions to the global methane budget. *Philosophical Transactions of the Royal Society A* 365:1657–1676.

WCI. 2007. Frequently Asked Questions: Western Climate Initiative To Reduce Greenhouse Gases. California Environmental Protection Agency.

Wenzel, T. P., and Ross, M. 2005. The effects of vehicle model and driver behavior on risk. *Accident Analysis and Prevention* 37: 479–494.

Williams, P. R. D., Cushing, C. A., and Sheehan, P. J. 2003. Data available for evaluating the risks and benefits of MBTE and ethanol as alternative fuel oxygenates. *Risk Analysis* 23(5): 1085–1115.

WMO (World Meteorological Organization). 2006. Statement on Tropical Cyclones and Climate Change. Sixth International Workshop on Tropical Cyclones, San Jose, Costa Rica, November 2006. http://www.wmo.ch/pages/prog/arep/tmrp/documents/iwtc_statement.pdf

WMO. 2006. Scientific Assessment of Ozone Depletion. 2006. Global Ozone Research and Monitoring Project Report No. 50, World Meteorological Organization, Geneva, 572 pp.)

WRI. 2008. Climate Analysis Indicators Tool (CAIT) Version 5.0. Washington, DC: World Resources Institute. http://cait.wri.org.

1   WWJ News Radio. 2008. Car Makers React to the Reality of Higher Gas Prices.
2   http://www.wwj.com/Car-Makers-React-to-the-Reality-of-Higher-Gas-Pric/2323458.

3   Zogorski, J. S., Carter, J. M., Ivahnenko, T., Lapham, W. W., Moran, M. J., Rowe, B. L., Squillace, P. J.,
4   and Toccalino, P. L. 2006. The quality of our Nation's waters—Volatile organic compounds in
5   the Nation's ground water and drinking-water supply wells. *U.S. Geological Survey Circular*
6   1292: 101 pp.

8.3   CHAPTER 4 REFERENCES

8   ACIA. 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University
9   Press, 139 pp.

10 Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B.,
11   and Takahashi, K. 2007. Assessment of adaptation practices, options, constraints and capacity.
12   In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of
13   Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate
14   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
15   (Editors), Cambridge University Press, Cambridge, UK, pp. 717–743.

16 Adger, W., Hughes, T., Folke, C., Carpenter, S., and Rockstorm, J. 2005. Social-ecological resilience to
17   coastal disastors. *Science* 309: 1036–1039. Cited in: IPCC, 2007. Climate Change 2007:
18   Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
19   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
20   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
21   Press, Cambridge, UK, 976 pp.

22 Ahren, M. J., Kovatis, R. S., Wilkinson, P., Few, R., and Mattheis, F. 2005. Global health impacts of
23   floods: epidemiological evidence. *Epidemiol. Rev.* 27: 36–45. Cited in: IPCC, 2007. Climate
24   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
25   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
26   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
27   University Press, Cambridge, UK, 976 pp.

28 Ainsworth, E. A., and Long, S. P. 2005. What have we learned from 15 years of free-air CO_2 enrichment
29   (FACE)? A meta-analytic review of the responses of photosynthesis canopy. *New Phytologist*
30   165(2): 351–371.

31 Alley et al. 2007. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on
32   Global Change Research. 2008. Analyses of the effects of global change on human health and
33   welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for
34   CCSP and CENR clearance. April, 273 pp.

35 Alley, R. B., et al. 2002. Abrupt Climate Change: Inevitable Surprises. US National Research Council
36   Report, National Academy Press, Washington, DC. 230 pp.

37 Allison, E. H., W. N. Adger, M. C. Badjeck, K. Brown, D. Conway, N. K. Dulvy, A. Halls, A. Perry, and
38   J. D. Reynolds. 2005. Effects of Climate Change on the Sustainability of Capture and
39   Enhancement Fisheries Important to the Poor: Analysis of the Vulnerability and Adaptability of
40   Fisherfolk Living in Poverty. Final Technical Report, Project No. R4778J, Fisheries Management

Science Programme, MRAG for Department for International Development, London, 167 pp. www.fmsp.org.uk/Documents/r4778j/R4778J_FTR1.pdf.

Alvarez, E., de Pablo, R., Tomas, C., and Rivas, L. 2000. Spatial and temporal variability of ground-level ozone in Castilla-Leon (Spain). *Int J. Biometeorol.* 44: 44–51. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

American Academy of Pediatrics, Committee on Environmental Health. 2007. Global Climate change and children's health. *Pediatrics* 120(5): 1149–1152.

American Lung Association. 2008. Protect the Air you Breathe. State of the Air. http://www.lungusa2.org/sota/SOTA2008.pdf.

Anderson, P. K., Cunningham, A. A., Patel, N. G., Morales, F. J., Epstein, P. R., and Daszak, P. 2004. Emerging infectious diseases of plants: Pathogen pollution, climate change, and agrotechnology drivers. *Trends in Ecology Evolution* 19: (2004).

Anderson, P., J. Brownstein, U. Confalonieri, D. Causey, N. Chan, K.L. Ebi, J.H. Epstein, J.S. Greene, R. Hayes, E. Hofmann, L.S. Kalkstein, T. Kjellstrom, R. Lincoln, A.J. McMichael, C. McNeill, D. Mills, A. Milne, A.D. Perrin, G. Ranmuthugala, C. Rogers, C. Rosenzweig, C. L. Soskolne, G. Tabor, M. Vicarelli, X.B. Yang. 2005. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School.

Andrey, J., and Mills, B. N. 2003. Climate change and the Canadian transportation system: Vulnerabilities and adaptations. In: Weather and Transportation in Canada, Andrey, J., and Knapper, C. J. (Editors), Department of Geography Publication Series 55, University of Waterloo, Waterloo, Ontario. pp. 235–279.

Anisimov, O. A., Vaughan, D. G., Callaghan, T. V., Furgal, C. Marchant, H., Prowse, T. D., Vilhjálmsson, H., and Walsh, J. E. 2007. Polar regions (Arctic and Antarctic). In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 653–686.

Anon. 2006. Bluetongue confirmed in France. News and Reports, *Veterinary Record*, 159: 331.

Ansmann, A., Bosenberg, J., Chaikovsky, A., Comeron, A., Echkardt, S., Eixmann, R., Freudenthaler, V., Ginoux, P., Komguem, L., Limme, H., Marquez, M. A. L., Sauvage, V., Sobolewsky, P., Srivastava, M. K., Stohl, A., Torres, O., Vaughan, G., Wandinger, U., and Wiegner, M. 2003. Long-range transport of Saharan dust to northern Europe: the 11-16 October 2001 outbreak observed with EARLINET. *Journal of Geophysical Research – Atmospheres* 108: 4783. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

358

1   Argonne. 2002. The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model.
2   Version 1.8a, Argonne National Laboratories, February 2002.
3   http://www.transportation.anl.gov/software/GREET/index.html

4   Arnell, N. 2002. Hydrology and Global Environmental Change. Pearson Education Ltd, Edinburgh,
5   United Kingdom.

6   Arnell, N.W. C. Liu, R. Compagnucci, L. da Cunha, K. Hanaki, C. Howe, G. Mailu, I Shiklomanov and
7   E. Stakhiv. 2001. Hydrology and water resources. In: Climate Change 2001: Impacts,
8   Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report
9   of the Intergovernmental Panel on Climate Change. J.J. McCarthy, O.F. Canziani, N.A. Leary,
10   D.J. Dokken, and K.S.White (Editors), Cambridge University Press, Cambridge, pp. 191–234.

11   Aucott, M., and Caldarelli, A. 2006. Climate Change Trends in New Jersey: Trends in Temperature and
12   Sea Level. New Jersey Department of Environmental Protection.

13   Australian Academy of Science. 2008. Acid test for the seas. Last revised: January 2008. Available
14   online at: http://www.science.org.au/nova/106/106key.htm. Accessed: June 23, 2008.

15   Aw, J. and Kleeman, M. J. 2003. Evaluating the first-order effect of inter-annual temperature variability
16   on urban air pollution. *Journal of Geophysical Research* 108:7-1–7-18. Cited in: U.S. Climate
17   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.
18   Analyses of the effects of global change on human health and welfare and human systems.
19   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
20   April, 273 pp.

21   AWWA (American Water Works Association). 2006. Optimizing Filtration Operations. CD-ROM
22   catalogue no. 64275. http://www.awwa.org/bookstore.

23   Bachelet, D., Neilson, R. P., Lenihan, J. M., and Drapek, R. J. 2001. Climate change effects on
24   vegetation distribution and carbon budget in the United States. *Ecosystems* 4: 164–185.

25   Bachelet, D., Neilson, R. P., Lenihan, J. M., and Drapek, R. J. 2004. Regional differences in the carbon
26   source-sink potential of natural vegetation in the U.S.A. *Environmental Management* 33: S23–
27   S43, doi:10.1007/s00267-003-9115-4.

28   Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball,
29   T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M. Ryan, S. Archer, R. Birdsey,
30   C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W.
31   Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L
32   Meyerson, B. Peterson, and R. Shaw. 2008. The effects of climate change on agriculture, land
33   resources, water resources, and biodiversity. SAP 4.3 by the U.S. Climate Change Science
34   Program and the Subcommittee on Global Change Research. U.S. Environmental Protection
35   Agency, Washington, DC., USA, 362 pp.

36   Baker, T. R., Phillips, O. L., Malhi, Y., Almeida, S., Arroyo, L., DiFiore, A., Erwin, T., Higuchi, N.,
37   Killeen, T. J., Laurance, S. G., Laurance, W. F., Lewis, S. L., Monteagudo, A., Neill, D. A.,
38   Vargas, P. N., Pitman, N. C. A., Silva, J. N. M, and Martinez, R. V. 2004. Increasing biomass in
39   Amazonian forest plots. *Philos. T. Roy. Soc. Lond. B* 359: 353–365.

Barber, R. 2001. Upwelling ecosystems. In: Encyclopedia of Ocean Sciences, Steele, J.H., Thorpe, S. A., and Turekian, K. K. (Editors), Academic Press, London, pp. 3128.

Barnett, T. P., and Pierce, D.W. 2008. When will Lake Mead go dry? *Water Resources Research* 10: 1029/R006704.

Barnett, T. P., D.W. Pierce, H.G. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan, and M.D. Dettinger. 2008. Human-induced changes in the hydrology of the western United States. *Science* 319: 1080–1083.

Barnett, T.P., J.C. Adam, and D.P. Lettenmaier. 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438: 303–309.

Bartholow, J.M. 2005. Recent water temperature trends in the Lower Klamath River, California. Journal of Fisheries Management 25: 152–162.

Basu, R., Dominici, F., and Samet, J. M. 2005. Temperature and mortality among the elderly in the United States: a comparison of epidemiologic methods. *Epidemiology* 16(1): 58–66. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Bates, D. V. 2005. Ambient ozone and mortality. *Epidemiology* 16: 427–429. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp. And in: Ebi, K., Blabus, J., Kinney, P., Lipp, E., Mills, D., O'Neill, M., and Wilson, M. 2008. Effects of Global Change on Human Health. Synthesis and Assessment Product 4.6 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA (peer-reviewed draft report).

Beaugrand, G. 2004. The North Sea regime shift: evidence, causes, mechanisms and consequences. *Progress in Oceanography* 60: 245–262.

Beaugrand, G., Reid, P. C., Ibanez, F., Lindley, J. A., and Edwards, M. 2002. Reorganization of North Atlantic marine copepod biodiversity and climate. *Science* 296: 1692–1694.

Beever, E. A., Brussard, P. F., and Berger, J. 2003. Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. *Journal of Mammology* 84: 37–54.

Beggs, P. J. 2004. Impacts of climate change on aeroallergens: past and future. *Clinical and Experimental Allergy* 34: 1507–1513. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Beggs, P. J., and Bambrick, H. J. 2005. Is the global rise of asthma an early impact of anthropogenic climate change? *Environmental Health Perspectives* 113: 915–919. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II

to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Bélanger, G., Rochette, P., Castonguay, Y., Bootsma, A., Mongrain, D., and Ryand, A. J. 2002. Climate change and winter survival of perennial forage crops in Eastern Canada. *Agron. J.* 94: 1120–1130. Cited in: (Field, C. B., Mortsch, L. D., Brklacich, M., Forbes, D. L., Kovacs, P., Patz, J. A., Running, S. W., and Scott, M. J. 2007. North America. In: IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 617–653.

Bell, M. L., Peng, R. D., and Dominici, F. 2006. The exposure-response curve for ozone and risk of mortality and the adequacy of current ozone regulations. *Environmental Health Perspectives* 114: 532–536. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Bell, M. L., Peng, R. D., Dominici, F., and Samet, J. M. 2005. A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study. *Epidemiology* 16: 436–445. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Benetiz, T. A., Rodriquez, A., and Sojo, M. 2004. Descripcion de un brote epidmemico de malaria de altura en un areas orignalmetne sin malaria del Estado Trujillo, Venesuela. *Boletin de Malariologia y Salud Ambiental* 44: 999. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Berthelot, M., et al. 2002. Global response of the terrestrial biosphere to CO_2 and climate change using a coupled climate-carbon cycle model. *Global Biogeochem. Cycles* 16: 1084.

Bertrand, M. R., and Wilson, M. L. 1996. Microclimate-dependent survival of unfed adult *Ixodes scapularis* (acari: Ixodidae) in nature: life cycle and study design implications. *Journal of Medical Entomology* 33:619–627. In: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Betts, R.A., O. Boucher, M. Collins, P.M. Cox, P.D. Falloon, N. Gedney, D.L. Hemming, C. Huntingford, C.D. Jones, D.M.H. Sexton, and M.J. Webb. 2007. Increase of projected 21st-century river runoff by plant responses to carbon dioxide rise. *Nature* doi: 10.1038/nature06045.

1   Bhatt, V. J., Eckmann, J., Horak, W. C., and Wilbanks, T. J. 2007. Possible indirect effects on energy
2   production an distribution in the United States Cited in: Effects of Climate Change on Energy
3   Produciton and Use in the United States. A Report by the U.S. Climate Change Science Program
4   and the subcommittee on Global change Research. Washington, DC.

5   Bindoff, N. L., Willebrand, J., Artale, V., Cazenave, A., Gregory, J., Gulev, S., Hanawa, K., Le Quéré, C.,
6   Levitus, S., Nojiri, Y., Shum, C. K., Talley, L. D., and Unnikrishnan, A. 2007. Observations:
7   Oceanic climate change and sea level. In: IPCC, 2007. Climate Change 2007: The Physical
8   Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the
9   Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z.,
10   Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press,
11   Cambridge, United Kingdom and New York, NY, USA, pp. 385–432.

12   Blaikie, P., Cannon, T., Davis, I., and Wsiner, B. 1994. At Risk: Natural Hazards, People's Vulnerability
13   and Disasters, 2nd ed., Routledge, New York, 320pp. Cited in: IPCC, 2007. Climate Change
14   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
15   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
16   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
17   Press, Cambridge, UK, 976 pp.

18   Bobba, A., V. Singh, R. Berndtsson, and L. Bengtsson. 2000. Numerical simulation of saltwater
19   intrusion into Laccadive Island aquifers due to climate change. J. Geol. Soc. India 55: 589–612.

20   Bouma, M. J. and Pascual, M. 2001. Seasonal and interannual cycles of endemic cholera in Bengal
21   1891-1940 in relation to climate and geography. *Hydrobiologia* 460: 147 – 56. Cited in: IPCC,
22   2007. Climate Change 2007 : Impacts, Adaptation and Vulnerability. Contribution of Working
23   Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,
24   Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., and Hanson, C.E. (Editors),
25   Cambridge University Press, Cambridge, UK, 976 pp.

26   Boyer, J. S. 1995. Biochemical and biophysical aspects of water deficits and the predisposition to
27   disease. *Annu. Rev. Phytopathol.* 33: 251–274. Cited in: Epstein, P. R., Mills, E., Frith, K.,
28   Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health,
29   Ecological and Economic Dimensions. The Center for Health and the Global Environment,
30   Harvard Medical School. 142 pp.

31   Brander, K. M. 2005. Cod recruitment is strongly affected by climate when stock biomass is low. *ICES*
32   *Journal of Marine Science* 62: 339–343.

33   Breshears, D. D., Cobb, N. S., Rich, P. M., Price, K. P., Allen, C. D., Balice, R. G., Romme, W. H.,
34   Kastens, J. H., Floyd, M. L., Belnap, J., Anderson, J. J., Myers, O. B., and Meyer, C. W. 2005.
35   Regional vegetation die-off in response to global-change-type drought. *Proceedings of the*
36   *National Academy of Sciences, USA* 102: 15144–15148.

37   Brown, J. L., Liand, S. H., and Bhagabati, B. 1999. Long-term trend toward earlier breeding in an
38   American bird: A response to global warming? *Proceedings of the National Academy of Sciences*
39   96: 5565–5569.

40   Brown, T. J., Hall, B. L., and Westerling, A. L. 2004. The impact of twenty-first century climate change
41   on wildland fire danger in the western United States: an applications perspective. *Climatic*
42   *Change* 62: 365–388. Cited in: Ebi, K., Blabus, J., Kinney, P., Lipp, E., Mills, D., O'Neill, M.,

1   and Wilson, M. 2008. Effects of Global Change on Human Health. Synthesis and Assessment
2   Product 4.6 by the U.S. Climate Change Science Program and the Subcommittee on Global
3   Change Research, Washington, DC, USA (peer-reviewed draft report).

4   Bruinsma, J. 2003. World Agriculture: Towards 2015/2030: An FAO perspective. Earthscan, London
5   and FAO, Rome, London. 432 pp.

6   Bryant, D., Burke, L., McManus, J., and Spalding, M. 1998. Reefs at Risk: A Map-Based Indicator of
7   Threats to the World's Coral Reefs. Washington, DC: WRI. http://pdf.wri.org/reefs.pdf

8   Buchanan, C. M., Beverland, I. J., and Heal, M. R. 2002. The influence of weather-type and long-range
9   transport on airborne particle concentrations in Edinburgh, UK. *Atmos. Environ.* 36: 5343–5354.
10   Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability.
11   Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental
12   Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and
13   Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

14   Bull, S. R., Bilello, D. E., Ekmann, J., Sale, M. J., and Schmalzer, D. K. 2007. Effects of climate change
15   on energy production and distribution in the United States. Cited in: Effects of Climate Change
16   on Energy Production and Use in the United States. A Report by theU.S. Climate Change
17   Science Program and the subcommittee on Global change Research. Washington, DC

18   Burke, E. J., Brown, S. J., and Christidis, N. 2006. Modelling the recent evolution of global drought and
19   projections for the 21st century with the Hadley Centre climate model. *J. Hydrometeorol.* 7: 113
20   – 1125.

21   Burke, L., Kura, Y., Kassem, K., Revenga, C., Spalding, M., and McAllister, D. 2001. Pilot Analysis of
22   Global Ecosystems. Coastal Ecosystems. Washington, D.C.: WRI.
23   http://pdf.wri.org/page_coastal.pdf

24   Bush, M. B., Silman, M. R., and Urrego D. H. 2004. 48,000 years of climate and forest change in a
25   biodiversity hot spot. *Science* 303: 827–829.

26   Butler, C. 2003. The disproportionate effect of climate change on the arrival dates of short distance
27   migrant birds. *Ibis* 145: 484–495.

28   California Climate Change Center. 2006a. Our Changing Climate. CEC-500-2006-077.

29   California Energy Commission. 2006. Our Changing Climate: Assessing the Risks to California.
30   http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF.

31   California Environmental Protection Agency. 2006. Climate Action Team Report to the Governor and
32   Legislature, 110 pp.

33   California Environmental Resources Evaluation System. 2000.
34   http://ceres.ca.gov/ceres/calweb/coastal/wetlands.html

35   Campbell-Lendrum, D., Pruss-Ustun, A., and Corvalan, C. 2003. How much disease could climate
36   change cause? Climate Change and Human Health: Risks and Responses, McMichael, A.,
37   Campbell-Lendrum, D., Corvalan, C., Ebi, K., Githeko, A., Scheraga, J., and Woodward, A.
38   (Editors), WHO/WMO/UNEP, Geneva, 113–159. Cited in: IPCC, 2007. Climate Change 2007:

Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Carbone, G. J., Kiechle, W., Locke, L., Mearns, L. O., McDaniel, L., and Downton, M. W. 2003. Response of soybean and sorghum to varying spatial scales of climate change scenarios in the southeastern United States. *Climatic Change* 60: 73–98.

Carson, C., Hajat, S., Armstrong, B., and Wilkinson, P. 2006. Declining vulnerability to temperature-related mortality in London over the 20th century. *American Journal of Epidemiology* 164(1): 77–84. U. S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Casola, J.H.; Kay, J.E.; Snover, A.K.; Norheim, R.A.; Whitely Binder, L.C.; the Climate Impacts Group. 2005. Climate impacts on Washington's hydropower, water supply, forests, fish, and agriculture. A report prepared for King County (Washington) by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle). 43 pp.

Cayan, D. et al. 2006. Projecting Future Sea Level Rise. California Climate Change Center.

Cayan, D. R., Kammerdiener, S., Dettinger, M. D., Caprio, J. M., and Peterson, D. H. 2001. Changes in the onset of spring in the western United States. *Bulletin of the American Meteorological Society* 82: 399–415.

CCF (Climate Change Futures). 2005. Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School.

CCSP. 2008. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, S.H., J.M. West (eds.), J.S. Baron, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, 873 pp. (SAP 4.4)

CCSP. 2008b. The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P. Backlund, A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M. Ryan, S. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L Meyerson, B. Peterson, R. Shaw. U.S. Environmental Protection Agency, Washington, DC., USA, 362 pp (SAP 4.3)

CCSP. 2008b. Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Savonis, M. J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, DC, USA, 445 pp.

364

Cecchi, L., Morabito, M., Paola. D. M., Crisci, A., Onorari, M., and Orlandini, S. 2006. Long distance transport of ragweed pollen as a potential cause of allergy in central Italy. *Annals of Allergy, Asthma, and Immunology.* 96: 86–91. Cited in: IPCC, 2007. Climate Change 2007 : Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Chan, C., Chan, L. Y., Lam, K. S., Li, Y. S., Harris, J. M., and Oltmans, S. J. 2002. Effects of Asian air pollution transport and photochemistry on carbon monoxide variability and ozone production in subtropical coastal south China. *Journal of Geophysical Research D* 107: 4746.

Chapin, F. S., Callaghan, T. V., Bergeron, Y., Fukuda, M., Johnstone, J. F., Juday, G., and Zimov, S. A. 2004. Global change and the boreal forest: thresholds, shifting states or gradual change? *Ambio* 33: 361–365.

Chaudhury, S. K., Gore, J. M., and Ray, K. C. S. 2000. Impact of heat waves in India. *Current Science* 79: 153–155. Cited in: IPCC, 2007. Climate Change 2007 : Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Checkley, W., Epstein, L. D., Gilman, R. H., Figueroa, D., Cama, R. J., Patz, J. A., and Black, R. E. 2000. Effects of El Nino and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet* 355: 112–118. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Checkley, W., Gilman, R. H., Black, R. E., Epstein, L. D., Cabrera, L., Sterling, C. R., and Moulton, L. H. 2004. Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. *Lancet* 363: 112–118. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Chen, K., Ho, Y., Lai, C., Tasi, Y., and Chen, S. 2004. Trends in concentration of the Kao-Ping Airshed, Taiwan. *Journal of Air and Waste Management* 54: 36–48. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Chorus, I. and Bartram, J. (Editors). 1999. Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring and Management (F & FN Spon for the World Health Organization, London, 1999). Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic

365

1   Dimensions. The Center for Health and the Global Environment, Harvard Medical School.
2   142 pp.

3   Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kwon, W. T., et al.
4   2007. Regional climate projections. In: IPCC, 2007. Climate Change 2007: The Physical
5   Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the
6   Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z.,
7   Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (Editors), Cambridge University Press,
8   Cambridge, United Kingdom and New York, NY, USA, pp. 847–940.

9   Ciais, P., Reichstein, M., Viovy, N., Granier, A., Ogee, J., Allard, V., Aubinet, M., Buchmann, N., et al.
10   2005. Europe-wide reduction in primary productivity caused by the heat and drought in 2003.
11   *Nature* 437: 529–534.

12 CIER (Center for Integrative Environmental Research). 2007. The US Economic Impacts of Climate
13   Change and the Costs of Inaction, University of Maryland.

14 Clark, M. E., Rose, K. A., Levine, D. A., and Hargrove, W. W. 2001. Predicting climate change effects
15   on Appalachian trout: Combining GIS and individual-based modeling. Ecological Applications
16   11: 161–178.

17 Colwell, R. R. 1996. Global climate and infectious disease: the cholera paradigm. *Science* 274: 2025–
18   2031. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability.
19   Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental
20   Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and
21   Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

22 Confalonieri U, Menne, B, Akhtar, R, Ebi, K. L., Hauengue, M., Kovats, R. S., Revich, B., and
23   Woodward, A. Human health. 2007. Cited in: IPCC, 2007. Climate Change 2007: Impacts,
24   Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment
25   Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F.,
26   Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press,
27   Cambridge, UK, 976 pp.

28 Conti, S., Meli, P., Mineeli, G., Solimini, R., Toccaceli, V., Vichi, M., Beltrano C., and Perini, L. 2005.
29   Epidemiologic study of mortality during the Summer 2003 heat wave in Italy. *Environmental*
30   *Research* 98: 390–399. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and
31   Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
32   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
33   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976
34   pp.

35 Cook, J.T., and D.A. Frank. 2007. Food security, poverty, and human development in the United States.
36   *Annals of the New York Academy of Sciences* 1–16.

37 Cox, P. M., Betts, R. A., Collins, M., Harris, P. P., Huntingford, C., and Jones, C. D. 2004. *Theor Appl*
38   *Clim.* 78: 137–156.

39 Cox, P. M., Betts, R. A., Jones, C. D., Spall, S. A., and Totterdell, I. J. 2000. Acceleration of global
40   warming due to carbon-cycle feedbacks in a coupled climate model. *Nature* 408: 184 – 187.

1 Craig, M. H., Kleinschmidt, I., Nawn, J. B., Le Sueur, D., and Sharp, B. 2004. Exploring 30 years of
2   malaria case data in KwaZulu-Natal, South Africa. Part I. The impact of climatic factors.
3   *Tropical Medicine and International Health* 9: 1247. Cited in: IPCC, 2007. Climate Change
4   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
5   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
6   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
7   Press, Cambridge, UK, 976 pp.

8 Crozier, L. 2003. Winter warming facilitates range expansion: Cold tolerance of the butterfly *Atalopedes*
9   *campestris*. *Oecologia* 135: 648–656.

10 Crozier, L., and R.W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential
11   population responses in juvenile Chinook salmon. *Journal of Animal Ecology* 75: 1100–
12   1109.

13 Csatho, B., Schenk, T., Van Der Veen, C. J., and Krabill, W. B. 2008. Intermittent thinning of
14   Jakobshavn Isbrae, West Greenland, since the Little Ace Age. *Journal of Glaciology* 54(184):
15   131–144. http://rsl.geology.buffalo.edu/documents/csatho_j07j061.pdf.

16 CSD. 2007. United Nations Commission on Sustainable Development. Indicators of Sustainable
17   Development: Third Edition. New York, 170. (On-line) Accessed on June 12, 2008 at
18   http://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets.pdf

19 Curriero, F. C., Patz, J. A., Rose, J. B. and Lele, S. 2001. The association between extreme precipitation
20   and waterborne disease outbreaks in the United States, 1948–1994. *American Journal of Public*
21   *Health* 91: 1194–1199. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and
22   Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic
23   Dimensions. The Center for Health and the Global Environment, Harvard Medical School.
24   142 pp.

25 Curriero, F., Heiner, K. S., Samat, J., Zeger, S., Strug, L., and Patz, J. A. 2002 Temperature and
26   mortality in 11 cities of the Eastern United States. *American Journal of Epidemiology* 155: 80–
27   87. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability.
28   Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental
29   Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and
30   Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

31 Curriero, F., Patz, J., Rose, J., and Lele, S. 2001. Analysis of the association between extreme
32   precipitation and waterborne disease outbreaks in the United States: 1948–1994. *American*
33   *Journal of Public Health* 91(8): 1194–1199. Cited in: U.S. Climate Change Science Program
34   (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of
35   global change on human health and welfare and human systems. Synthesis and Assessment
36   Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

37 Curry, R., and Mauritzen, C. 2005. Dilution of the Northern North Atlantic Ocean in recent decades.
38   *Science* 308: 1772–1774.

39 D'Amato, G., Liccardi, G., D'Amato, M., and Cazzola, M. 2002. Outdoor air pollution, climatic changes
40   and allergic bronchial asthma. *European Respiratory Journal* 20: 763–776. Cited in: IPCC,
41   2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working
42   Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,

1   Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors),
2   Cambridge University Press, Cambridge, UK, 976 pp.

3 D'Antonio, J.R. 2006 The Impact Of Climate Change On New Mexico's Water Supply And Ability To
4   Manage Water Resources. New Mexico Office of the State Engineer/Interstate Stream
5   Commission.

6 D'Souza, R., Becker, N., Hall, G., and Moodie, K. 2004 Does ambient temperature affect foodborne
7   disease? *Epidemiology* 15: 86–92. Cited in: IPCC, 2007. Climate Change 2007: Impacts,
8   Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment
9   Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F.,
10   Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press,
11   Cambridge, UK, 976 pp.

12 DaSilva, J., Garanganga, B., Teveredzi, V., Marx, S., Mason, S., and Connor, S. 2004. Improving
13   epidemic malaria planning, preparedness and response in South Africa. *Malaria Journal* 3: 37.
14   In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of
15   Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate
16   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
17   (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

18 Davis, M. B., and Shaw, R. G. 2001. Range shifts and adaptive responses to Quaternary climate change.
19   *Science* 292: 673–679.

20 Davis, M. S., Mader, T. L., Holt, S. M., and Parkhurst, A. M. 2003. Strategies to reduce feedlot cattle
21   heat stress: effects on tympanic temperature. Journal of Animal Science 81: 649–661.

22 Davis, R. E., Knappenberger, P. C., Michaels, P. J., and Novicoff, W. M. 2003a. Changing heat-related
23   mortality in the United States. *Environmental Health Perspectives* 111(14): 1712–1718. Cited
24   in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change
25   Research. 2008. Analyses of the effects of global change on human health and welfare and
26   human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR
27   clearance. April, 273 pp.

28 Davis, R. E., Knappenberger, P. C., Novicoff, W. M., and Michaels, P. J. 2003b. Decadal changes in
29   summer mortality in U.S. cities. *International Journal of Biometeorology* 47(3): 166–175. Cited
30   in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change
31   Research. 2008. Analyses of the effects of global change on human health and welfare and
32   human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR
33   clearance. April, 273 pp.

34 Davis, R., Knappenberger, P., Novicoff, W., and Michaels, P. 2002. Decadal changes in heat-related
35   human mortality in the eastern United States. *Climate Research* 22: 175–184. Cited in: U.S.
36   Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research.
37   2008. Analyses of the effects of global change on human health and welfare and human systems.
38   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
39   April, 273 pp.

40 Day, J. C. 1996. Population Projections of the United States by Age, Sex, Race and Hispanic Origin:
41   1995–2050. (Census UsBot, ed.), Current Population Reports P25-1130. Cited in: U.S. Climate
42   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.

1   Analyses of the effects of global change on human health and welfare and human systems.
2   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
3   April, 273 pp.

4   De, U. S., and Mukhopadhyay, R. K. 1998. Severe heat wave over the Indian sub-continent in 1998, in
5   perspective of global climate. *Current Science* 75: 1308–1315. Cited in: IPCC, 2007. Climate
6   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
7   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
8   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
9   University Press, Cambridge, UK, 976 pp.

10   De, U. S., Khole, M., and Dandekar, M. 2004. Natural hazards associated with meteorological extreme
11   events. *Natural Hazards* 31: 487–497. Cited in: IPCC, 2007. Climate Change 2007: Impacts,
12   Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment
13   Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F.,
14   Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press,
15   Cambridge, UK, 976 pp.

16   Denman, K. L., Brasseur G., Chidthaisong, A., Ciais, P., Cox, P. M., Dickinson, R. E., Hauglustaine, D.,
17   Heinze, C., Holland, E., Jacob, D., Lohmann, U., Ramachandran, S, da Silva Dias, P. L., Wofsy,
18   S. C., and Zhang, X. 2007. Couplings Between Changes in the Climate System and
19   Biogeochemistry. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis.
20   Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental
21   Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.
22   B., Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United
23   Kingdom and New York, NY, USA, pp. 499–588.

24   Derocher, A. E., Lunn, N. J., and Stirling, I. 2004. Polar bears in a warming climate. *Integrative and*
25   *Comparative Biology* 44: 163–176.

26   DFID (Department for International Development). 2004. Key Sheet Series on the Impact of Climate
27   Change on Poverty, Focusing on Vulnerability, Health and Pro-poor Growth. No. 01, 6 pp.

28   Diaz, H. F., Eischeid, J. K., Duncan, C., and Bradley, R. S. 2003. Variability of freezing levels, melting
29   season indicators, and snow cover for selected high-elevation and continental regions in the last
30   50 years. *Climatic Change* 59: 33–52.

31   Diaz, J., Jordan, A., Garcia, R., Lopez, C., Alberdi, J. C., Hernandez, E., et al. 2002. Heat waves in
32   Madrid 1986–1997: Effects on the health of the elderly. *International Archives of Occupational*
33   *& Environmental Health* 75(3): 163–170. Cited in: U.S. Climate Change Science Program
34   (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of
35   global change on human health and welfare and human systems. Synthesis and Assessment
36   Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

37   Dockery, D. W., Pope, C. A., III, Xu, X., et al. 1993. An association between air pollution and mortality
38   in six U.S. cities. *New England Journal of Medicine* 329: 1753–59. Cited in: U.S. Climate
39   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.
40   Analyses of the effects of global change on human health and welfare and human systems.
41   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
42   April, 273 pp.

1   Doctor, S., and Wazniak, C. E. 2005. Status of horseshoe crab, *Limulus polyphemus*, populations in
2   Maryland coastal bays. Chapter 8.7 in Wazniak, C.E. and M.R. Hall (Editors). 2005.
3   Maryland's Coastal Bays: Ecosystem Health Assessment 2004. DNR-12-1202-0009. Maryland
4   Department of Natural Resources, Tidewater Ecosystem Assessment, Annapolis, MD.

5   Döll, P., and M. Flörke. 2005. Global-scale estimation of diffuse groundwater recharge. Frankfurt
6   Hydrology Paper 03. Institute of Physical Geography, Frankfurt University, 26 pp.

7   Domingues, C. M., Church, J., White, N., Glecker, P., Wijffels, S., Barker P., and Dunn, J. 2008.
8   Improved estimates of upper-ocean warming and multi-decadal sea-level rise. *Nature* 453: 1090–
9   1093.

10   Dominici, F., Peng, R. D., Bell, M. L., Pham, L., McDermott, A., Zeger, S. L., and Samet, J. M. 2006.
11   Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases.
12   *Journal of the American Medical Association* 295(10): 1127–34. Cited in: U.S. Climate Change
13   Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of
14   the effects of global change on human health and welfare and human systems. Synthesis and
15   Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

16   Donaldson, G. C., Rintamaki, H., and Nayha, S. 2001. Outdoor clothing: its relationship to geography,
17   climate, behaviour and cold-related mortality in Europe. *International Journal of*
18   *Biometeorology* 45(1): 45–51. Cited in: U.S. Climate Change Science Program (CCSP) and the
19   Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on
20   human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third
21   review draft for CCSP and CENR clearance. April, 273 pp.

22   Dukes, J. S., et al. 2005. Responses of grassland production to single and multiple global environmental
23   changes. *PLoS Biology* 3(10): 1829–1836.

24   Durongdej, S. 2001. Land use changes in coastal areas of Thailand. Proceedings of the
25   APN/SURVAS/LOICZ Joint Conference on Coastal Impacts of Climate Change and Adaptation
26   in the Asia-Pacific Region, 14 – 16 November 2000, Kobe, Japan. Asia Pacific Network for
27   Global Change Research, pp. 113–117.

28   Easterling, D. R. 2002. Recent changes in frost days and the frost-free season in the United States.
29   *Bulletin of the American Meteorological Society* 83, doi:10.1175/1520-0477.

30   Easterling, D. R., and Karl, T. R. 2001. Potential Consequences of Climate Variability and Change for
31   the Midwestern United States. Climate Change Impacts on the United States: The Potential
32   consequences of Climate Variability and Change. Ch. 6, pp 167-188. Report for the U.S. Global
33   Change Research Program. Cambridge University Press, Cambridge, UK. Availabe online at
34   http://www.usgcrp.gov/usgcrp/nacc/midwest.htm.

35   Easterling, D. R., Horton, B., Jones, P. D., et al. 1997. Maximum and minimum temperature trends for
36   the globe. *Science* 277: 363–367. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E.,
37   Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and
38   Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical
39   School. 142 pp.

40   Easterling, W. E., Aggarwal, P. K., Batima, P., Brander, K. M., Erda, L., Howden, S. M., Kirilenko, A.,
41   Morton, J., Soussana, J. F., Schmidhuber, J., and Tubiello, F. N. 2007. Food, fibre, and forest

1   products. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability.
2   Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental
3   Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and
4   Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 273–314.

5   Ebi, K., Balbus, J., Kinney, P., Lipp, E., Mills, D., O'Neill, M., and Wilson, M. 2008. Chapter 2: Effects
6   of Global Change on Human Health. Cited in: U.S. Climate Change Science Program (CCSP)
7   and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global
8   change on human health and welfare and human systems. Synthesis and Assessment Product 4.6.
9   Third review draft for CCSP and CENR clearance. April. pp. 2-1–2-78.

10   EEA 2005. Climate change and river flooding in Europe. *EEA Briefing* 1: 1–4. Cited in: IPCC, 2007.
11   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
12   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
13   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
14   University Press, Cambridge, UK, 976 pp.

15   Eheart, J.W., A.J. Wildermuth, and E.E. Herricks. 1999. The effects of climate change and irrigation on
16   criterion low streamflows used for determining total maximum daily loads. *J. Amer. Water*
17   *Resour. Assoc.* 35: 1365–1372.

18   EIA. 2007. Annual Energy Outlook 2007. Energy Information Administration, Department of Energy.
19   DOE/EIA-0383(2007). February.

20   EIA. 2007. International Energy Annual 2005. Energy Information Agency. http://www.eia.doe.gov/
21   iea/carbon.html.

22   Eiguren-Fernandez, A., Miguel, A., Froines, J., Thurairatnam, S. and Avol, E. 2004. Seasonal and
23   spatial variation of polycyclic aromatic hydrocarbons in vapor-phase and PM2.5 in Southern
24   California urban and rural communities. *Aerosol Science and Technology* 38: 447–455. Cited in:
25   IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of
26   Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate
27   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
28   (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

29   Elguindi, N., and F. Giorgi. 2006. Projected changes in the Caspian Sea level for the 21st century based
30   on the latest AOGCM simulations. *Geophys. Res. Lett.* 33: L08706.

31   EM-DAT. 2006 The OFDA/CRED International Disaster Database. http://www.em-dat.net. Cited in:
32   IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of
33   Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate
34   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
35   (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

36   Environment Canada. 1997. The Canada country study: climate impacts and adaptation. Adaptation and
37   Impacts Research Group, Downsview, Ontario.

38   Environment Canada. 2001. Threats to sources of drinking water and aquatic ecosystems health in
39   Canada. National Water Research Report No.1. National Water Resources Research Institute,
40   Burlington, Ontario, 72 pp.

1   Environment Canada. 2004. Threats to water availability in Canada. NWRI Scientific Assessment
2   Report No. 3. Prowse and ASCD Science Assessments series No. 1. National Water Research
3   Institute, Burlington, Ontario, 128 pp.

4   Environmental and Energy Study Institute. 2001. Wildlife and Human Diseases: Symptoms of
5   Endangered Marine Ecosystems and Climate Change. Background from Congressional Briefing,
6   May 22. 4 pp. http://www.eesi.org/briefings/Pre2003/paper.pdf.

7   EPA. 1997. Climate Change and New Jersey. U.S. Environmental Protection Agency, Office of Policy,
8   Planning and Evaluation, EPA 230-F-97-008dd.

9   EPA. 2000. 2000 National Water Quality Inventory. U.S. Environmental Protection Agency.

10 EPA. 2002. National Water Quality Inventory: Report to Congress, 2002 Reporting Cycle. U.S.
11   Environmental Protection Agency.

12 EPA. 2006. Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990 – 2020 (revised).
13   http://www.epa.gov/nonco2/econ-inv/international.html.

14 EPA. 2006. Office of Water. http://www.epa.gov/owow/wetlands/types/marsh.html

15 EPA. 2008. Greenbook. Currently Designated Nonattainment Areas for All Criteria Pollutants. U.S.
16   Environmental Protection Agency. http://www.epa.gov/air/oaqps/greenbk/ancl3.html. Accessed
17   June 12, 2008.

18 EPA. 2008. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006. Washington, DC:
19   U.S. Environmental Protection Agency. EPA 430-R-08-005. April.
20   http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

21 Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate
22   Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the
23   Global Environment, Harvard Medical School. 142 pp.

24 Epstein, P., and Mills, E. 2006. Climate Change Futures: Health, Ecological and Economic Dimensions.
25   The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

26 Ezzati, M., Lopez, A., Rodgers, A., and Murray, C. (Editors). 2004. Comparative Quantification of
27   Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors, Vols I
28   and 2. World Health Organization, Geneva, 2235 pp. Cited in: IPCC, 2007. Climate Change
29   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
30   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
31   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
32   Press, Cambridge, UK, 976 pp.

33 Fallico, F, Nolte, K., Siciliano, L., and Yip, F. 2005. Hypothermia-related deaths – United States, 2003–
34   2004. *MMWR – Morbidity & Mortality Weekly Report* 54(07): 173–175. Cited in: U.S. Climate
35   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.
36   Analyses of the effects of global change on human health and welfare and human systems.
37   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
38   April, 273 pp.

1   FAO. 2000. Global forest resources assessment 2000. FAO Forestry Paper 140, Food and Agriculture
2   Organization of the United Nations, Rome. 511 pp.

3   FAO. 2004c. The state of world fisheries and aquaculture (SOFIA) 2004. Fisheries Department, Food
4   and Agriculture Organization of the United Nations, Rome, 153 pp.

5   Feng, S., and Hu, Q. 2004. Changes in agro-meteorological indicators in the contiguous United States:
6   1951–2000. *Theoretical and Applied Climatology* 78: 247–264.

7   Fenn, M. E., Baron, J. S., Allen, E. B., Reuth, H. M., Nydick, K. R., Geiser, L., Bowman, W. D.,
8   Sickman, J. O., Meixner, T., Johnson, D. W., and Neitlich, P. 2003. Ecological effects of
9   nitrogen deposition in the western United States. BioScience 53: 404–420.

10   Ferrier, R., and A. Edwards. 2002. Sustainability of Scottishwater quality in the early 21st century. *Sci.*
11   *Total Environ.* 294: 57–71.

12   Few, R. and Matthies, F. 2006. Flood Hazards and Health: Responding to Present and Future Risks.
13   Earthscan, London, 240 pp. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation
14   and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
15   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
16   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976
17   pp.

18   Field, C. B., Mortsch, L. D., Brklacich, M., Forbes, D. L., Kovacs, P., Patz, J. A., Running, S. W., and
19   Scott, M. J. 2007. North America. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation
20   and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
21   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
22   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp.
23   617–652.

24   Fischlin, A., Midgley, G. F., Price, J.,T., Leemans, R., Gopal, B., Turley, C., Rounsevell, M. D. A., Dube,
25   O. P., Tarazona, J., and Velichko, A. A. 2007. Ecosystems, their properties, goods, and services.
26   In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of
27   Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate
28   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
29   (Editors), Cambridge University Press, Cambridge, UK, pp. 211–272.

30   Fisher, A., Abler, D., Barron, E., Bord, R., Crane, R., DeWalle, D., Knight, C., Najjar, R., Nizeyimana,
31   E., O'Connor, R., Rose, A., Shortle, J., and Yarnal, B. 2000. Preparing for a Changing Climate,
32   The Potential Consequences of Climate Variability and Change. Mid-Atlantic Overview. 75 pp.

33   Flannigan, M. D., Stocks, B. J., and Wotton, B. M. 2000. Climate change and forest fires. *Science of the*
34   *Total Environment* 262: 221–229.

35   Fleury, M., Charron, D. F., Holt, J. D., Allen, O. B., and Maarouf, A. R. 2006. A time series analysis of
36   the relationship of ambient temperature and common bacterial enteric infections in two Canadian
37   provinces. *International Journal of Biometeorology* 50: 385–391. Cited in: IPCC, 2007.
38   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
39   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
40   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
41   University Press, Cambridge, UK, 976 pp.

Flick, R. E. 1998. Comparison of California tides, storm surges, and mean sea level during the El Niño winters of 1982 – 1983 and 1997 – 1998. *Shore and Beach* 66(3): 7-11. Cited in: California Climate Change Center, 2006b. Scenarios of Climate change in California: An Overview. CEC-500-2005-186-SF. 11 pp.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., et al. 2005. Global consequences of land use. *Science* 309: 570–574.

Forister, M.L., and Shapiro, A. M. 2003. Climatic trends and advancing spring flight of butterflies in lowland California. *Global Change Biology* 9: 1130–1135.

Forster, P., Ramaswamy, V., Araxo, P., Berntsen, T., Betts, R. A., Fahey, D. W., Haywood, J., Lean, J., Lowe, D. C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulze, M., and Van Dorland, R. 2007. Changes in atmospheric constituents and in radiative forcing. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 130–234.

Fowler, A. M. and Hennessey, K. J. 1995. Potential impacts of global warming on the frequency and magnitude of heavy precipitation. *Natural Hazards* 11: 283–303. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Frank, K. L., Mader, T. L., Harrington, J. A., Hahn, G. L., and Davis, M. S. 2001. Climate change effects on livestock production in the Great Plains. In: Livestock Environment VI: Proceedings of the 6th International Symposium, Stowell, R. R., Bucklin, R., and Bottcher, R. W. (Editors), ASAE, St. Joseph, Michigan. pp. 351–358.

Franken, R. J., and Hik, D.S. 2004. Interannual variation in timing of parturition and growth of collared pikas (*Ochotana collaris*) in the Southwest Yukon. *Integrative and Comparative Biology* 44: 186.

Fried, J. S., Torn, M. S., and Mills, E. 2004. The impact of climate change on wildfire severity: a regional forecast for northern California. *Climatic Change* 64:169–191. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Frumhoff, P. C., McCarthy, J. J., Melillo, J. M., Moser, S. C., and Wuebbles, D. J. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS).

Frumkin, H. 2008. Statement of Howard Frumkin, M.D., DrPH, Director, National Center for Environmental Health, Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Service http://www.cdc.gov/washington/testimony/2008/t20080409.htm.

Fung, I. Y., Doney, S. C., Lindsay, K., and John, J. 2005. Evolution of carbon sinks in a changing climate. *Proceedings of the National Academy of Sciences* 102(32): 11201–11206.

Gallagher, P., and Wood, L. 2003. Proceedings of the World Summit on Salmon, June 10-13, 2003. Vancouver, British Columbia. www.sfu.ca/cstudies/science/summit.htm.

Gamble, J. L., Ebi, K., Sussman F., and Wilbanks, T. 2008. Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems. Synthesis and Assessment Product 4.6 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA.

Gan, J. B. 2004. Risk and damage of southern pine beetle outbreaks under global climate change. *Forest Ecology and Management* 191: 61–71.

Gangoiti, G., Millan, M. M., Salvador, R., and Mantilla, E. 2001. Long-range transport and re-circulation of pollutants in the western Mediterranean during the project Regional Cycles of Air Pollution in the West-Central Mediterranean Area. *Atmospheric Environment* 35: 6267–6276. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

GEO-LAC. 2003. Global Environmental Outlook. United Nations Environmental Program, 279 pp. http://www.unep.org/geo/pdfs/GEO__lac2003English.pdf

Gerber, S., Joos, F., and Prentice, I. C. 2004. Sensitivity of a dynamic global vegetation model to climate and atmospheric CO_2. *Global Change Biol.* 10: 1223–1239.

Gibbs, J. P., and Breisch, A. R. 2001. Climate warming and calling phenology of frogs near Ithaca, New York, 1900–1999. *Conservation Biology* 15: 1175–1178.

Gilvear, D., K. Heal, and A. Stephen. 2002. Hydrology and the ecological quality of Scottish river ecosystems. *Sci. Total Environ.* 294: 131–159.

Gleick, P. H. 2000. Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States. The Report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change. For the U.S. Global Change Research Program. http://www.gcrio.org/NationalAssessment/water/water.pdf)

Glick, P. H., Singh, A., and Shi, H. 2001. Threats to the World's Freshwater Resources. Pacific Institute, Oakland, California, USA.

Goodman, P. G., Dockery, D. W., and Clancy, L. 2004. Cause-specific mortality and the extended effects of particulate pollution and temperature exposure. [erratum appears in *Environ Health Perspect.* 2004 Sep; 112(13): A729]. *Environmental Health Perspectives* 112(2): 179–185. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

1   Gouveia, N., Hajat, S., and Armstrong, B. 2003. Socio-economic differentials in the temperature-
2   mortality relationship in Sao Paulo, Brazil. *International Journal of Epidemiology* 32: 390–397.
3   Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global
4   Change Research. 2008. Analyses of the effects of global change on human health and welfare
5   and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and
6   CENR clearance. April, 273 pp.

7   Greenberg, J. H., Bromberg, J., Reed, C. M., Gustafson, T. L., and Beauchamp. R. A. 1983. The
8   epidemiology of heat-related deaths, Texas – 1950, 1970–79, and 1980. *American Journal of*
9   *Public Health* 73(7): 805–807. Cited in: U.S. Climate Change Science Program (CCSP) and the
10   Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on
11   human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third
12   review draft for CCSP and CENR clearance. April, 273 pp.

13   Greenough, G., McGeehin, M. A., Bernard, S. M., Trtanji, J., Raid, J., and Engelberg, D. 2001. The
14   potential impacts of climate variability and change on health impacts of extreme weather events
15   in the United States. *Environmental Health Perspectives* 109: 191–198. Cited in: IPCC, 2007.
16   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
17   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
18   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
19   University Press, Cambridge, UK, 976 pp.

20   Gregg, W. W., Conkright, M. E., Ginoux, P., O'Reilly, J. E., and Casey, N. W. 2003. Ocean primary
21   production and climate: global decadal changes. *Geophysical Research Letters* 30: 1809.

22   Grize, L., Huss, A., Thommen, O., Schindler, C., and Braun-Fahrlander, C. 2005. Heat wave 2003 and
23   mortality in Switzerland. *Swiss Medical Weekly* 135: 200–205. Cited in: IPCC, 2007. Climate
24   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
25   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
26   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
27   University Press, Cambridge, UK, 976 pp.

28   Groisman, P. Y., Knight, R. W., Karl, T. R., Easterling, D. R., Sun, B., and Lawrimore, J. M. 2004.
29   Contemporary changes of the hydrological cycle over the contiguous United States: Trends
30   derived from in-situ observations. *Journal of Hydrometeorology* 5: 64–85.

31   Gryparis, A., Forsberg, B., Katsouyanni, K., Analitis, A., Touloumi, G., Schwartz, J., Samoli, E., Medina,
32   S., Anderson, H. R., Niciu, E. M., Wichmann, H. E., Kriz, B., Kosnik, M., Skorkovsky, J., Vonk,
33   J. M., and Dortbudak, Z. 2004. Acute effects of ozone on mortality from the "Air Pollution and
34   Health: A European Approach" project. *American Journal of Respiratory and Critical Care*
35   *Medicine* 170: 1080–1087. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation
36   and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
37   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
38   der Linden, P. J., and Hanson C. E. (Editors), Cambridge University Press, Cambridge, UK, 976
39   pp.

40   Gunderson, A. 2007. Ursus Maritimus (On-line). Animal Diversity Web. University of Michigan
41   Museum of Zoology. Accessed June 9, 2008 at
42   http://animaldiversity.ummz.umich.edu/site/accounts/information/Ursus_maritimus.html.

Gurdak, J.J., R.T. Hanson, P.B. McMahon, B.W. Bruce, J.E. McCray, G.D. Thyne, and R.C. Reedy. 2007. Climate variability controls on unsaturated water and chemical movement, High Plains Aquifer, USA. *Vadose Zone Journal* 6: 533–547.

Gutierrez, B., Williams, S., and Thieler, E. 2007. Potential for shoreline changes due to sea-level rise along the U.S. Mid-Atlantic Region. U.S. Geological Survey. Open-File Report 2007-1278

Hadley, S. W., Erickson, D. J., Hernandez, J. L., Broniak, C. T., and Blasing, T. J. 2006. Reponese of energy use to climate change: a climate modeling study. *Geophys. Res. Lett.*, 33, L17703, doi: 10.1029/2006GL026652. Cited in Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 357–390.

Hahn, G. L., Chen, Y. R., Nienaber, J. A., Eigenberg, R. A., and Parkhurst, A. M. 1992. Characterizing animal stress through fractal analysis of thermoregulatory responses. *Journal of Thermal Biology* 17: 115–120.

Haines, A., A. McMichael, and P. Epstein. 2000. Environment and health. 2. Global climate change and health. *Can. Med. Assoc. J.* 163: 729–734.

Hajat, S. 2006. Heat- and cold-related deaths in England and Wales: Who is at risk? *Occup. Environ. Med.* 64: 93–100. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Hajat, S., Armstrong, B., Baccini, M., Biggeri, A., Bisanti, L., Russo, A., Paldy, A., Menne, B., and Kosatsky, T. 2006. Impact of high temperatures on mortality: is there an added "heat wave" effect? *Epidemiology* 17: 632–638. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Hajat, S., Ebi, K. L., Kovats, R. S., et al. 2003. The human health consequences of flooding in Europe and the implications for public health: a review of the evidence. *Applied Environmental Science and Public Health* 1:13–21. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Hales, S., de Wet, N., Maindonald, J., and Woodward, A. 2002. Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet* 360: 830–834. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental

Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Hansen, J., M. Sato, P. Kharecha, G. Russell, D.W. Lea, and M. Siddall. 2007a. Climate change and trace gases. *Phil. Trans. R. Soc. A* 365: 1925-1954.

Hansen, J., M. Sato, R. Ruedy, P. Kharecha, A. Lacis, R. Miller, L. Nazarenko, K. Lo, G. A. Schmidt, G. Russell, I. Aleinov, S. Bauer, E. Baum, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N. Y. Kiang, D. Koch, G. Labow, J. Lerner, S. Menon, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou1, R. Schmunk, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D. Thresher, N. Unger, M. Yao, and S. Zhang. 2007b. Dangerous human-made interference with climate: a GISS modelE study. *Atmos. Chem. Phys.* 7: 2287-2312.

Hanson, R,T., and M.D. Dettinger. 2005. Ground water/surface water responses to global climate simulations, Santa Clara-Calleguas basin, Ventura, California. *Water Resources Bulletin* 41: 517–536.

Harvell, C. D., Kim, K., Burkholder, J. M., et al. 1999. Emerging marine diseases – climate links and anthropogenic factors. *Science* 285: 1505–1510. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Hazenkamp-von Arx, M. E., Gotschi Fellmann, T., Oglesby, L., Ackermann-Liebrich, U., Gislason, T., Heinrich, J., Jarvis, D., Luczynska, C., Manzanera, A. J., Modig, L., Norback, D., Pfeifer, A., Poll, A., Ponzio, M., Soon, A., Vermeire, P., and Kunzli, N. 2003. PM2.5 assessment in 21 European study centers of ECRHS II: method and first winter results. *J. Air Waste Manage* 53: 617–628. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

He, Z., Kim, Y. J., Ogunjobi, K. O., and Hong, C. S. 2003. Characteristics of PM2.5 species and long-range transport of air masses at Taean background station, South Korea. *Atmos. Environ.* 37: 219–230. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Healy, J. D. 2003. Excess winter mortality in Europe: a cross country analysis identifying key risk factors. *Journal of Epidemiology and Community Health* 57(10): 784–789. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Heath, J., Ayres, E., Possell, M., Bardgett, R. S., Black, H. I. J., Grant, H., Ineson, P., and Kerstiens, G. 2005. Rising atmospheric CO_2 reduces sequestration of root-derived soil carbon. *Science* 309: 1711–1713.

1   Helmis, C. G., Moussiopoulos, N., Flocas, H. A., Sahm, P., Assimakopoulos, V. D., Naneris, C., and
2   Maheras, P. 2003. Estimation of transboundary air pollution on the basis of synoptic-scale
3   weather types. *Int. J. Climatol.* 23: 405–416. Cited in: IPCC, 2007. Climate Change 2007:
4   Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
5   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
6   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
7   Press, Cambridge, UK, 976 pp.

8   Hemon, D. and Jougla, E. 2004. La canicule du mois d'aout 2003 en France [The heatwave in France in
9   August 2003]. *Rev. Epidemiol. Santé* 52: 3–5. Cited in: IPCC, 2007. Climate Change 2007:
10   Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
11   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
12   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
13   Press, Cambridge, UK, 976 pp.

14   Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C.
15   D., Sale, P. F., Edwards, A. J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R.,
16   Muthiga, N., Bradbury, R. H., Dubi, A., and Hatziolos, M. E. 2007. Coral reefs under rapid
17   climate change and ocean acidification. *Science* 318(5857): 1737–1742.

18   Hofmann, E., Ford, S., Powell, E., and Klinck, J. 2001. Modeling studies of the effect of climate
19   variability on MSX disease in eastern oyster (Crassostrea virginica) populations. Hydrobiologia
20   460: 195–212.

21   Holsten, E. H., Thier, R. W., Munson, A. S., and Gibson, K. E. 2000. The Spruce Beetle. U.S. Forest
22   Service. http://www.na.fs.fed.us/spfo/pubs/fidls/sprucebeetle/sprucebeetle.htm. Cited in:
23   Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006.
24   Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health
25   and the Global Environment, Harvard Medical School. 142 pp.

26   Honda, Y., Ono, M., Sasaki, A., and Uchiyama, I. 1998. Shift of the short term temperature mortality
27   relationship by a climate factor: some evidence necessary to take account of in estimating the
28   health effect of global warming. *J. Risk Res.* 1: 209–220. Cited in: IPCC, 2007. Climate Change
29   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
30   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
31   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
32   Press, Cambridge, UK, 976 pp.

33   Hopp, M. J., and Foley, J. A. 2003. Worldwide fluctuations in dengue fever cases related to climate
34   variability. *Climate Res.* 25: 85–94. Cited in: IPCC, 2007. Climate Change 2007: Impacts,
35   Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment
36   Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F.,
37   Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press,
38   Cambridge, UK, 976 pp.

39   Houghton, J. T., Ding. Y., Griggs, D. J., et al. (Editors). 2001. Climate change 2001: The Scientific
40   Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental
41   Panel on Climate Change. (Cambridge University Press, Cambridge, UK, New York, USA,
42   2001). Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R.
43   (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The
44   Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Houghton, R. A. 2003. Emissions (and Sinks) of Carbon from Land-Use Change. (Estimates of national sources and sinks of carbon resulting from changes in land use, 1950 to 2000). Report to the World Resources Institute from the Woods Hole Research Center. http://cait.wri.org.

Hurd, B.H., M. Callaway, J. Smith, and P. Kirshen. 2004. Climatic change and US water resources: from modeled watershed impacts to national estimates. *J. Am. Water Resour. As.* 40: 129–148.

Huschke, R. E. (Editor). 1959. Glossary of meteorology: Boston. American Meteorological Society, 638 pp.

Huynen, M. and Menne, B. 2003. *Phenology and human health: allergic disorders. Report of aWHO meeting in Rome, Italy, 16–17 January 2003.* Health and Global Environmental Series, EUR/03/5036791. World Health Organization, Copenhagen, 64 pp. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

IEA. 2006. CO_2 Emissions from Fuel Combustion (2006 edition). International Energy Agency. http://data.iea.org/ieastore/co2_main.asp.

Inouye, D. B., Barr, B., Armitage, K. B., and Inouye B. D. 2000. Climate change is affecting altitudinal migrants and hibernating species. *Proceedings of the National Academy of Sciences USA* 97: 630.

IPCC. 2007. Intergovernmental Panel on Climate Change Working Group 1 Contribution to the Fourth Assessment Report. Outline. Climate Change 2007: The Physical Science Basis.

IPCC. 2007. Summary for Policymakers. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–18.

IPCC. 2007. Summary for Policymakers. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.1–18.

IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

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

1   Ito, K., De Leon, S. F., and Lippmann, M. 2005. Associations between ozone and daily mortality:
2   analysis and meta-analysis. *Epidemiology* 16: 446–457. Cited in: IPCC, 2007. Climate Change
3   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
4   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
5   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
6   Press, Cambridge, UK, 976 pp.

7   IUCN. 2008. International Union for the Conservation of Nature and Natural Resources Red List of
8   Threatened Species (On-line). Accessed June 9, 2008 at
9   http://www.iucnredlist.org/search/details.php/22823/all.

10 Jacobson, M. Z. 2008. On the casual link between carbon dioxide and air pollution mortality.
11   *Geophysical Research Letters* 35: 3809.

12 Janda, J. M., Powers, C., Bryant, R. G., and Abbott, S. L. 1988. Clinical perspectives on the
13   epidemiology and pathogenesis of clinically significant *Vibrio* spp. *Clinical Microbiology*
14   *Reviews* 1(3): 245–267. Cited in: U.S. Climate Change Science Program (CCSP) and the
15   Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on
16   human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third
17   review draft for CCSP and CENR clearance. April, 273 pp.

18 Janetos, A., Hansen, L., Inouye, D., Kelly, B. P., Meyerson, L., Peterson, B., and Shaw, R. 2008.
19   Biodiversity. In: The effects of climate change on agriculture, land resources, water resources,
20   and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee
21   on Global Change Research. Washington, DC, USA, 362 pp.

22 Johnson, H., Kovats, R. S., McGregor, G. R., Stedman, J. R., Gibbs, M., Walton, H., Cook, L., and Black,
23   E. 2005. The impact of the 2003 heatwave on mortality and hospital admissions in England.
24   *Health Statistics Q.* 25: 6–12. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation
25   and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
26   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
27   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK,
28   976 pp.

29 Johnson, K. and Murphy, D. E. 2004. Drought Settles In, Lake Shrinks, and West's Worries Grow. The
30   New York Times (May 2). Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B.,
31   and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic
32   Dimensions. The Center for Health and the Global Environment, Harvard Medical School.
33   142 pp.

34 Jones, M. L., Shuter, B. J., Zhao, Y. M., and Stockwell, J. D. 2006. Forecasting effects of climate
35   change on Great Lakes fisheries: Models that link habitat supply to population dynamics can
36   help. Canadian Journal of Fisheries and Aquatic Sciences 63: 457–468.

37 Jones, T. S., Liang, A. P., Kilbourne, E. M., Griffin, M. R., Patriarca, P. A., Wassilak, S. G., et al. 1982.
38   Morbidity and mortality associated with the July 1980 heat wave in St Louis and Kansas City,
39   Mo. *Journal of the American Medical Association* 247(24): 3327–3331. Cited in: U.S. Climate
40   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.
41   Analyses of the effects of global change on human health and welfare and human systems.
42   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
43   April, 273 pp.

1   JS Online. 2008. The Mighty Microbe. Last revised: March 16, 2008. Available online at:
2   http://www.jsonline.com/story/index.aspx?id=728254. Accessed: June 23, 2008.

3   Jump, A. S., and Peñuelas, J. 2005. Running to stand still: Adaptation and the response of plants to rapid
4   climate change. *Ecol. Lett.* 8: 1010 – 1020.

5   Kafalenos, R.S., K.J. Leonard, D.M. Beagan, V.R. Burkett, B.D. Keim, A Meyers, D.T. Hunt, R.C.
6   Hyman, M.K. Maynard, B. Fritsche, R.H. Henk, E.J. Seymour, L.E. Olsen, J.R. Potter, M.J.
7   Savonis. 2008. What are the Implications of Climate Change and Variability for Gulf Coast
8   Transportation? In: Impacts of Climate Change and Variability in Transportation Systems and
9   Infrastructure: Gulf Coast Study, Phase I. A report by the U.S. Climate Change Science Program
10   and the subcommittee on Gloabal Change Researh [Savonis, M.J., V.R. Burkett, and J.R. Potter
11   (eds.)]. Department of Transportation, Washington, D.C.

12   Kalashnikov, I. A., Mkrtchan, M. O., Shevyreva, T. V., Kazhekina, E. F. and Techeva, S. C. 2003.
13   Prevention of acute enteric infections and viral hepatitis a in the Krasnodar Territory appearing in
14   connection with a natural disaster in 2002. *Zh Mikrobiol. Epidemiol. Immunobiol.* 6: 101–104.
15   Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors).
16   2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for
17   Health and the Global Environment, Harvard Medical School. 142 pp.

18   Kang, G., Ramakrishna, B. S., Daniel, J., Mathan, M., and Mathan, V. 2001. Epidemiological and
19   laboratory investigations of outbreaks of diarrhoea in rural South India: implications for control
20   of disease. *Epidemiol. Infect.* 127: 107–112. Cited in: IPCC, 2007. Climate Change 2007:
21   Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
22   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
23   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
24   Press, Cambridge, UK, 976 pp.

25   Kashian, D. M., Romme, W. H., Tinker, D. B., Turner, M. G., and Ryan, M. G. 2006. Carbon storageon
26   landscapes with stand-replacing fires. *BioScience* 56: 598–606.

27   Kassomenos, P., Gryparis, A., Samoli, E., Katsouyanni, K., Lykoudis, S., and Flocas, H. A. 2001.
28   Atmospheric circulation types and daily mortality in Athens, Greece. *Environ. Health Persp.*
29   109: 591–596.

30   Kates, R. and Wilbanks, T. 2003. Making the global local: responding to climate change concerns from
31   the bottom up. *Environment* 45: 12–23.

32   Kato, S., Kajiia, Y., Itokazu, R., Hirokawad, J., Kodae, S., and Kinjof, Y. 2004. Transport of
33   atmospheric carbon monoxide, ozone, and hydrocarbons from Chinese coast to Okinawa island in
34   the Western Pacific during winter. *Atmospheric Environment* 38: 2975–2981. Cited in: IPCC,
35   2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working
36   Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,
37   Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors),
38   Cambridge University Press, Cambridge, UK, 976 pp.

39   Kayanickupuram, J. 2002. "Euphydryas editha" (On-line), Animal Diversity Web.
40   http://animaldiversity.ummz.umich.edu/site/accounts/information/Euphydryas_editha.html.

382

Keatinge, W. R. and Donaldson, G. C. 2001. Mortality related to cold and air pollution in London after allowance for effects of associated weather patterns. *Environmental Research* 86(3): 209–216. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Kemp, D. A. 2004. Exploring Environmental Issues, An Integrated Approach. Routledge, London, 444 pp.

Kennedy, V., Twilley, R., Kleypas, J., Cowan, J., and Hare, S. 2002. Coastal and Marine Ecosystems & Global Climate Change: Potential Effects on U.S. Resources. Pew Center on Global Climate Change. http://www.pewclimate.org/docUploads/marine_ecosystems.pdf

Kennish, M. 2002. Environmental threats and environmental future of estuaries. *Environ. Conserv.* 29: 78–107.

King, J. R. 2005. Report of the study group on fisheries and ecosystem responses to recent regime shifts. PICES Scientific Report 28. 162 pp.

King, J. S., Hanson, P. J., Bernhardt, E., Deangelis, P., Norby, R. J., and Pregitzer, K.S. 2004b. A multiyear synthesis of soil respiration responses to elevated atmospheric CO_2 from four forest FACE experiments. *Global Change Biology* 10: 1027–1042.

Kirilenko, A. P., and Sedjo, R. A. 2007. Climate Change Impacts on Forestry. PNAS, 104 no. 50, doi: 10.1073/pnas.0701424104.

Kirshen, P. H., Ruth, M. R., and Anderson, W. 2006. Climate's long-term impacts on urban infrastructure and services: the case of Metro Boston. Regional Climate Change and Variability: Impacts and Responses. Ruth, M., Donaghy, K., and Kirshen, P. H. (Editors) Edward Elgar Publishers, Cheltenham, pp. 192–252. Cited in: Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 357–390.

Kirshen, P., Ruth, M., Anderson, W., and Lakshmanan, T. R. 2004. Infrastructure Systems, Services and Climate Change:Integrated Impacts and Response Strategies for the Boston Metropolitan Area. Climate's Long-term Impacts on Metro Boston (CLIMB). Available online at http://www.publicpolicy.umd.edu/faculty/ruth/CLIMB_full_report.pdf

Kirshen, P.H. 2002. Potential impacts of global warming in eastern Massachusetts. *J. Water Res. Pl. and Management.*, *128, 216–226.* Cited in Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 357–390.

Kirshen, P.H., M. Ruth, W. Anderson, T. R. Lakshmanan, S. Chapra, W. Chudyk, L. Edgers, D. Gute, M. Sanayei, and R. Vogel. 2004. Climate's Long-term Impacts on Metro Boston. Final Report to the U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC, USA.

Kleinen, T., and G. Petschel-Held. 2007. Integrated assessment of changes in flooding probabilities due to climate change. *Climatic Change* 81: 283–312.

Klinenberg, E. 2002. Heat Wave: A Social Autopsy of Disaster in Chicago. The University of Chicago Press, Chicago. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Knowles, N., Dettinger, M. D., and Cayan, D. R. 2006. Trends in snowfall versus rainfall for the western United States, 1949-2004. *Journal of Climate* 19: 4545–4559.

Knowles,N., M.D.Dettinger, and D.R. Cayan. 2006. Trends in snowfall versus rainfall for the western United States, 1949-2004. *J. Climate* 19: 4545–4559.

Knowlton, K., B. Lynn, R. Goldberg, C. Rosenzweig, C. Hogrefe, J. Rosenthal, et al. 2007. Projecting heat-related mortality impacts under a changing climate in the New York City region. *American Journal of Public Health* 97(11): 2028–34.

Koerner, C., et al. 2005. Carbon flux and growth in mature deciduous forest trees exposed to elevated CO_2. *Science* 309(5739): 1360–1362.

Kosatsky, T. and Menne, B. 2005. Preparedness for extreme weather among national ministries of health of WHO's European region. Climate Change and Adaptation Strategies for Human Health, Menne, B. and Ebi, K.L. (Editors), Springer, Darmstadt, pp. 297–329. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Kossmann, M., and Sturman, A. 2004. The surface wind field during winter smog nights in Christchurch and coastal Canterbury, New Zealand. *International Journal of Climatology* 24: 93–108. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Kovats, R. S., Bouma, M. J., Hajat, S., Worrall, E., and Haines, A. 2003. El Nino and health. *Lancet* 362: 1481–1489. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp., and cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

384

Kovats, R. S., Edwards, S., Hajat, S., Armstrong, B., Ebi, K. L., and Menne, B. 2004. The effect of temperature on food poisoning: time series analysis in 10 European countries. *Epidemiolology and Infection* 132: 443–453. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Kabat, P., Jiménez, B., Miller, K. A., Oki, T., Sen, Z., and Shiklomanov, I. A. 2007. Freshwater resources and their management. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 173–210.

Künzli, N., Jerrett, M., Mack, W. J., Beckerman, B., LaBree, L., Gilliland, F., Thomas, D., Peters, J., and Hodis, H. N. 2005. Ambient air pollution and atherosclerosis in Los Angeles. *Environmental Health Perspectives* 113: 201–206. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Laden, F., Schwartz, J., Speizer, F. E., and Dockery, D. W. 2006. Reduction in fine particulate air pollution and mortality: extended. *American Journal of Respiratory and Critical Care Medicine* 173: 667–72. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Lama, J. R., Seas, C. R., León-Barúa, R., Gotuzzo, E., and Sack, R. B. 2004. Environmental temperature, cholera, and acute diarrhoea in adults in Lima, Peru. *Journal of Health, Population and Nutrition* 22: 399–403. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Lehman, J. 2002. Mixing patterns and plankton biomass of the St. Lawrence Great Lakes under climate change scenarios. *J. Great Lakes Res.* 28: 583–596.

Lehner, B., P. Döll, J. Alcamo, H. Henrichs, and F. Kaspar. 2005. Estimating the impact of global change on flood and drought risks in Europe: a continental, integrated assessment. *Climatic Change* 75: 273–299.

Lehodey, P., Chai, F., and Hampton, J. 2003. Modelling climate-related variability of tuna populations from a coupled ocean biogeochemical-populations dynamics model. *Fisheries Oceanography* 12: 483–494.

Leipprand, A., and D. Gerten. 2006. Global effects of doubled atmospheric CO_2 content on evapotranspiration, soil moisture and runoff under potential natural vegetation. *Hydrol. Sci. J.* 51: 171–185.

Lemke, P., Ren, J., Alley, R. B., Allison, I., Carrasco, J., Flato, G., Fujii, Y., Kaser, G., Mote, P., Thomas, R. H., and Zhang, T. 2007. Observations: changes in snow, ice and frozen ground. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M., and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 338–383.

Lepers, E., Lambin, E. F., Janetos, A. C., DeFries, R., Achard, F., Ramankutty, N., and Scholes. R. J. 2004. A synthesis of information on rapid land-cover change for the period 1981 – 2000. *BioScience* 55: 115–124.

Lettenmaier, D. P. 2003. The role of climate in water resources planning and management. Cited in: *Water: Science, Policy, and Management*, Lawford, R., Fort, D., Hartmann, H., and Eden, S. (Editors). Water Resources Monograph 16, American Geophysical Union, Washington, DC, USA, pp. 247–266.

Lettenmaier, D. P., Major, D., Poff, L., and Running, S. 2008. Water resources. In: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. Synthesis and Assessment Product 4.3 (SAP 4.3) [Backlund, P., A. Janetos, and D. Schimel (eds.)] by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA.

Leung, R. L. and Gustafson Jr., W. I. 2005. Potential regional climate change and implications to U.S. air quality. *Geophysical Research Letters* 32(16). Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Levin, R. B., Epstein, P. R., Ford, T. E., et al. 2002. Drinking water challenges in the twenty-first century. *Environmental Health Perspectives* 110: 43–52. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Levy, J. I., Chemerynski, S. M., and Sarnat, J. A. 2005. Ozone exposure and mortality: an empiric bayes metaregression analysis. *Epidemiology* 16: 458–468. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Lewis, S.L., Phillips, O. L., Baker, T. R., Lloyd, J., Malhi, Y., Almeida, S., Higuchi, N., Laurance, W. F., Neill, D.A., Silva, J. N. M., Terborgh, J., Lezama, A. T., Martinez, R. V., Brown, S., Chave, J., Kuebler, C., Vargas, P. N., and Vinceti, B. 2004b. Concerted changes in tropical forest structure and dynamics: evidence from 50 South American long-term plots. *Philos. T. Roy. Soc. Lond. B* 359: 421–436.

Liang, Q., Jaegle, L., Jaffe, D., Weiss-Penzias, P., Heckman, A., and Snow, J. 2004. Long-range transport of Asian pollution to the northeast Pacific: seasonal variations and transport pathways of carbon monoxide. *Journal of Geophysical Research D*. 109: D23S07. Cited in: IPCC, 2007.

1   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
2   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
3   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
4   University Press, Cambridge, UK, 976 pp.

5   Lipp, E. K., Huq, A., and Colwell, R. R. 2002. Effects of global climate on infectious disease: the
6   cholera model. *Clinical Microbiology Reviews* 15: 757. Cited in: IPCC, 2007. Climate Change
7   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
8   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
9   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
10   Press, Cambridge, UK, 976 pp. And in: U.S. Climate Change Science Program (CCSP) and the
11   Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on
12   human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third
13   review draft for CCSP and CENR clearance. April, 273 pp.

14   Lischke, H., Lotter, A. F., and Fischlin, A. 2002. Untangling a Holocene pollen record with forest model
15   simulations and independent climate data. *Ecol. Model.* 150: 1–21.

16   List, J. H., Farris, A. S., and Sullivan, C. 2006. Reversing storm hotspots on sandy beaches; spatial and
17   temporal characteristics. *Marine Geology* 226: 261–279. Cited in: Gutierrez, B., Williams, S.,
18   and Thieler, E. 2007. Potential for shoreline changes due to sea-level rise along the U.S. Mid-
19   Atlantic Region. U.S. Geological Survey. Open-File Report 2007-1278

20   Loaiciga, H.A., D.R. Maidment, and J.B. Valdes. 2000. Climate change impacts on a regional Karst
21   aquifer, Texas, USA. *Journal of Hydrology* 227: 173–194.

22   Lobell, D. B., and Asner, G. P. 2003. Climate and management contributions to recent trends in U.S.
23   agricultural yields. *Science* 299: 1032.

24   Lobell, D. B., and. Field, C. B. 2007. Global scale climate-crop yield relationships and the impact of
25   recent warming. *Environmental Research Letters* 2: 1–7.

26   Lofgren, B., A. Clites, R.Assel, A. Eberhardt, and C. Luukkonen. 2002. Evaluation of potential impacts
27   on Great Lakes water resources based on climate scenarios of two GCMs. *J. Great Lakes Res.*
28   28: 537–554.

29   London Climate Change Partnership. 2004. London's Warming: A Climate Change Impacts in London
30   Evaluation Study, London, 293 pp.

31   Long, S.P., Ainsworth, E. A., Leakey, A. D. B., Nösberger, J., and Ort, D. R. 2006. Food for thought:
32   Lower-than-expected crop yield stimulation with rising CO_2 concentrations. *Science* 312(5782):
33   1918–1921.

34   Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S. M.,
35   Kirby, M. X., Peterson, C. H., and Jackson, J. B. C. 2006. Depletion, degradation and recovery
36   potential of estuaries and coastal seas. *Science* 312: 1806–1809.

37   Luketina, D., and M. Bender. 2002. Incorporating long-term trends in water availability in water supply
38   planning. *Water Sci. Technol.* 46(6-7): 113–120.

Luo, Y., et al. 2005. Progressive nitrogen limitation of ecosystem responses to rising atmospheric carbon dioxide. *Bioscience* 54: 731–739.

MA. 2005b. Ecosystems and human well-being: Current state and trends. Findings of the Condition and Trends Working Group

MA. 2005c. Ecosystems and human well-being: scenarios: Findings of the Scenarios Working Group. Edited by Steve R.Carpenter et al

MA. 2005d. Ecosystems and human well-being: multiscale assessments: Findings of the Sub-global Assessments Working Group of the Millennium Ecosystem Assessment / edited by Doris Capistrano et al.

MacCracken, M. C., F. Moore, and J. C. Topping Jr., (Editors). 2008. Sudden and Disruptive Climate Change. The Climate Institute. Earthscan, Sterling, VA.

Mader, T. L. 2003. Environmental stress in confined beef cattle. *Journal of Animal Science* 81 *(electronic suppl. 2)*: 110–119.

Mader, T. L., Fell, L. R., and McPhee, M. J. 1997. Behavior response of non-Brahman cattle to shade in commercial feedlots. In: Livestock Environment VI: Proceedings of the 6th International Symposium. ASAE, St. Joseph, Michigan. pp. 795–802.

Malhi, Y. and Philips, O. L. 2004. Tropical forests and global atmospheric change: a synthesis. *Philos. T. Roy Soc. Lond. B* 359: 549–555.

Mark, B.G., and G.O. Seltzer. 2003. Tropical glacier meltwater contribution to stream discharge: a case study in the Cordillera Blanca, Peru. *J.Glaciol.* 49: 271–281.

Marland, G., Boden, T. A., and Andres, R. J. 2007. Global, Regional, and National Fossil Fuel CO_2 Emissions. In: Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. http://cdiac.ornl.gov/trends/emis/meth_reg.htm.

Martin, B., Fuelberg, H., Blake, N., Crawford, J., Logan, L., Blake, D., and Sachse, G. 2002. Long-range transport of Asian outflow to the equatorial Pacific. *Journal of Geophysical Research D*. 108: 8322. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Martinez-Navarro, F., Simon-Soria, F., and Lopez-Abente, G. 2004. Valoracion del impacto de la ola de calor del verano de 2003 sobre la mortalidad [Evaluation of the impact of the heatwave in the summer of 2003 on mortality]. *Gaceta Sanitaria* 18: 250–258. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Mattson, W. J., and Haack, R. A. 1987. The role of drought in outbreaks of planteating insects. *Bioscience* 37:110–118. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and

Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Mauget, S. A. 2003. Multidecadal regime shifts in U.S. streamflow, precipitation, and temperature at the end of the twentieth century. *Journal of Climate* 16: 3905–3916.

McGeehin, M. A., and Mirabelli, M. 2001. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. *Environmental Health Perspectives* 109(2):185–189. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

McGranahan, G., Balk, D., and Anderson, B. 2006. Low coastal zones settlements. *Tiempo* 59: 23–26.

McKenzie, D., Hessland, A. E., and Peterson, D. L. 2001. Recent growth of conifer species of western North America: Assessing spatial patterns of radial growth trends. *Canadian Journal of Forest Research* 31: 526–538.

McMichael, A and Githek, O. A. DATE. Human health. Cited in: McCarthy, J. T., Canziani, O. F., Leary, N.A., Dokken, D.J., White, K.S. (Editors). Climate Change 2001: Impacts, Adaptations, and Vulnerability. Geneva, Switzerland: Intergovernmental Panel on Climate Change; 2001:453–485. www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARchap9.pdf. Cited in: American Academy of Pediatrics. 2007. Global Climate Change and Children's Health. *Pediatrics 2007* 120: 1149–1152.

McMichael, A. 2004. Climate change. Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors, Vol. 2, Ezzati, M., Lopez, A., Rodgers, A., and Murray, C. (Editors),World Health Organization, Geneva, 1543–1649. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

McMichael, A. J., Haines, A., Slooff, R. and Kovats, S (Editors). 1996. Climate change and human health. World Health Organization, World Meteorological Organization, United Nations Environmental Programme, Geneva. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

McPhaden, M. J., and Zhang, D. 2002. Slowdown of themeridional overturning circulation in the upper Pacific Ocean. Nature 415: 603–608.

Mead, P. S., Slutsker, L., Dietz, V., McCaig, L. F., Bresee, J. S., Shapiro, C., Griffin, P. M., and Tauxe, R. V. 1999. Food-related illness and death in the United States. *Emerging Infectious Diseases* 5(5): 607–625. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Mearns, L. O., Carbone, G., Doherty, R. M., Tsvetsinskaya, E. A., McCarl, B. A., Adams, R. M., and McDaniel, L. 2003. The uncertainty due to spatial scale of climate scenarios in integrated assessments: An example from U.S. agriculture. IntegratedAssessment 4: 225–235.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao. 2007. Global climate projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L.Miller (Editors), Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 747–846.

Meier, M., Dyurgerov, M., Rick, U., O'Neel, S., Pfeffer, T., Anderson, R., Anderson, S., and Glazovsky, A. 2007. Glaciers dominate eustatic sea-level rise in the 21st Century. *Science* 317: 1064–1067. http://www.sciencemag.org/cgi/content/abstract/1143906v1.

Menne, B. 2000. Floods and public health consequences, prevention and control measures. UN 2000 (MP.WAT/SEM.2/1999/22). Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Menne, B. and Bertollini, R. 2000. The health impacts of desertification and drought. *Down to Earth* 14: 4–6. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Metro East Coast Regional Assessment. 2000. Climate Change and a Global City: An Assessment of the Metropolitan East Coast Region.

Michelozzi, P., de Donato, F., Accetta, G., Forastiere, F., D'Ovido, M., and Kalkstein, L. S. 2004. Impact of heat waves on mortality: Rome, Italy, June–August 2003. *Journal of the American Medical Association* 291: 2537–2538. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Michelozzi, P., de'Donato, F., Bisanti, L., Russo, A., Cadum, E., DeMaria, M, D'Ovidio, M., Costa, G., and Perucci, C. A. 2005. The impact of the summer 2003 heatwaves on mortality in four Italian cities. *Eurosurveillance* 10: 161–165. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Mickley, L. J., Jacob, D. J., Field, B. D., and Rind, D. 2004 Effects of future climate change on regional air pollution episodes in the United States. *Geophysical Research Letters* 31: L24103.

1   Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z., Lettenmaier, D. P., and
2   Stouffer, R. J. 2008. Stationarity is dead: Whither water management. *Science* 319: 573–574.

3   Milly, P. C. D., K. A. Dunne, and A. V. Vecchia. 2005. Global pattern of trends in streamflow and water
4   availability in a changing climate. *Nature* 438: 347–350.

5   Mirza, M.M.Q. 2003. Three recent extreme floods in Bangladesh: a hydrometeorological analysis. *Nat.*
6   *Hazards* 28: 35–64.

7   Mohanti, M. 2000. Unprecedented supercyclone in the Orissa Coast of the Bay of Bengal, India.
8   Cogeoenvironment Newsletter. Commission on Geological Sciences for Environmental Planning
9   of the International Union on Geological Sciences 16: 11–13.

10   Mohanty, P. and Panda, U. 2003. Heatwave in Orissa: A Study Based on Heat Indices and Synoptic
11   Features –Heatwave Conditions in Orissa. Regional Research Laboratory, Institute of
12   Mathematics and Applications, Bubaneshwar, 15 pp. Cited in: IPCC, 2007. Climate Change
13   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
14   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
15   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
16   Press, Cambridge, UK, 976 pp.

17   Mohseni, O., Stefan, H. G., and Eaton, J. G. 2003. Global warming and potential changes in fish habitat
18   in U.S. streams. *Climatic Change* 59: 389–409.

19   Monson, R. K., Sparks, J. P., Rosenstiel, T. N., Scott-Denton, L. E., Huxman, T. E., Harley, P. C.,
20   Turnipseed, A. A., Burns, S. P., Backlund, B., and Hu, J. 2005. Climatic influences on net
21   ecosystem CO_2 exchange during the transition from wintertime carbon source to springtime
22   carbon sink in a high-elevation, subalpine forest. *Oecologia* 146: 130–147.

23   Moore, K., Clarke, A., Kapustin, V., and Howell, S. 2003. Long-range transport of continental plumes
24   over the Pacific Basin: aerosol physiochemistry and optical properties during PEM-Tropics A and
25   B. *Journal of Geophysical Research D.* 108: 8236. Cited in: IPCC, 2007. Climate Change 2007:
26   Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
27   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
28   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
29   Press, Cambridge, UK, 976 pp.

30   Morton, R. A. 1994. Texas barriers. In: Davis, R. A., Editor, Geology of Holocene Barrier Island
31   Systems: New York, Springer-Verlag, pp. 75–114. Cited in: Gutierrez, B., Williams, S., and
32   Thieler, E. 2007. Potential for shoreline changes due to sea-level rise along the U.S. Mid-Atlantic
33   Region. U.S. Geological Survey. Open-File Report 2007-1278.

34   Mortsch, L., M. Alden, and J. Scheraga. 2003. Climate change and water quality in the Great Lakes
35   Region - risks opportunities and responses. Great Lakes Water Quality Board for the
36   International Joint Commission, 213 pp.

37   Moss, R. H., and Schneider, S. H. 2000. Uncertainties in the IPCC TAR: Recommendations to lead
38   authors for more consistent assessment and reporting. In: Guidance Papers on the Cross Cutting
39   Issues of the Third Assessment Report of the IPCC [eds. R. Pachauri, T. Taniguchi and K.
40   Tanaka], World Meteorological Organization, Geneva, pp. 33-51.

Mote, P., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in western North America. *Bull. Amer. Meteor. Soc.*, 86, doi: 10.1175/BAMS-1186-1171-1139.

Mote, P.W., E.A. Parson, A.F.Hamlet, W.S.Keeton, D. Lettenmaier, N.Mantua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter, and A.K. Snover. 2003. Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. *Clim. Change* 61: 45–88.

Mott, J. A., Meyer, P., Mannino, D., Redd, S., Smith, E., Gotway-Crawford, C., and Chase, E. 1999. Wildland forest fire smoke: health effects and intervention evaluation. *Western Journal of Medicine* 176(2002): 157–162.

Mudway, I. S. and Kelly, F. J. 2000. Ozone and the lung: a sensitive issue. *Molecular Aspects of Medicine* 21: 1–48. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Nagendra, S. and Khare, M. 2003. Diurnal and seasonal variations of carbon monoxide and nitrogen dioxide in Delhi city. *International Journal of Environment and Pollution* 19: 75–96. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Najjar, R. G., Walker, H. A., Anderson, P. J., Barron, E. J., Bord, R., Gibson, J., Kennedy, V. S., Knight, C. G., Megonigal, J. P., O'Connor, R. E., Polsky, C. J., Psuty, N. P., Richards, K. B., Sorenson, L. G., Steele, E., and Swanson, R. S. 1999. The potential impacts of climate change on the Mid-Atlantic coastal region. *Climate Research* 14(2): 219–233. Cited in: Fisher, A., Abler, D., Barron, E., Bord, R., Crane, R., DeWalle, D., Knight, C., Najjar, R., Nizeyimana, E., O'Connor, R., Rose, A., Shortle, J., and Yarnal, B. 2000. Preparing for a Changing Climate, The Potential Consequences of Climate Variability and Change: Mid-Atlantic Overview. 75 pp.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., et al. 2000. Special Report on Emissions Scenarios. Working Group III, Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, 595 pp. http://www.grida.no/climate/ipcc/emission/index.htm

National Assessment Synthesis Team (NAST). 2001. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. Report for the US Global Change Research Program. CambridgeUniversity Press, Cambridge, UK. Available online at http://www.usgcrp.gov/usgcrp/nacc/background/regions.htm.

National Science and Technology Council (U.S.), United States, and Climate Change Science Program (U.S.). 2008. Scientific assessment of the effects of global change on the United States. Washington, D.C.: National Science and Technology Council (U.S.), Committee on Environment and Natural Resources. http://www.ostp.gov/galleries/NSTC%20Reports/Scientific%20Assessment%20FULL%20Report.pdf.

Nature. 2008. Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. Letters to Nature. Last revised: June 8, 2008. Available: http://www.nature.com/nature/journal/vaop/ncurrent/full/nature07051.html. Accessed: June 23, 2008.

Nature. 2008. "Too late" to save Pacific island nation from submersion. Last revised: June 6, 2008. Available online at: http://www.nature.com/news/2008/080606/full/news.2008.880.html. Accessed: June 23, 2008.

Nature. 2008. Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions. Last revised: June 2008. Available: http://www.nature.com/ngeo/journal/v1/n6/abs/ngeo202.html. Accessed: June 23, 2008.

Naumova, E. N., Jjagai, J. S., Matyas, B., DeMaria, A., MacNeill, I. B., and Griffiths, J. K. 2006. Seasonality in six enterically transmitted diseases and ambient temperature. *Epidemiology and Infection* pp. 1–12. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Nchito, M., Kelly, P., Sianongo, S., Luo, N. P., Feldman, R., Farthing, M., and Baboo, K. S. 1998. Cryptosporidiosis in urban Zambian children: an analysis of risk factors. *American Journal of Tropical Medicine and Hygiene* 59: 435–437. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Needham, G. R. and Teel, P. D. 1991. Off-host physiological ecology of ixodid ticks. *Annual Review of Entomology* 36: 659–681. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Nelson, F. E., Anisimov, O. A., and Shiklomanov, N. I. 2001. Subsidence risk from thawing permafrost. *Nature* 410: 889–890. Cited in Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 357–390.

Nemani, R. R., Keeling, C.D., Hashimoto, H., Jolly, W. M., Piper, S. C., Tucker, C. J., Myneni, R. B., and Running, S. W. 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999. *Science* 300: 1560 – 1563.

Neumann, J.E., G. Yohe, R. Nichols, and M. Manion. 2000. Sea Level Rise and Global Climate Change: A Review of Impacts to U.S. Coasts. Pew Center on Global Climate Change, Washington, DC, USA.

393

1 New York City Department of Environmental Protection. 2008. Assessment and Action Plan: Report 1,
2   A Report Based on the Ongoing Work of the DEP Climate Change Task Force.

3 Ng, W. S., and Mendelsohn, R. 2005. The impact of sea level rise on Singapore. *Environment and*
4   *Developement Economics* 10: 201–215.

5 NHS. 2006. Heatwave Plan for England. Protecting Health and Reducing Harm from Extreme Heat and
6   Heatwaves. Department of Health, United Kingdom. Cited in: IPCC, 2007. Climate Change
7   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
8   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
9   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
10   Press, Cambridge, UK, 976 pp.

11 Nicholls, K. H. 1999. Effects of temperature and other factors on summer phosphorus in the inner Bay
12   of Quinte, Lake Ontario: Implications for climate warming. *J. Great Lakes Res.* 25: 250–262.

13 Nicholls, R. J. 2003. An expert assessment of storm surge "hotspots. Interim Report to Center for
14   Hazards and Risk Research, Lamont-Doherty Observatory, Columbia University. Flood Hazard
15   Research Centre, University of Middlesex, London, 10 pp. Cited in: IPCC, 2007. Climate
16   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
17   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
18   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
19   University Press, Cambridge, UK, 976 pp.

20 Nicholls, R. J., Wong, P. P., Burkett, V. R., Codignotto, J. O., Hay, J. E., McLean, R. F., Ragoonaden, S.,
21   and Woodroffe, C. D. 2007. Coastal systems and low-lying areas. In: IPCC, 2007. Climate
22   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
23   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
24   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
25   University Press, Cambridge, UK, pp. 315–356.

26 NOAA. 2001. Winter Storms, The Deceptive Killers. U.S. Department of Commerce. National Oceanic
27   and Atmospheric Administration. National Weather Service. ARC 4467 December 2001
28   NOAA/PA 200160. http://www.weather.gov/om/brochures/winterstorm.pdf

29 NOAA. 2005. Heatwave a Major Summer Killer. National Weather Service. Office of Climate. Water
30   and Weather Services. NOAA/PA 85001.
31   http://www.nws.noaa.gov/om/brochures/heat_wave.shmtl

32 NOAA. 2005. Impacts of Anthropgenic CO_2 on Ocean Chemistry and Biology. Office of Oceanic and
33   Atmospheric Research. Last revised: October 3, 2005. Available online at:
34   http://www.oar.noaa.gov/spotlite/spot_gcc.html. Accessed: June 23, 2008.

35 Nogueira, P. J. 2005. Examples of heat warning systems: Lisbon's ICARO's surveillance system,
36   summer 2003. Extreme Weather Events and Public Health Responses Kirch, W., Menne, B. and
37   Bertollini, R. (Editors), Springer, Heidelberg, 141–160. Cited in: IPCC, 2007. Climate Change
38   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
39   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
40   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
41   Press, Cambridge, UK, 976 pp.

1   Norby, R. J., and Iversen, C. M. 2006. Nitrogen uptake, distribution, turnover, and efficiency of use in a
2   CO_2-enriched sweetgum forest. *Ecology* 87, 5–14.

3   NY City DEP. 2008. Assessment and Action Plan, Report 1. The City of New York Department of
4   Environmental Protection. May.

5   O'Brien, K. L., and Leichenko, R. M. 2000. Double Exposure: assessing the impacts of climate change
6   within the context of economic globalization. *Global Environ. Change* 10: 221–232. Wilbanks,
7   T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood,
8   R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change
9   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
10   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
11   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
12   Press, Cambridge, UK, pp. 357–390.

13 O'Brien, K., L. Sygna and J. E. Haugen. 2004. Vulnerable or resilient? amulti-scale assessment of
14   climate impacts and vulnerability in Norway. *Climatic Change* 62: 75-113.

15 O'Reilly, C., S. Alin, P. Plisnier, A. Cohen, and B. Mckee. 2003. Climate change decreases aquatic
16   ecosystem productivity of Lake Tanganyika, Africa. *Nature* 424: 766–768.

17 Olmos, S. 2001. Vulnerability and adaptation to climate change: concepts, issues, assessment methods.
18   Climate Change Knowledge Network Foundation Paper, Oslo, 20 pp. Cited in: IPCC, 2007.
19   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
20   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
21   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
22   University Press, Cambridge, UK, 976 pp.

23 O'Neill M. S., Zanobetti A, and Schwartz J. 2005. Disparities by race in heat-related mortality in four
24   U.S. cities: the role of air conditioning prevalence. *Journal of Urban Health* 82(2): 191–197.
25   Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global
26   Change Research. 2008. Analyses of the effects of global change on human health and welfare
27   and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and
28   CENR clearance. April, 273 pp.

29 O'Neill, M. S., Jerrett, M., Kawachi, I., Levy, J. I., Cohen, A. J., Gouveia, N., Wilkinson, P., Fletcher, T.,
30   Cifuentes, L., and Schwartz, J. 2003. Health, wealth, and air pollution: advancing theory and
31   methods. *Environmental Health Perspectives* 111(16): 1861–1870. Cited in: U.S. Climate
32   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.
33   Analyses of the effects of global change on human health and welfare and human systems.
34   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
35   April, 273 pp.

36 O'Neill, M., Hajat, S., Zanobetti, A., Ramirez-Aguilar, M., and Schwartz, J. 2005. Impact of control for
37   air pollution and respiratory epidemics on the estimated associations of temperature and daily
38   mortality. *International Journal of Biometeorology*.

39 ORNL/CDIAC. 1990. Carbon Dioxide and Climate, 1990. ORNL/CDIAC-39. Carbon Dioxide
40   Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Third
41   Edition. Fred O'Hara, Jr. (Editor). http://cdiac.ornl.gov/pns/convert.html.

Parkinson, A. J. and Butler, J. C. 2005. Potential impacts of climate change on infectious diseases in the Arctic. *International Journal of Circumpolar Health* 64: 478–486. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Parmesan, C. 1996. Climate and species range. *Nature* 382: 765–766.

Parmesan, C., and Galbraith, H. 2004. Observed Impacts of Global Climate Change in the U.S. Prepared for the Pew Center on Global Environmental Change. 56 pp.

Parmesan, C., and Yohe, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421: 37–42.

Parry, M. L., Canziani, O. F., Palutikof, J. P., et al. 2007. Technical Summary. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 23–78.

Parry, M. L., Canziani, O. F., Palutikof, J. P., et al. 2007. Technical Summary. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 23–78.

Pascal, M., Laaidi, K., Ledrans, M., Baffert, E., Caseiro-Schönemann, C., Tertre, A. L., Manach, J., Medina, S., Rudant, J., and Empereur-Bissonnet, P. 2006. France's heat health watch warning system. *International Journal of Biometeorology* 50: 144–153. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Pascual, M., Ahumada, J. A., Chaves, L. F., Rodo, X., and Bouma, M. 2006. Malaria resurgence in the East African highlands: temperature trends revisited. *Proceedings of the National Academy of Sciences* 103: 5829–5834. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Patrinos, A., and A. Bamzai. 2005. Policy needs robust climate science. *Nature* 438: 285.

Pattenden, S., Nikiforov, B., and Armstrong, B. G. 2003. Mortality and temperature in Sofia and London. *Journal of Epidemiology and Commununity Health* 57: 628–633. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

1　Patz, J. and J.M. Baldus. 2001. USCCSP 07 (Patz, J.A. and J.M. Balbus, 2001; Global climate change
2　　　　and air pollution. In: *Ecosystem Change and Public Health. A Global Perspective* [Aron, J.L. and
3　　　　J.A. Patz (eds.)]. The Johns Hopkins University Press, Baltimore, pp. 379-408.) Cited in:
4　　　　Scientific Assessment of the Effects of Global Change on the United States: A Report of the
5　　　　Committee on Environment and Natural Resources National Science and Technology Council
6　　　　(May 2008).

7　Patz, J. 2001. Public health risk assessment linked to climatic and ecological change. *Hum. Ecol. Risk*
8　　　　*Assess.* 7: 1317–1327.

9　Perry, D. A. 1994. Forest Ecosystems. The Johns Hopkins University Press. Baltimore, MD.

10　Petterson, J.S., L.D. Stanley, E.G. and J. Philipp. 2006. A Preliminary Assessment of Social and
11　　　　Economic Impacts Associated with Hurricane Katrina. *American Anthropologist* 108(4): 643–
12　　　　670.

13　Physorg. 2005. More extreme weather is predicted. Last revised: October 17, 2005. Available:
14　　　　http://www.physorg.com/news7290.html. Accessed: June 23, 2008.

15　Pinho, O. S., and Orgaz, M. D. 2000. The urban heat island in a small city in coastal Portugal.
16　　　　*International Journal of Biometeorology* 44(4): 198–203. Cited in: U.S. Climate Change Science
17　　　　Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the
18　　　　effects of global change on human health and welfare and human systems. Synthesis and
19　　　　Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

20　Pope, C. A., and Dockery, D. W. 2006. Health effects of fine particulate air pollution: Lines that
21　　　　connect. *Journal of Air and Waste Management Association* 54: 709–742. Cited in: U.S.
22　　　　Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research.
23　　　　2008. Analyses of the effects of global change on human health and welfare and human systems.
24　　　　Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
25　　　　April, 273 pp.

26　Pope, C. A., III , Burnett, R. T., Thurston, G. D., Thun, M. J., Calle, E. E., Krewski, D., and Godleski, J.
27　　　　J. 2004. Cardiovascular mortality and long-term exposure to particulate air pollution:
28　　　　epidemiological evidence of general pathophysiological pathways of disease. *Circulation.*
29　　　　109(1): 71–7. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on
30　　　　Global Change Research. 2008. Analyses of the effects of global change on human health and
31　　　　welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for
32　　　　CCSP and CENR clearance. April, 273 pp.

33　Pope, C. A., III, Burnett, R. T, Thun, M. J., Calle, E. E., Krewski, D., Ito, K., and Thurston, G. D. 2002.
34　　　　Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution.
35　　　　*Journal of the American Medical Association* 287: 1132–1141. Cited in: U.S. Climate Change
36　　　　Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of
37　　　　the effects of global change on human health and welfare and human systems. Synthesis and
38　　　　Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

39　Pope, C. A., III, Thun, M., Namboodiri, M., et al. 1995. Particulate air pollution as a predictor of
40　　　　mortality in a prospective study of U.S. adults. *American Journal of Respiratory and Critical*
41　　　　*Care Medicine* 151: 669–74. Cited in: U.S. Climate Change Science Program (CCSP) and the
42　　　　Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on

human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Pope, C. A., III. 2000. Epidemiology of fine particulate air pollution and human health: biological mechanisms and who's at risk? *Environmental Health Perspectives* 108: 713–723. As cited by American Lung Association. State of the Air: 2008. Protect the Air you Breathe, http://www.lungusa2.org/sota/SOTA2008.pdf.

Porter, J. R., and M. A. Semenov. 2005. Crop responses to climatic variation. *Philos. T. Royal Soc. B* 360: 2021-2035.

Pruett, L., and Cimino, J. 2000. Coastal Length, Area of Continental Shelf, Territorial Seas, Claimed Exclusive Economic Zone, and Exclusive Fishing Zone. Unpublished data derived from Global Maritime Boundaries Database. Fairfax, VA: Veridian-MRJ Technology Solutions.

Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. *Science* 315(5810): 368–370.

Randolph, S. E., and Rogers, D. J. 2000. Fragile transmission cycles of tick-borne encephalitis virus may be disrupted by predicted climate change. *Proceedings Biological Sciences/The Royal Society*, 267(1454): 1741–1744. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Rappengluck, B., Oyola, P., Olaeta, I., and Fabian, P. 2000. The evolution of photochemical smog in the Metropolitan Area of Santiago de Chile. *Journal of Applied Meteorology* 39: 275–290. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Regonda, S. K., Rajagopalan, B., Clark, M., and Pitlick, J. 2005. Seasonal cycle shifts in hydroclimatology over the western United States. *Journal of Climate* 18: 372–384.

Reid, P., and Vogel, C. 2006. Living and responding to multiple stressors in South Africa–Glimpses from KwaZulu-Natal. *Global Environmental Change* 16: 195–206.

Reid, W. V., Mooney, H. A., Cropper, A., Capistrano, D., Carpenter, S. R., Chopra, K., Dasgupta, P., Dietz, T., Duraiappah, A. K., Hassan, R., Kasperson, R., Leemans, R., May, R. M., McMichael, A. J., Pingali, P., Samper, C., Scholes, R., Watson, R. T., Zakri, A. H., Shidong, Z., Ash, N. J., Bennett, E., Kumar, P., Lee, M. J., Raudsepp-Hearne, C., Simons, H., Thonell J., and Zurek, M.B. (Editors). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. 155 pp.

Ren, C., Williams, G. M., and Tong, S. 2006. Does particulate matter modify the association between temperature and cardiorespiratory diseases? *Environmental Health Perspectives* 114(11): 1690–1696. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

1   Revenga, C., Brunner, J., Kassem, K., and Payne, R. 2000. Pilot Analysis of Global Ecosystems,
2   Freshwater Systems. World Resources Institute, Washington, DC, USA.

3   Reynard, N., S. Crooks, R. Wilby, and A. Kay. 2004. Climate Change and Flood Frequency in the UK.
4   Proceedings of the 39th DEFRA Flood and Coastal Management Conference, York. Defra,
5   London, 11.1.1–11.1.12.

6   RGGI. 2006. Preliminary Electricity Sector Modeling Results: Phase III RGGI Reference and Package
7   Scenario. Updated Reference, RGGI Package – 10/11/06, updated 5/22/2007. August 17, 2006.
8   ICF Consulting.

9   Richardson, A. J., and Poloczanska, E. S. 2008. Ocean science: Under-resourced, under threat. *Science*
10   320(5881): 1294–1295.

11 Riggs, S. R., and Ames, D. V. 2003. Drowning of North Carolina; Sea-Level Rise and Estuarine
12   Dynamics. N.C. Sea Grant College Program, Raleigh, N.C., Pub. No. UNC-SG-03-04, 152 p. In:
13   Gutierrez, B., Williams, S., and Thieler, E. 2007. Potential for shoreline changes due to sea-level
14   rise along the U.S. Mid-Atlantic Region. U.S. Geological Survey. Open-File Report 2007-1278

15 RIVM/TNO. 2003. EDGAR 3.2, Olivier, J.G.J., and Berdowski, J.J.M. 2001. Global emission sources
16   and sinks. In: Berdowski, J., Guicherit, R., and Heij, B.J. (Editors). The Climate System: 33–77.
17   Lisse: Swets & Zeitlinger Publishers). http://www.mnp.nl/edgar/.

18 Rogers, C., Wayne, P., Macklin, E., Muilenberg, M., Wagner, C., Epstein, P., and Bazzaz, F. 2006a.
19   Interaction of the onset of spring and elevated atmospheric CO2 on ragweed (*Ambrosia*
20   *artemisiifolia* L.) pollen production. *Environmental Health Perspectives* 114: 865–869. Cited in:
21   IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of
22   Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate
23   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
24   (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

25 Rogers, D. J., Wilson, A. J, Hay, S. I., and Graham, A. J. 2006b. The global distribution of yellow fever
26   and dengue. *Advances in Parasitology* 62: 181–220. Cited in: IPCC, 2007. Climate Change
27   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
28   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
29   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
30   Press, Cambridge, UK, 976 pp.

31 Rood, S. B., Samuelson, G. M., Weber, J. K., and Wywrot, K. A. 2005. Twentieth-century decline in
32   streamflows from the hydrographic apex of North America. *Journal of Hydrology* 306: 215–233.

33 Rosenzweig, C. and D. Hillel. 2005. Global warming and agriculture. In Perspectives in World Food and
34   Agriculture, Volume 2. J.A. Miranowski and C.G. Scanes, Eds. Blackwell Publishing, pp. 183–
35   209.

36 Rosenzweig, C. and Hillel, D. 1998. Climate Change and the Global Harvest: Potential Impacts of the
37   Greenhouse Effect on Agriculture (Oxford University Press, New York).

38 Rosenzweig, C. and Hillel, D. 2005. Climate change, agriculture and sustainability. In Climate Change
39   and Global Food Security. R. Lal, N. Uphoff, B.A. Stewart, and D.O. Hansen, Eds. Taylor &
40   Francis, pp. 243–268.

Rosenzweig, C., Casassa, G., Karoly, D. J., Imeson, A., Liu, C., Menzel, A., Rawlins, S., Root, T. L., Seguin, B., and Tryjanowski, P. 2007. Assessment of observed changes and responses in natural and managed systems. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 79–131.

Rosenzweig, C., Casassa, G., Karoly, D. J., Imeson, A., Liu, C., Menzel, A., Rawlins, S., Root, T. L., Seguin, B., and Tryjanowski, P. 2007. Assessment of observed changes and responses in natural and managed systems. In: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 79–132.

Rural Industries Research & Development Corporation. 2002. Impact of Climate Change on Important Plant Diseases in Australia. Last revised: April 8, 2002. Available online at: http://www.rirdc.gov.au/reports/AFT/02-010sum.html. Accessed: June 23, 2008.

Ruth, M., B. Davidsdottir, and A. Amato. 2004. Climate change policies and capital vintage effects: the case of U.S. pulp and paper, iron and steel, and ethylene. *J. Environ. Manage.* 70: 235–252. Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 357–390.

Ruth, M., C. Bernier, N. Jollands, N. Golubiewski. 2007. Adaptation to urban water supply infrastructure to impacts from climate and socioeconomic changes: The case of Hamilton, New Zealand. *Water Resources Management* (21): 1031-1045.

Ryall, D. B., Derwent, R. G., Manning, A. J., Redington, A. L., Corden, J., Millington, W., Simmonds, P. G., O'Doherty, S., Carslaw, N., and Fuller, G. W. 2002. The origin of high particulate concentrations over the United Kingdom, March 2000. *Atmospheric Environment* 36: 1363–1378. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Ryan, M. G., Archer, S. R., Birdsey, R. A., Dahm, C. N., Heath, L. S., Hicke, J. A., Hollinger, D. Y., Huxman, T. E., Okin, G. S., Oren, R., Randerson, J. T., and Schlesinger, W.H. 2008. Land resources. In: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. Synthesis and Assessment Product 4.3 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

Rybnicek, O., and Jaeger, S. 2001. *Ambrosia* (ragweed) in Europe. *ACI International* 13: 60–66. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate

1   Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E.
2   (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

3   Sabine, C. L., Heimann, M., Artaxo, P., Bakker, D. C. E., Chen, C. T. A., Field, C. B., and Gruber, N.
4   2004. Current status and past trends of the global carbon cycle. In: Global Carbon Cycle:
5   Integrating Humans, Climate, and the Natural World, Field, C. B., and Raupach, M. R. (Editors).
6   Island Press, Washington, DC, USA, pp. 17–44.

7   Sacks, W., Schimel, D., and Monson, R. 2007. Coupling between carbon cycling and climate in a high
8   elevation, subalpine forest: a model-data fusion analysis. *Oecologia* 151(1): 54–68,

9   Saito, Y. 2001. Deltas in Southeast and East Asia: Their evolution and current problems. In:
10   Proceedings of the APN/SURVAS/LOICZ Joint Conference on Coastal Impacts of Climate
11   Change and Adaptation in the Asia–Pacific Region, 14–16 November 2000, Kobe, Japan, Asia
12   Pacific Network for Global Change Research, pp. 185–191.

13 Samet, J. M., Domenici, F., Curriero, F., Coursac, I., and Zeger, S. L. 2000. Fine Particulate Air
14   Pollution and Mortality in 20 U.S. Cities, 1987–1994. *New England Journal of Medicine* 343:
15   1742–1749. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on
16   Global Change Research. 2008. Analyses of the effects of global change on human health and
17   welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for
18   CCSP and CENR clearance. April, 273 pp.

19 Saunders, S., Montgomery, C., Easley, T., and Spencer, T. 2008. Hotter and Drier: The West's Changed
20   Climate. The Rocky Mountain Climate Organization and Natural Resources Defense Council,
21   New York, NY, USA, 54 pp.

22 Savonis, M. J., Burkett, V. R., and Potter, J. R. 2008. Impacts of Climate Change and Variability on
23   Transportation Systems and Infrastructure: Gulf Coast Study, Phase I: A Report by the U. S.
24   Climate Change Science Program and the subcommittee on Global Change Research,
25   Washington, DC. [SAP 4–7].

26 Scavia, D., Field, J. C., Boesch, D. F., Buddemeier, R. W., Burkett, V., Cayan, D. R., Fogarty, M.,
27   Harwell, M. A., Howarth, R. W., Mason, C., Reed, D. J., Royer, T. C., Sallenger, A.,H., and
28   Titus, J. G. 2002. Climate change impacts on US coastal and marine ecosystems. *Estuaries* 25:
29   149–164.

30 Schimel, D., Melillo J., Tian, H., McGuire, A. D., Kicklighter, D., Kittel, T., Rosenbloom, N., Running,
31   S., Thornton, P., Ojima, D., Parton, W., Kelly, R., Sykes M., Neilson, R., and Rizzo, B. DATE.
32   *Science* 287: 2004–2006.

33 Schneeberger, C., H. Blatter, A. Abe-Ouchi, and M. Wild. 2003. Modelling changes in the mass balance
34   of glaciers of the northern hemisphere for a transient $2\times CO_2$ scenario. *J. Hydrol.* 282: 145–163.

35 Schneider, S. H. and Londer, R. 1984. The Coevolution of Climate and Life, San Francisco. Sierra Club
36   Books.

37 Schneider, S. H., and Root, T. L. 1996. Ecological implications of climate change will include surprises.,
38   *Biodiversity and Conservation* 5: 1109–1119

Schröter, D., Cramer, W., Leemans, R., Prentice, I. C., Araújo, M. B., Arnell, N. W., Bondeau, A., Bugmann, H., Carter, T. R, Gracia, C. A., de la Vega-Leinert, A. C., Erhard, M., Ewert, F., Glendining, M., House, J. J., Kankaanpää, S., Klein, R. J. T., Lavorel, S., Lindner, M., Metzger, M. J., Meyer, J., Mitchell, T. D., Reginster, I., Rounsevell, M., Sabaté, S., Sitch, S., Smith, B., Smtih, J., Smith, P., Sykes, M. T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S., and Zierl, B. 2005. Ecosystem service supply and vulnerability to global change in Europe. *Science* 310: 1333–1337.

Schwartz, J. 2005. Who is sensitive to extremes of temperature? A case-only analysis. *Epidemiology* 16(1): 67–72. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Schwartz, J., Samet, J. M., and Patz, J. A. 2004. Hospital admissions for heart disease: The effects of temperature and humidity. *Epidemiology* 15(6): 755–761. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Schwartz, M. D., and Reiter, B. E. 2000. Changes in North American spring. *International Journal of Climatology* 20: 929–932.

Schwartz, R.C., P.J. Deadman, D.J. Scott, and L.D. Mortsch. 2004. Modeling the impacts of water level changes on a Great Lakes community. *J. Am. Water Resour. As.* 40: 647–662.

Scibek, J., and D.M. Allen. 2006. Comparing modeled responses to two high-permeability, unconfined aquifers to predicted climate change. *Global and Planetary Change* 50: 50–62.

ScienceDaily. 2007. Elevated carbon dioxide changes soil microbe mix below plants may help plants grow. Available online at: http://www.sciencedaily.com/releases/2007/12/071219105808.htm. Accessed: June 23, 2008.

Scott, J. 1986. The Butterflies of North America, A Natural History and Field Guide. Stanford, California: Stanford University Press.

Semenov, S. M., Gelver, E. S., and Yasyukevich, V. V. 2002. Temperature conditions for development of two species of malaria pathogens in Russia in 20th century. *Doklady Akademii Nauk* 387: 131–136. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Semenza, J. C., McCullough, J. E., Flanders, W. D., McGeehin, M. A., and Lumpkin, J. R. 1999. Excess hospital admissions during the July 1995 heat wave in Chicago. *American Journal of Preventive Medicine* 16(4): 269–277. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

402

1   Semenza, J. C., Rubin, C. H., Falter, K. H., Selanikio, J. D., Flanders, W. D., Howe, H. L., et al. 1996.
2   Heat-related deaths during the July 1995 heat wave in Chicago. *New England Journal of*
3   *Medicine* 335(2): 84–90. Cited in: U.S. Climate Change Science Program (CCSP) and the
4   Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on
5   human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third
6   review draft for CCSP and CENR clearance. April, 273 pp.

7   Senat. 2004. Easterling 07 Senat 2004 – Easterling 07 Sénat, 2004: La France et les Français face a la
8   canicule: les leçons d'une crise [France and the French facing the heat wave: lessons from a
9   crisis]. Rapport d'Information No. 195 (2003–2004) deMme Letard,M.M. Flandre, S. Lepeltier,
10   fait au nom de la mission commune d'information du Senat, depose le 3 Fevrier 2004.
11   http://www.senat.fr/rap/r03-195/r03-1951.pdf.

12 Sénat. 2004. Information report no. 195 – France and the French face the canicule: the lessons of a
13   crisis: appendix to the minutes of the session of February 3, 2004, 59-62. [Accessed 21.03.07:
14   http://www.senat.fr/rap/r03-195/r03-195.html]

15 Shepherd, A., and Wingham. 2007. Recent sea-level contributions of the Antartic and Greenland Ice
16   Sheets. *Science* 315: 1529–1532.
17   http://www.sciencemag.org/cgi/content/abstract/315/5818/1529.

18 Sheridan, S., and Dolney, T. 2003. Heat, mortality, and level of urbanization: measuring vulnerability
19   across Ohio, USA. *Climate Research* 24: 255–266. Cited in: U.S. Climate Change Science
20   Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the
21   effects of global change on human health and welfare and human systems. Synthesis and
22   Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

23 Sherman, K. 1993. Large Marine Ecosystems as Global Units for Marine Resource Management – An
24   Ecological Perspective. In: Sherman, K., Alexander, L., and Gold, B. (Editors). Large Marine
25   Ecosystems: Stress, Mitigation and Sustainability. Washington, DC: American Academy for the
26   Advancement of Science.

27 Shiklomanov, I. A., and Rodda, J. C. (Editors). 2003. World Water Resources at the Beginning of the
28   21st Century. Cambridge University Press, Cambridge, 435 pp.

29 Shinn, E. A., Griffin, D. W., and Seba, D. B. 2003. Atmospheric transport of mold spores in clouds of
30   desert dust. *Archives of Environmental Health* 58: 498–504. Cited in: IPCC, 2007. Climate
31   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
32   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
33   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
34   University Press, Cambridge, UK, 976 pp.

35 Simón, F., López-Abente, G., Ballester, E., and Martinez, F. 2005. Mortality in Spain during the
36   heatwaves of summer 2003. *Eurosurveillance* 10: 156–160. Cited in: IPCC, 2007. Climate
37   Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the
38   Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.,
39   Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
40   University Press, Cambridge, UK, 976 pp.

41 Singer, B. D., Ziska, L. H., Frenz, D. A., Gebhard, D. E., and Straka, J. G. 2005. Increasing Amb a 1
42   content in common ragweed (*Ambrosia artemisiifolia*) pollen as a function of rising atmospheric

CO2 concentration. *Functional Plant Biology* 32: 667–670. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Singh, P. 2003. Effect of warmer climate on the depletion of snowcovered area in the Satluj basin in the western Himalayan region. *Hydrol. Sci. J.* 48: 413–425.

Singh, P., and N. Kumar. 1997. Impact assessment of climate change on the hydrological response of a snow and glacier melt runoff dominated Himalayan river. *J. Hydrol.* 193: 316–350.

Small, C., and Nicholls, R. J. 2003. A global analysis of human settlement in coastal zones. *Journal of Coastal Research* 19:584–599.

Sohngen, B., and Sedjo, R. 2005. Impacts of climate change on forest product markets: Implications for North American producers. *Forestry Chronicle* 81: 669–674.

Soulsby, C., C. Gibbins, A. Wade, R. Smart, and R. Helliwell. 2002. Water quality in the Scottish uplands: a hydrological perspective on catchment hydrochemistry. *Sci. Total Environ.* 294: 73–94.

Speelmon, E. C., Checkley, W., Gilman, R. H., Patz, J., Calderon, M., and Manga, S. 2000. Cholera incidence and El Nino-related higher ambient temperature. *Journal of the American Medical Association* 283: 3072–3074. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Stewart, I. T., Cayan, D. R., and Dettinger, M. D. 2005. Changes toward earlier streamflow timing across western North America. *Journal of Climate* 18: 1136–1155.

Stohl, A., Haimberger, L., Scheele, M., and Wernli, H. 2001. An intercomparison of results from three trajectory models. *Journal of Applied Meteorology* 8: 127–135. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Stouffer, R.J. and S. Manabe. 2003. Equilibrium response of thermohaline circulation to large changes in atmospheric CO2 concentration. *Clim. Dyn.* 20: 759–773.

Summers, J. K., Burgan, B., Brown, D., Bigler, J., Pesch, G. G., Walker, H. A., Kiddon, J. A., Harvey, J. E., Garza, C., Engle, V. D., Smith, L. M., Harwell, L. C., Nelson, W. G., Lee, H., and Lambertson, J. 2004. National Coastal Condition Report II. U.S. Environmental Protection Agency, Washington, DC, EPA-620/R-03/002. http://www.epa.gov/owow/oceans/nccr/2005/downloads.html

Sussman, F., Cropper, M., Galbraith, H., Godschalk, D., Loomis, J., Luber, G., McGeehin, M., Neumann, J., Shaw, W. D., Vedlitz, A., and Zahran S. 2008. Chapter 4: Effects of Global Change on

Human Welfare. In: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April. pp. 4-1–4-74.

Swetnam, T. W., and Betancourt, J. L. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate* 11: 3128–3147.

Taramarcaz, P., Lambelet, B., Clot, B., Keimer, C., and Hauser, C. 2005. Ragweed (*Ambrosia*) progression and its health risks: will Switzerland resist this invasion? *Swiss Medical Weekly* 135: 538–548. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Thanh, T. D., Saito, Y., Huy, D. V., Nguyen, V. L., Oanh, T. K. O., and Tateishi, M. 2004. Regimes of human and climate impacts on coastal changes in Vietnam. *Regional Environmental Change* 4: 49–62.

The NY City Department of Environmental Protection (NY City DEP) Climate Change Program. 2008. Assessment and Action Plan Report 1: A Report Based on the Ongoing Work of the DEP Climate Change Task Force.

The Royal Society. 1998. Carbon dioxide starvation, the development of C4 ecosystems, and mammalian evolution. Available online at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1692178. Accessed: June 23, 2008.

The State of the Nation's Ecosystems. 2002. The H. John Heinz III Center for Science, Economics and the Environment, Washington, DC, USA.

Thompson, J. R., Randa, M. A., Marcelino, L. A., Tomita-Mitchell, A., Lim, E., and Polz, M. F. 2004. Diversity and dynamics of a North Atlantic coastal *Vibrio* community. *Applied and Environmental Microbiology* 70(7): 4103–4110. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Thomson, M. C., Mason, S. J., Phindela, T., and Connor, S. J. 2005. Use of rainfall and sea surface temperature monitoring for malaria early warning in Botswana. *American Journal of Tropical Medicine and Hygiene* 73: 214–221. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Tibbetts, J. 2004. The state of the ocean, Part 2: Delving deeper into the sea's bounty. *Environmental Health Perspectives* 112(8): 4. http://findarticles.com/p/articles/mi_m0CYP/is_8_112/ai_n15688532.

405

1   Titus, J. G., et al. 2008. Coastal Elevations and Sensitivity to Sea Level Rise. Synthesis and Assessment
2   Product 4.1 by the U.S. Climate Change Science Program and the Subcommittee on Global
3   Change Research, Washington, DC, USA (peer-reviewed draft report).

4   Tol, R. S. J. 2002a. Estimates of the damage costs of climate change, Part I: Benchmark Estimates.
5   *Environ. Resour. Econ.* 21: 47–73. Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F.,
6   Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry,
7   settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and
8   Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
9   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
10   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp.
11   357–390.

12   Tol, R. S. J. 2002b. Estimates of the damage costs of climate change, Part II: Dynamic Estimates.
13   *Environ. Resour. Econ.* 21: 135–160. Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F.,
14   Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry,
15   settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and
16   Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
17   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
18   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp.
19   357–390..

20   Transportation Research Board. 2008. Potential Impacts of Climate Change on U.S. Transportation.
21   Transportation Research Board Special Report 290, Washington, DC.

22   Trenberth, K. E., Dai, A. G., Rasmussen, R. M., and Parsons, D. B. 2003. The changing character of
23   precipitation. *B. Am. Meteorol. Soc.* 84: 1205–1217.

24   Trenberth, K. E., Jones, P. D., Ambenje, P. G., Bojariu, R., Easterling, D. R, Klein Tank, A. M. G.,
25   Parker, D. E., Renwick, J. A., et al. 2007. Observations: Surface and atmospheric climate
26   change. In: IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of
27   Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate
28   Change, Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M.,
29   and Miller, H. L. (Editors), Cambridge University Press, Cambridge, United Kingdom and New
30   York, NY, USA, pp. 235–336.

31   Trenberth, K.E., A.G. Dai, R.M. Rasmussen, and D.B. Parsons. 2003. The changing character of
32   precipitation. *B. Am. Meteorol. Soc.* 84: 1205–1217.

33   Triggs, J. M., B. A. Kimball, P. J. Pinter, Jr., G. W. Wall, M. M. Conley, T. J. Brooks, R. L. LaMorte, N.
34   R. Adam, M. J. Ottman, A. D. Matthias, S. W. Leavitt and R. S. Cerveny. 2004. Free-Air CO2
35   Enrichment Effects on the Energy Balance and Evapotranspiration of Sorghum. *Agricultural and
36   Forest Meteorology* 124(2):63-79.

37   Tu, F., Thornton, D., Brandy, A., and Carmichael, G. 2004. Long-range transport of sulphur dioxide in
38   the central Pacific. *Journal of Geophysical Research D.* 109: D15S08. Cited in: IPCC, 2007.
39   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
40   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
41   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
42   University Press, Cambridge, UK, 976 pp.

Tubiello, F. N. 2005. Climate variability and agriculture: Perspectives on current and future challenges. In: Impact of Climate Change, Variability and Weather Fluctuations on Crops and Their Produce Markets, Knight, B. (Editor), Impact Reports, Cambridge, UK, pp. 45–63.

Tuffs, A. and Bosch, X. 2002. Health authorities on alert after extensive flooding in Europe. *British Medical Journal* pp. 325–405. Cited in: Epstein, P. R., Mills, E., Frith, K., Linden, E., Thomas, B., and Weireter, R. (Editors). 2006. Climate Change Futures: Health, Ecological and Economic Dimensions. The Center for Health and the Global Environment, Harvard Medical School. 142 pp.

Tuyet, D. T., Thiem, V. D., Von Seidlein, L., Chowdhury, A., Park, E., Canh, D. G., Chien, B. T., Van Tung, T., Naficy, A., Rao, M. R., Ali, M., Lee, H., Sy, T. H., Nichibuchi, M., Clemens, J., and Trach, D. D. 2002. Clinical, epidemiological, and socioeconomic analysis of an outbreak of *Vibrio parahaemolyticus* in Khanh Hoa Province, Vietnam. *Journal of Infectious Diseases* 186 1615–1620. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

U.S. Environmental Protection Agency (EPA). 2008. 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.)

U.S. Environmental Protection Agency. 2004 Air Quality Criteria for Particulate Matter, October 2004. Cited in: American Lung Association, State of the Air: 2008, Protect the Air you Breathe, http://www.lungusa2.org/sota/SOTA2008.pdf.

U.S. EPA. 2005. *Heat island effect.* U.S. Environmental Protection Agency. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

U.S. Global Change Research Program. 2007. Hurricanes & Climate Change. Last revised: October 8, 2007. Available online at: http://www.usgcrp.gov/usgcrp/links/hurricanes.htm. Accessed: June 23, 2008.

U.S. Government Accountability Office (US GAO). 2007a. Climate Change: Financial Risks to Federal and Private Insurers in Coming Decades Are Potentially Significant.. Available online at http://www.gao.gov/new.items/d07820t.pdf.

Udvardy, M. D. F. 1975. A classification of the biogeographical provinces of the world. IUCN Occasional Paper no. 18. Morges, Switzerland: IUCN.

UNESCO (United Nations Educational Scientific and Cultural Organization)-WWAP (World Water Assessment Programme). 2006. Water: A Shared Responsibility. World Water Development Report 2.

UNESCO and WWAP. 2006. Water a Shared Responsibility: The United Nations World Water Development Report 2. http://unesdoc.unesco.org/images/0014/001454/145405E.pdf.

Union of Concerned Scientists. 2007. New Jersey: Confronting Climate change in the U.S. Northeast. Science, Impacts, and Solutions. Report of the Northeast Climate Impacts Assessment (NECIA).

United National Environment Programme. 2007. Global Environment Outlook, GEO-4 …

United Nations Educational Scientific and Cultural Organization (UNESCO)-World Water Assessment Programme (WWAP), World Meteorological Organization (WMO), International Atomic Energy Agency (IAEA). 2006. Water a Shared Responsibility. Chapter 4, The State of the Resource.

University Corporation for Atmospheric Research. 2006. Report Warns about Carbon Dioxide Threats to Marine Life. Last revised: July 5, 2006. Available online at: http://www.ucar.edu/news/releases/2006/acidification.shtml. Accessed: June 23, 2008.

University of California. 2006. How Plants Respond to Elevated Carbon Dioxide. Last revised: May 1, 2006. Available online at: http://www.universityofcalifornia.edu/news/article/8127. Accessed: June 23, 2008.

Unsworth, J., Wauchope, R., Klein, A., Dorn, E., Zeeh, B., Yeh, S., Akerblom, M., Racke, K., and Rubin, B. 2003. Significance of the long range transport of pesticides in the atmosphere. *Pest Management Science* 58: 314. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

US Department of Health and Human Services. 2007. Agency for Healthcare Research and Quality. Pediatric terrorism and disaster preparedness: a resource guide for pediatricians. www.ahrq.gov/research/pedprep/resource.htm. American Academy of Pediatrics. 2007. Global Climate Change and Children's Health. *Pediatrics* 120: 1149-1152.

USCCSP (U. S. Climate Change Science Program). 2000. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change, National Assessment Synthesis Team, U. S. Global Change Research Program, Washington, DC, USA.

USCCSP (U. S. Climate Change Science Program). 2008. Scientific Assessment of the Effects of Global Change on the United States by the Committee on Environment and Natural Resources, National Science and Technology Council, Washington, DC, USA.

USDA. 2008. Plant Science Research. Agricultural Research Service. Last revised: June 22, 2008. Available online at: http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=187020. Accessed: June 23, 2008.

USFWS (U.S. Fish and Wildlife Service). 1988. Endangered Species Information Booklet: Piping Plover. U.S. Fish and Wildlife Service Arlington, Virginia.

USGS. 2004. Estimated Use of Water in the United States in 2000, USGS Circular 1268,Washington, DC: U.S. Geological Survey.

408

1   Vaccaro, J. 1992. Sensitivity of groundwater recharge estimates to climate variability and change,
2   Columbia Plateau, Washington. *Journal of Geophysical Research* 97: 2821–2833.

3   van der Linden, P. J., and Hanson, C. E. (Editors). DATE. Cambridge: Cambridge University Press. pp.
4   391–431. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on
5   Global Change Research. 2008. Analyses of the effects of global change on human health and
6   welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for
7   CCSP and CENR clearance. April, 273 pp.

8   van Wuijckhuise, L., Dercksen, D., Muskens, J., de Bruyn, J., Scheepers, M., and Vrouenraets, R. 2006.
9   Bluetongue in the Netherlands; description of the first clinical cases and differential diagnosis;
10   Common symptoms just a little different and in too many herds. Tijdschr. Diergeneesd. 131:
11   649–654.

12   Vandentorren, S., Suzan, F., Medina, S., Pascal, M., Maulpoix, A., Cohen, J. C., and Ledrans, M. 2004.
13   Mortality in 13 French cities during the August 2003 heatwave. *American Journal of Public*
14   *Health* 94: 1518–1520. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and
15   Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
16   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
17   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK,
18   976 pp.

19   Vila, M., Corbin, J. D., Dukes, J. S., Pino, J., and Smith, S. D. 2007. Linking plant invasions to global
20   environmental change. In: Terrestrial Ecosystems in a Changing World, Canadell, J., Pataki, D.,
21   and Pitelka, L. (Editors). Springer, New York.

22   Viosin, N., A. F. Hamlet, L.P. Graham, D.W. Pierce, T.P. Barnett, and D.P. Lettenmaier. 2006. The role
23   of climate forecasts in wester U.S. power planning. J. Appl. Meteorol. 45: 653–673. In Wilbanks,
24   T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood,
25   R., and Zapata-Marti, R. 2007. Industry, settlement and society. IPCC. 2007: Climate Change
26   2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth
27   Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O.
28   F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University
29   Press, Cambridge, UK, pp. 357–390.

30   Vogel, C. 2005. "Seven fat years and seven lean years?" Climate change and agriculture in Africa. *IDS*
31   *Bulletin-Institue of Development Studies* 36: 30–35.

32   Volney, W. J. A., and Fleming, R. A. 2000. Climate change and impacts of boreal forest insects.
33   *Agriculture, Ecosystems & Environment* 82: 283–294.

34   Vose, R., Karl, T., Easterling, D., Williams, C., and Menne, M. 2004. Climate (communication arising):
35   Impact of land-use change on climate. *Nature* 427(6971): 213–214. Cited in: IPCC, 2007.
36   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
37   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
38   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
39   University Press, Cambridge, UK, 976 pp.

40   Vuglinsky, V., and T. Gronskaya. 2005. Strategic Forecast up to 2010–2015 on the Effect of Expected
41   Climate Changes on the Economy of Russia. ROSHYDROMET, Moscow (in Russian).

Walker, R.R. 2001. Climate change assessment at a watershed scale. Water and Environment Association of Ontario Conference, Toronto, Canada, 12 pp.

Walter, K.M., L.C. Smith, and F.S. Chapin, III. 2007. Methane bubbling from northern lakes: present and future contributions to the global methane budget. Philosophical Transactions of the Royal society A 365:1657–1676.

Walter, M.T., D.S.Wilks, J.Y. Parlange, and B.L. Schneider. 2004. Increasing evapotranspiration from the conterminous United States. *J.Hydrometeorol.* 5: 405–408.

Wan, S. Q., Yuan, T., Bowdish, S., Wallace, L., Russell, S. D., and Luo, Y. Q. 2002. Response of an allergenic species *Ambrosia psilostachya* (Asteraceae), to experimental warming and clipping: implications for public health. *American Journal of Botany* 89: 1843–1846. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Wardle, D. A., Bardgett, R. D., Klironomos, J. N., Setäl&auml, H., van der Putten, W. H., and Wall, D. H. 2004. Ecological linkages between aboveground and belowground biota. *Science* 304(5677): 1629–1633.

Watkins, S. J., Byrne, D., and McDevitt, M. 2001. Winter excess morbidity: is it a summer phenomenon? *Journal of Public Health Medicine* 23(3): 237–241. Cited in: Ebi, K., Blabus, J., Kinney, P., Lipp, E., Mills, D., O'Neill, M., and Wilson, M. 2008. Effects of Global Change on Human Health. Synthesis and Assessment Product 4.6 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA (peer-reviewed draft report).

Wayne, P., Foster, S., Connolly, J., Bazzaz, F., and Epstein, P. 2002. Production of allergenic pollen by ragweed (*Ambrosia artemisiifolia* L.) is increased in CO2-enriched atmospheres. *Annals of Allergy, Asthma and Immunology* 88: 279–282. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

WCI. 2007. Frequently Asked Questions: Western Climate Initiative To Reduce Greenhouse Gases.

Weber, R. G. 2001. Preconstruction horseshoe crab egg density monitoring and habitat availability at Kelly Island, Port Mahon, and Broadkill Beach Study areas. Prepared for the Philadelphia District Corps of Engineers, Philadelphia, PA. December.

Weber, R. W. 2002. Mother Nature strikes back: global warming, homeostasis, and implications for allergy. *Annals of Allergy, Asthma and Immunology* 88: 251–252. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

1   Wentz, F. J., Ricciardulli, L., Hilburn, K., and Mears, C. 2007. How much more rain will global
2   warming bring? *Science* 317(5835): 233–235.
3   http://www.sciencemag.org/cgi/content/abstract/1140746.

4   Westerling, A. L., Hidalgo, H. G., Cayan, D. R., and Swetnam, T. W. 2006. Warming and earlier spring
5   increase western U.S. forest wildfire activity. *Science* 313:940–943.

6   Westling, A., and Bryant, B. 2006. Climate Change and Wildfire in and Around California: Fire
7   Modeling and Loss Modeling. California Climate Change Center.

8   White, N., Sutherst, R. W., Hall, N., and Whish-Wilson, P. 2003. The vulnerability of the Australian
9   beef industry to impacts of the cattle tick (*Boophilus microplus*) under climate change. Climatic
10   Change 61: 157–190.

11   Whitman, S., Good, G., Donoghue, E. R., Benbow, N., Shou, W., and Mou, S. 1997. Mortality in
12   Chicago attributed to the July 1995 heat wave. *American Journal of Public Health* 87(9): 1515–
13   1518. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global
14   Change Research. 2008. Analyses of the effects of global change on human health and welfare
15   and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and
16   CENR clearance. April, 273 pp.

17   WHO. 2005. Ecosystems and human well-being: health synthesis. A report of the Millennium
18   Ecosystem Assessment. World Health Organization, Geneva, 54 pp. Cited in: IPCC, 2007.
19   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
20   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
21   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
22   University Press, Cambridge, UK, 976 pp.

23   Wigley, T. M. L. 2003. MAGICC/SCENGEN 4.1: Technical Manual, UCAR - Climate and Global
24   Dynamics Division, Boulder, CO.

25   Wigley. 2003. MAGICC (Model for Assessment of Greenhouse gas-Induced Climate Change), version
26   4.1

27   Wilbanks, T. J. 2007. Conclusions and Research Priorities in Effects of Climate Change on Energy
28   Production and Use in the United States: A Report by the U.S. Climate Change Science Program
29   and the subcommittee on Global Change Research, Washington, DC. [SAP 4–5].

30   Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-
31   Wood, R., and Zapata-Marti, R. 2007. Industry, settlement and society. In: IPCC, 2007.
32   Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II
33   to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.
34   L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge
35   University Press, Cambridge, UK, pp. 357–390.

36   Wilbanks, T. J., P. Leiby, R. Perlack, J. T. Ensminger and S.B. Wright. 2005. Toward an integrated
37   analysis of mitigation and adaptiation: some preliminary findings. Mitigation and Adaptation
38   Strategies for Global Change. In Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F.,
39   Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., and Zapata-Marti, R. 2007. Industry,
40   settlement and society. IPCC. 2007: Climate Change 2007: Impacts, Adaptation and
41   Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the

Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, pp. 357–390.

Wilby, R., Hedger, M., and Orr, H. G. 2005. Climate change impacts and adaptation: a science agenda for the Environment Agency of England and Wales. *Weather* 60: 206–211. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Wiley, J. W. and Wunderle, J. M., Jr. 1994. The effects of hurricanes on birds, with special reference to Caribbean islands. *Bird Conserv. Int.* 3: 319–349.

Wilkinson, P, Pattenden, S., Armstrong, B., Fletcher, A., Kovats, R. S., Mangtani, P., et al. 2004. Vulnerability to winter mortality in elderly people in Britain: population based study. *British Medical Journal* 329(7467): 647. Cited in: U.S. Climate Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008. Analyses of the effects of global change on human health and welfare and human systems. Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance. April, 273 pp.

Winkler, J.A., J.A. Andresen, G. Guentchev, and R. D. Kriegel. 2002. Possible impacts of projected temperature change on commercial fruit production in the Great Lakes Region. *J. Great Lakes Res. 28, 608-625.*

Wisdom, M. J., Rowland, M. M., and Suring, L. H. (Editors). 2005. Habitat Threats in the Sagebrush Ecosystem: Methods of Regional Assessment and Applications in the Great Basin. Allen Press/Alliance Communication Group Publishing, Lawrence, Kansas, USA.

Wittmann, R., and Flick, G. 1995. Microbial contamination of shellfish: prevalence, risk to human health and control strategies. *Annual Review of Public Health* 16: 123–140. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK, 976 pp.

Wolfe, D. W., Schwartz, M. D., Lakso, A. N., Otsuki, Y., Pool, R. M., and Shaulis, N. 2005. Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. *International Journal of Biometeorology* 49(5): 303–309.

Woodward, F. I., and Lomas, M. R. 2004. Vegetation dynamics: simulating responses to climatic change. *Biol. Rev.* 79: 643–670.

World Bank. 2006. World Development Indicators. The International Bank for Reconstruction and Development, The World Bank, Washington DC. 242 pp.

WRI. 2008. Climate Analysis Indicators Tool (CAIT) Version 5.0. Washington, DC: World Resources Institute. http://cait.wri.org.

412

1   Wrona, F. J., Prowse, T. D., and Reist, J. D. 2005. Freshwater Ecosystems and Fisheries. ACIA.Arctic
2   Climate ImpactAssessment, CambridgeUniversity Press, NewYork, pp. 353–452. [Accessed
3   12.02.07: http://www.acia.uaf.edu/]

4   Wu, H. and Chan, L. 2001. Surface ozone trends in Hong Kong in 1985–1995. *Environment*
5   *International* 26: 213–222. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation
6   and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
7   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
8   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK,
9   976 pp.

10 Xu, H. Q., and Chen, B. Q. 2004. Remote sensing of the urban heat island and its changes in Xiamen
11   City of SE China. *Journal of Environmental Sciences* 16(2): 276–281. Cited in: U.S. Climate
12   Change Science Program (CCSP) and the Subcommittee on Global Change Research. 2008.
13   Analyses of the effects of global change on human health and welfare and human systems.
14   Synthesis and Assessment Product 4.6. Third review draft for CCSP and CENR clearance.
15   April, 273 pp.

16 Zervas, C. 2001. Sea Level Variations of the United States 1854–1999. NOAA Technical Report NOS
17   CO-OPS 36, 201 pp. Cited in: Gutierrez, B., S. Williams and E. Thieler, 2007. Potential for
18   shoreline changes due to sea-level rise along the U.S. Mid-Atlantic Region. U.S. Geological
19   Survey. Open-File Report 2007-1278.

20 Zhang, K., Douglas, B. C., and Leatherman, S.P. 2004. Global warming and coastal erosion. *Climatic*
21   *Change* 64(1-2): 41–58. Cited in: Gutierrez, B., S. Williams and E. Thieler, 2007. Potential for
22   shoreline changes due to sea-level rise along the U.S. Mid-Atlantic Region. U.S. Geological
23   Survey. Open-File Report 2007-1278.

24 Zhang, X., Zwiers, F., Hergerl, H., Lambert, F., Gillet, N., Solomon, S., Stott, P. and Nozawa, T. 2007.
25   Detection of human influence on twentieth-century precipitation trends. *Nature* 48: 461–465.
26   http://www.nature.com/nature/journal/v448/n7152/abs/nature06025.html.

27 Ziska, L. H., Emche, S. D., Johnson, E. L., George, K., Reed, D. R., and Sicher, R. C. 2005. Alterations
28   in the production and concentration of selected alkaloids as a function of rising atmospheric
29   carbon dioxide and air temperature: implications for ethno-pharmacology. *Global Change*
30   *Biology* 11: 1798–1807. Cited in: IPCC, 2007. Climate Change 2007: Impacts, Adaptation and
31   Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the
32   Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van
33   der Linden, P. J., and Hanson, C. E. (Editors), Cambridge University Press, Cambridge, UK,
34   976 pp.

35 Ziska, L. H., Teasdale, J. R., and Bunce, J. A. 1999. Future atmospheric carbon dioxide may increase
36   tolerance to glyphosate. *Weed Science* 47: 608–615.

37 Zolbrod, A. N., and Peterson, D. L. 1999. Response of high-elevation forests in the Olympic Mountains
38   to climatic change. *Canadian Journal of Forest Research* 29: 1966–1978.

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

1	▪	U.S. Department of Health and Human Services, Indian Health Service
2	▪	U.S. Department of Health and Human Services, National Institutes of Health
3	▪	U.S. Department of Homeland Security, Office of Safety and Environment
4	▪	U.S. Department of Homeland Security, Federal Emergency Management Agency
5	▪	U.S. Department of Homeland Security, U.S. Coast Guard
6	▪	U.S. Department of Housing and Urban Development
7	▪	U.S. Department of Interior, Office of Environmental Policy and Compliance
8	▪	U.S. Department of Justice, Environment and Natural Resources Division
9	▪	U.S. Department of Labor, Mine Safety and Health Administration
10	▪	U.S. Department of Labor, Occupational Safety and Health Administration
11	▪	U.S. Department of State, Bureau of Oceans and International Environmental and Scientific
12		Affairs
13	▪	U.S. Department of Transportation, Secretary for Policy
14	▪	U.S. Department of Transportation, Federal Aviation Administration
15	▪	U.S. Department of Transportation, Federal Highway Administration
16	▪	U.S. Department of Transportation, Federal Motor Carrier Safety Administration
17	▪	U.S. Department of Transportation, Federal Railroad Administration
18	▪	U.S. Department of Transportation, Maritime Administration
19	▪	U.S. Department of Transportation, Federal Transit Administration
20	▪	U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration
21	▪	U.S. Department of Transportation, Research and Innovative Technology Administration
22	▪	U.S. Department of Transportation, Saint Lawrence Seaway Development Corporation
23	▪	U.S. Department of Transportation, Surface Transportation Board
24	▪	U.S. Environmental Protection Agency, Office of Federal Activities
25	▪	U.S. Environmental Protection Agency, NEPA Compliance Division
26	▪	U.S. Federal Energy Regulatory Commission, Office of Energy Projects
27	▪	U.S. Federal Energy Regulatory Commission, Division of Hydropower, Environment and
28		Engineering
29	▪	U.S. Federal Energy Regulatory Commission, Division of Gas – Environmental and
30		Engineering
31	▪	U.S. Fish and Wildlife Service
32	▪	U.S. Forest Service
33	▪	U.S. Institute for Environmental Conflict Resolution
34	▪	Valles Caldera Trust
35		
36	**9.2**	**STATE AGENCIES**
37	▪	Alabama Department of Environmental Management
38	▪	California Office of Attorney General
39	▪	Connecticut Office of Attorney General
40	▪	Florida Department of Environmental Protection
41	▪	Florida Department of Transportation
42	▪	Florida Energy Office
43	▪	Hawaii Department of Transportation
44	▪	Maryland Historical Trust
45	▪	Massachusetts Office of Attorney General
46	▪	Minnesota Pollution Control Agency
47	▪	Missouri Department of Natural Resources
48	▪	Montana Department of Transportation
49	▪	New Jersey Department of Environmental Protection
50	▪	New Jersey Office of Attorney General

1	▪ New Mexico Department of Attorney General
2	▪ New York State Department of Transportation
3	▪ New York State Office of Attorney General
4	▪ Nevada Department of Transportation
5	▪ Nevada Division of Environmental Protection
6	▪ Oregon Department of Attorney General
7	▪ Oregon Department of Environmental Quality
8	▪ Pennsylvania Department of Environmental Protection
9	▪ Rhode Island Department of Attorney General
10	▪ Rhode Island Department of Environmental Management
11	▪ South Carolina Department of Transportation
12	▪ South Dakota Department of Environmental & Natural Resources
13	▪ Tennessee Department of Transportation
14	▪ Vermont Agency of Natural Resources
15	▪ Vermont Office of Attorney General
16	▪ Washington State Department of Ecology
17	

18 9.3 ELECTED OFFICIALS

19	▪ The Honorable Sarah Palin, Governor of Alaska
20	▪ The Honorable Togiola T.A. Tulafono, Governor of American Samoa
21	▪ The Honorable Janet Napolitano, Governor of Arizona
22	▪ The Honorable Mike Beebe, Governor of Arkansas
23	▪ The Honorable Bill Ritter, Governor of Colorado
24	▪ The Honorable Ruth Ann Minner, Governor of Delaware
25	▪ The Honorable Sonny Perdue, Governor of Georgia
26	▪ The Honorable Felix P. Camacho, Governor of Guam
27	▪ The Honorable C.L. "Butch" Otter, Governor of Idaho
28	▪ The Honorable Rod R. Blagojevich, Governor of Illinois
29	▪ The Honorable Mitchell E. Daniels, Governor of Indiana
30	▪ The Honorable Chet Culver, Governor of Iowa
31	▪ The Honorable Kathleen Sebelius, Governor of Kansas
32	▪ The Honorable Steve Beshear, Governor of Kentucky
33	▪ The Honorable Bobby Jindal, Governor of Louisiana
34	▪ The Honorable John E. Baldacci, Governor of Maine
35	▪ The Honorable Martin O'Malley, Governor of Maryland
36	▪ The Honorable Jennifer M. Granholm, Governor of Michigan
37	▪ The Honorable Tim Pawlenty, Governor of Minnesota
38	▪ The Honorable Haley Barbour, Governor of Mississippi
39	▪ The Honorable Dave Heineman, Governor of Nebraska
40	▪ The Honorable John Lynch, Governor of New Hampshire
41	▪ The Honorable Bill Richardson, Governor of New Mexico
42	▪ The Honorable Michael F. Easley, Governor of North Carolina
43	▪ The Honorable John Hoeven, Governor of North Dakota
44	▪ The Honorable Benigno R. Fitial, Governor of the Commonwealth of the Northern Mariana
45	Islands
46	▪ The Honorable Ted Strickland, Governor of Ohio
47	▪ The Honorable Brad Henry, Governor of Oklahoma
48	▪ The Honorable Edward G. Rendell, Governor of Pennsylvania
49	▪ The Honorable Aníbal Acevedo-Vilá, Governor of Puerto Rico
50	▪ The Honorable Rick Perry, Governor of Texas

1   ▪   The Honorable Jon Huntsman, Jr., Governor of Utah
2   ▪   The Honorable John P. deJongh, Jr., Governor of the United States Virgin Islands
3   ▪   The Honorable Timothy M. Kaine, Governor of Virginia
4   ▪   The Honorable Joe Manchin III, Governor of West Virginia
5   ▪   The Honorable Jim Doyle, Governor of Wisconsin
6   ▪   The Honorable Dave Freudenthal, Governor of Wyoming
7
8   **9.4   NATIVE AMERICAN TRIBES**

9   ▪   Atmautlauk Traditional Council
10   ▪   Big Pine Paiute Tribe of the Owens Valley
11   ▪   Bois Forte Band of Chippewa
12   ▪   Buckland Fuel Project
13   ▪   Chalkyitsik Village Council
14   ▪   Chickasaw Nation
15   ▪   Enterprise Rancheria
16   ▪   Flandreau Santee Sioux Tribe
17   ▪   Fond du Lac Reservation
18   ▪   Goshute Business Council
19   ▪   Greenville Rancheria
20   ▪   Holy Cross Village
21   ▪   Jena Band of Choctaw Indians
22   ▪   Kaibab Paiute Tribe
23   ▪   Kokhanok Village Council
24   ▪   Leech Lake Band Ojibwe
25   ▪   Leisnoi Village aka Woody Island Tribal Council
26   ▪   Lime Village Traditional
27   ▪   Louden Tribal Council
28   ▪   Miami Tribe of Oklahoma
29   ▪   Mille Lacs Band of Ojibwe
30   ▪   Minto Village Council
31   ▪   Modoc Tribe
32   ▪   Native Village of Atka
33   ▪   Native Village of Buckland
34   ▪   Native Village of Savoonga
35   ▪   Native Village of Wales
36   ▪   Nightmate Traditional Council
37   ▪   Pinoleville Domo Nation
38   ▪   Pueblo de San Ildefonso
39   ▪   Red Cliff Tribe
40   ▪   Skagway Traditional Council
41   ▪   Swinomish Indian Tribal Community
42   ▪   Tatitlek Village IRA Council
43   ▪   Wiyot Tribe
44   ▪   Yakutat Tlingit Tribe
45
46   **9.5   COUNTY/LOCAL GOVERNMENTS**

47   ▪   Knox County, TN Department of Air Quality Management
48   ▪   City of New York Environmental Law Division
49

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

Chapter 10   Index

422

Mr. DUVALL. The comment period on our proposal will end next week. We will carefully analyze all of the comments and expect to issue a final decision this year, less than 1 year after the enactment of the EISA. This will be an accomplishment in which we can all take credit and pride. And I will be pleased to answer any questions on the rulemaking.

[The statement of Mr. Duvall follows:]

Statement of The Honorable Tyler Duvall
Acting Under Secretary for Policy
U.S. Department of Transportation
before the
Select Committee on Energy Independence and Global Warming
U.S. House of Representatives
Hearing on Improving Automobile Fuel Economy

June 26, 2008

Mr. Chairman, I am Tyler Duvall, Acting Under Secretary for Policy for the Department of Transportation. I appreciate the opportunity to appear before the Committee to discuss our most recent proposal for substantial increases in the fuel economy standards. These increases are needed more than ever to achieve energy independence and security and reduce carbon dioxide emissions.

The demand for petroleum is steadily increasing around the world and here in the U.S. Altogether, the U.S. consumes about 25 percent of the total amount of petroleum consumed worldwide. Much of that petroleum goes to providing us the mobility on which our economy depends. Sixty percent of the petroleum needed to meet that demand is imported.

The U.S. produces an estimated 23 percent of the world's greenhouse gas (GHG) emissions. Carbon dioxide is the predominant GHG emitted by human sources. As EPA has said, carbon dioxide is responsible for about 95 percent of transportation GHG emissions, with all of the other emissions combined accounting for the remaining 5 percent of GHG emissions. The transportation sector is the largest and fastest growing source of domestic carbon dioxide emissions, producing approximately 30 percent of the nation's total.

The problems posed by light vehicle fuel consumption and carbon dioxide emissions have a common solution. Carbon dioxide is a natural by-product of the combustion of fuel in light vehicles. Given that tailpipe emissions of carbon dioxide cannot be destroyed or feasibly captured by control technologies in light vehicles, the feasible way to make the most substantial reductions in their tailpipe emissions of carbon dioxide now and for the foreseeable future is to reduce fuel consumption.

This fundamental scientific reality was the basis for the President's "Twenty in Ten" proposal to reduce domestic gasoline consumption by 20 percent in 2017. A key component of his proposal was a significant increase in fuel economy standards for cars and light trucks. By increasing standards beginning in model year 2010 for cars and in model year 2012 for light trucks, the President's aggressive proposal was projected to save up to 8.5 billion gallons of gasoline in 2017 alone and reduce consumption by 5 percent. These amounts were based on an assumption that, on average, fuel economy standards for both light trucks and passenger cars would increase 4 percent per year.

To enable us to increase the car standards responsibly, the President asked Congress to give us the authority to set attribute-based car standards just as we had set attribute-based light truck standards. We took that step in response to the safety concerns expressed by the National Academy of Science in a congressionally mandated report. NAS said that significantly and quickly increasing the fuel economy standards without first reforming the standards by making them attribute-based would likely lead to the further downsizing of vehicles and thus to additional deaths and injuries on our highways.

In December of last year, Congress opened the way to substantial increases in the car standards when it enacted the Energy Information and Security Act (EISA). EISA mandated that the car standards and light truck standards be set high enough to ensure that the combined industry-wide average reaches at least 35 mpg in model year 2020. It not only gave us the authority to set attribute-based car standards, but also mandated that both car and light truck standards must be attribute-based.

Using the guidance and new tools provided by EISA, we have proposed standards for model years 2011 to 2015. Those standards are based in large measure on the joint work of the technical staffs of our agency and the Environmental Protection Agency. Our staffs met nearly daily for seven months and completely revamped the foundations of CAFE rulemaking. For example, they reviewed and revised the list of technologies that will be available during those years and updated the estimated costs and effectiveness figures for those technologies. In addition, they updated and refined assumptions, methodologies and models.

Our proposed fuel economy standards were developed with the aid of cost-benefit analysis. We updated our benefit estimates as well as our cost estimates. The benefits consist primarily of three things: the fuel saved, the contribution that fuel savings makes to energy security and independence, and the reduction in carbon dioxide emissions resulting from that fuel savings. We updated the dollar values of the first two and for the first time placed a value on the third. We recognize that there are uncertainties regarding each of these values and have requested public comments on all of them. We then conducted a balancing that ensured every dollar we ask companies to spend for better fuel economy returns at least one dollar's worth of benefits.

The proposed standards would increase fuel economy 4.5 percent per year over the 5-year period ending in 2015. This rate substantially exceeds not only the 3.3 percent per year needed on average to meet the 35 mpg minimum established by Congress last year, but also the 4 percent per year increase called for in the President's Twenty-in-Ten proposal. An average annual increase of only 2.1% for combined fleet from 2016 onward would be needed to reach the required level of 35 mpg by model year 2020.

For passenger cars, the proposal would increase fuel economy from the current 27.5 miles per gallon to an industry average of 35.7 miles per gallon by 2015. For light trucks, the proposal calls for increases from 23.5 miles per gallon in 2010 to an industry average of 28.6 miles per gallon in 2015. We estimate achieving these levels of fuel

economy would require nearly $50 billion of investments in fuel saving technologies through 2015.

These standards are tough, but achievable and necessary. All told, the proposal will save nearly 55 billion gallons of fuel and a reduction in carbon dioxide emissions estimated at 521 million metric tons over the life of the affected vehicles.

To provide manufacturers with added flexibility, we have proposed regulations permitting them to transfer and trade compliance credits.

We will soon be receiving public comments on our proposal. Our decisions about the final rule will be reached after careful analysis of the comments and with the benefit of full analysis of the environmental impacts of the alternatives before the agency.

We expect to make a final decision this year, less than one year after the enactment of EISA. This will be an accomplishment in which we can all take credit and pride.

I would be pleased to answer any questions.

Mr. INSLEE. Would your colleague like to answer anything? He is certainly welcome to.

Thank you.

The Chair will recognize himself for 5 minutes.

This may be clear to everyone, but I do want to make sure we are all on the same page. The recently enacted bill was billed as a 35-miles-per-gallon standard, but it actually is more than that. It required the maximum feasible rate to be achieved every year; is that right?

Mr. DUVALL. Yeah. The law, EPCA, requires basically max feasible, and that was not changed in this.

Mr. INSLEE. So I want to focus on fuel costs and your modeling and assumptions regarding new technology. First off, in your assumptions what percentage of the U.S. automobile fleet does your agency believe is reasonably attainable by the year of, let us say, 2015 to be electric propulsion or at least partially electric propulsion?

Mr. DUVALL. Congressman, we did not estimate in the rulemaking proposal percentage of electrified vehicles. Obviously the product plans that were submitted to us by the auto manufacturers included a percentage of hybrid vehicles.

I am not sure, Steve, if we made that information public. These are confidential product plans, so I do not believe we published the precise automaker decisions with respect to hybrid vehicles; is that right? Yeah, that is right.

Mr. INSLEE. I will tell you what causes me a little concern. We have cars driving around the country today, and I have driven one that gets 150 miles per gallon because it is a plug-in hybrid electric car. These are not hypothetical vehicles, they are real vehicles. You can buy one today from various vendors in the United States. Chevrolet certainly intends to have one on the road by 2010 or 2011.

Is it your understanding that you simply in your decisionmaking let the automakers tell you how many electric vehicles are going to be on the road, or don't you think it is the Federal Government's obligation under this bill to say, look, we have this technology available, our obligation is to figure out what is maximally achievable, what is feasible? It is clearly feasible to do this. Why are we not setting a goal for 2015 on what percentage of cars will be plug-in hybrids, forgetting for the moment full-electric vehicles.

Mr. DUVALL. Right. Good question, Congressman. The way the rule works and the structure of the rule is basically an input-output model in which basically the array of technologies, including hybrid technologies, which is, I think, the most expensive technology that could be applied—but there is a whole range and suite of technologies, lower costs than hybrids, that get applied basically directly to the automobiles through the model. We take the product plans that are submitted to us from the automobile companies who did not submit substantial numbers of plug-in hybrids. I will say those product plans will be updated very soon right after the close of the comment period——

Mr. INSLEE. I have to tell you this is not satisfactory to me. It is our job to decide what is maximally feasible, not the producers. We have been following their lead, frankly, for 30 years, and we

have fallen way behind the world in technology as a result. We have this known technology, we know it is technologically feasible, we know it is economically feasible. It is just a question of how fast to get it to market.

Now, when I voted for that bill, I was of the understanding that the Federal Government, Uncle Sam, protecting consumers would start making some decisions. If we have a technically feasible electrical vehicle, why should we not expect our Federal agency to be assessing what percentage can be part of the fleet by what certain date using the best available evidence? I have no objection receiving evidence from the geniuses, and there are geniuses in this industry, but isn't it our job, or don't you think it should be our job, to be a little more aggressive in that regard?

Mr. DUVALL. The way the rule is structured, we do not mandate specific technologies. What we do is apply technologies based on their costs. At the point of which the cost of applying those technologies exceeds the benefit largely in the form of fuel savings, the model basically determines that it is no longer cost-beneficial to society to continue the technology.

Mr. INSLEE. Right. That is my next question. What assumption did you make what fuel costs in deciding whether a plug-in hybrid should be produced or not?

Mr. DUVALL. There is a range—we use the base case, the average case, EIA forecast as was noted in the Chairman's opening statement. Obviously out through 2015 those prices as were indicated appeared to be somewhat off of current prices.

Mr. INSLEE. First tell us what they are.

Mr. DUVALL. 2.42 in 2015, and that is the EIA forecast for 2015.

Mr. INSLEE. We hope to do some things to bring it down with our anti-excessive-speculation bills we passed today. That really appears to be—and I think that most of my constituents paying 4.15 at the pump—kind of silly. Basing a major Federal policy on the assumption in 2015 gas is going to cost 2.42 a gallon with the emerging Chinese economy, the lack, isn't that kind of a silly number to use?

Mr. DUVALL. Not at all, Congressman. I think, as you noted, long-term oil prices are obviously inherently uncertain. I think, as you noted, a number of people are talking about the potential that speculation is driving up prices. Obviously there is an internal inconsistency to argue on the one hand that speculation is driving up prices, but that long-run prices should be significantly lower.

We are dealing obviously in an extremely volatile oil price environment. Currently this is a long-term policy, however. We have taken comment on that exact question in the rulemaking, however, and if we receive substantial comments, and if EIA updates its oil price forecast, we will obviously take that into consideration.

Mr. INSLEE. I would like to provide you a comment right now, if I may. It is ridiculous to assume the price will be 2.42 a gallon in the year 2015, number one.

Number two, I believe it is Uncle Sam's responsibility to use a reasonable gas price, and if you use a reasonable gas price, plug-in, full-electric vehicles will be eminently economically feasible within just a few years. It is your job to be making that decision, and I hope you will do so.

With that I yield to Mrs. Miller.

Mrs. MILLER. Thank you, Mr. Chairman. And I appreciate the witnesses being here today.

Let me just ask you gentlemen, what is your opinion of how CAFE standards have worked since the 1970s since there seems to be some disagreement up here? Are you willing to bite on that one?

Mr. DUVALL. Yes, Congresswoman, we are. We think obviously there were significant structural problems with the model for doing fuel economy requirements in previous years, and we believe we corrected that in 2006 with the light truck standard using an attribute-based system.

We greatly appreciated that the Congress recognized the merits of that approach, which treats all manufacturers equally, and recognizes consumers have diverse preferences, and also recognizes the safety risks associated with a flat standard that will provide incentives for auto manufacturers not to deploy technologies, but simply to make lighter vehicles, which are more of a safety hazard. We believe the current approach proposed in the last rulemaking, which builds on the 2006 model, was a substantial improvement and remedied many of the failures I just talked about.

Mrs. MILLER. If I understood what you just said, you are looking to apply uniformity across the industry with a new CAFE standards with the modeling that you are using right now.

Mr. DUVALL. It is a size-based standard, so we take the product plans provided to us by the manufacturers, apply that into a model, which produces a curve. On the left-hand side of the curve is a smaller-footprint vehicle; on the right-hand of the curve is a larger-footprint vehicle. For the larger-footprint vehicle, obviously the corresponding fuel economy requirements are different.

Basically the rule's intent is to recognize the reverse product mix that our car makers have across the globe, not just in the U.S., and to really drive technologies across the board. I think the previous approach you are talking about really did not drive technologies efficiently and had a potentially serious safety impact if pursued aggressively.

Mrs. MILLER. I am looking forward to hearing from the next panel, particularly the fellow from Nissan. And I appreciate the American jobs that they provide, but it has been said that Nissan requested and received a special interest exemption during the CAFE standards, sort of a loophole in the law that allows them to combine their domestic and import car fleets through 2013; is that correct?

Mr. DUVALL. I am not going to characterize it as a loophole. There is a special provision, obviously, that impacts Nissan related to the combination of those fleets, yes.

Mrs. MILLER. Now, how did that happen, and do you believe that that is fair?

Mr. DUVALL. I am not sure how it happened. I was not up here, obviously, when the bill was being written. And as far as fairness, obviously the law, it was signed by the President and passed by the Congress, and we are going to implement it.

Mrs. MILLER. Well, I think it is good for them that they were able to get that, but I think it would have been fair to have every-

body in the industry, both domestic and foreign, all treated equally. I just point that out. I think that is something of note.

The model, the proposed—in your notice of rulemaking that you sent out in April, your proposed standards as we looked at it are essentially resulting in the increase, I believe, of the CAFE standards, about 17 percent. And you heard me say in my opening statement we thought that that was—I am not sure if—so I guess it is part of my question. We are trying to figure it out in the office before I came over, what is the percentage of increase actually in this. But dollarwise you heard me say in my opening statement we think it interpolates to $85 billion on the domestic autos, and that is not a number that came out of my office. It is some of the fellows from the domestic autos have been saying that.

Do you think the 17 percent is somewhere in the ballpark? And what about the $85 billion mandate? When you are doing your model, do you take into consideration job loss or the economics that you are foisting on an industry in a State in particular.

Mr. DUVALL. Congresswoman, I think our estimate is approximately 25 percent increase over the time period. The overall statute requires by 2020 a 35 mpg standard across the board for trucks and light cars, and we put forward a proposal that exceeds that pace by a decent margin, but not too much, in our view.

As far as total cost, we estimate basically across the board, not with respect to U.S. companies or non-U.S. companies, a $46.7 billion impact, which is among the most expensive rulemakings ever completed in the Federal Government's history. It is an extremely aggressive proposal. We are very cognizant of the impacts of this proposal on the industry.

The benefits of the proposal from a societal perspective do exceed those basically in a benefit-cost ratio of about 1.5 to 1.6. So from a societal perspective, the rulemaking makes a lot of sense, but we are extremely aware of the impacts on various manufacturers.

I think the attribute-based system, as I indicated previously, is an extremely important element of the fairness of this proposal, and the distribution of cost is far more fair and efficient, frankly, from an economics perspective than would have been done under a flat standard increase.

Mrs. MILLER. I appreciate that.

My final question would be have you interpolated how much the special exemption for Nissan is saving that company or for the others?

Mr. DUVALL. No, we have not estimated that, Congresswoman.

Mrs. MILLER. Will that be part of your work as well?

Mr. DUVALL. I do not believe we are going to estimate that, but I will check with our technical folks on that.

Mrs. MILLER. Thank you.

Thank you, Mr. Chairman.

Mr. INSLEE. Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman.

And I sympathize with my colleague's concern about a level playing field for American manufacturers and those that are owned by foreign companies.

I also have to say that as somebody who never got any subsidies or incentives or grants from the government to start a small busi-

ness and try to produce a product that the public will buy—in my case it happened to be music—it certainly is a long shot. And it was my judgment or lack thereof that made some records that I made successful and some records that I made dogs, that sold only a few copies and disappeared into the cut-out bins rather quickly. So they are all downloads now, they are not records.

Anyway, my point is that I read recently that GM and Ford have been—even as they are cutting back on the manufacturing of the SUVs and light trucks, that they have had to add shifts for some of their smaller cars because the demand has moved in that direction. So I would suggest that perhaps better management would have foreseen that coming. It is the kind of thing that it is hard to hear when it is your district and your company. It is hard for me to hear from people when I was being told why my record wasn't a hit.

I do think that there is a factor here regarding how many millions of dollars it costs or how many billions or millions of dollars it would have cost to tool up for hybrids, for fuel-efficient cars 10 years ago or 20 years ago and not be in the situation now of having to have it legislated.

But when President Kennedy issued his challenge to us as a country to go to the moon, he didn't have NASA run a feasibility study on that goal. He just set an example of government setting a seemingly impossible mark and challenging the country to meet it, which is what we need to do here for our family budgets, for economy and for our national security.

I thank you for your testimony. I wanted to ask in predicting feasibility, technological feasibility, is NHTSA attempting to factor in the potential market impact of plug-in hybrids like the Chevy Volt or other models that may be available, or other batteries that may be on the verge of coming into play, including some that I am aware of that are orders of magnitude more efficient and hold that much deeper a charge than those used today?

Mr. DUVALL. There is little question, in our view, that there is enormous progress with respect to battery technologies and plug-in hybrids. As I said to the then-Chairman, the structure of the rule basically takes the cost of all these technologies—and the technologies you have cited are obviously extremely expensive technologies, but produce potentially enormous benefits if they can be commercialized successfully—and inputs those into a model which basically says that at some point it is not cost-beneficial to society to apply a technology whose costs produce fewer amounts of fuel savings in basically dollar terms.

So at some point it doesn't make sense to impose costs on manufacturers if the fuel savings that are produced from those cost requirements do not produce obviously benefits equivalent to the cost. So it is a marginal cost and marginal benefit analysis.

Now, as these technologies develop over the coming years, and as we absorb additional product plans, which is what we will do here soon, very soon actually, for the next round of product plans, it is important to note that the product plans we utilized for this NPRM were 2007 product plans. The next round of product plans may include precisely the types of technologies you are talking about, and those will then be included in the rulemaking.

Mr. HALL. Thank you so much.

I only have a little bit of time. GM and Ford both have been making flex-fuel vehicles, E85-compatible vehicles, and there are a couple hundred thousand of them on the roads in my State of New York. However, there are only a few stations that carry E85, and none in my district. West Point has just agreed to put in a 5,000-gallon tank for their motor pool and commissary so that their concentrated population that buys a lot of product can get some flowing through the pipeline.

Does the administration have an opinion on whether something should be done, and perhaps something needs to be legislated or a rule made so that these alternative or biofuel mixes can be made available since the cars are being sold ostensibly for that purpose.

Mr. DUVALL. Congressman, actually the administration, the President, pushed extremely hard in the energy bill to not only increase the fuel economy requirements under our NPRM, but also for an alternative energy mandate that we will see a huge increase in ethanol-powered vehicles in the United States. So we had the push on the production side through the mandate included in the December act, and then on our side we have a huge push of technology requirements and obviously incentives through the structure of CAFE for flex-fuel vehicles.

So the short answer is yes, mandates combined with market-based regulations we think are going to push these very aggressively.

Mr. HALL. Thank you, Mr. Chairman.

The CHAIRMAN [presiding]. I thank the gentleman.

The Chair recognizes the gentlelady from Tennessee Mrs. Blackburn.

Mrs. BLACKBURN. Thank you, Mr. Chairman.

Mr. Duvall, thank you for your testimony and your time. I want to ask you a question, end of page 22, top of page 3, on your testimony. You are talking about between now and 2015 you estimate that $50 billion of investment R&D is going to be necessary to develop fuel-saving technologies that we will need by 2015; is that correct?

Mr. DUVALL. That is the cost that we have estimated on the manufacturers of the rulemaking.

Mrs. BLACKBURN. Who is bearing that cost?

Mr. DUVALL. The manufacturers will bear those costs.

Mrs. BLACKBURN. The manufacturers. So that is all private-sector dollars that they are putting in to bring a better product to the American marketplace.

Mr. DUVALL. Yes. Under the rule that is the requirement, yes.

Mrs. BLACKBURN. All right. I just wanted to be certain we had that clarification on the record.

Mr. DUVALL. Okay.

Mrs. BLACKBURN. Now, as we look at the opportunities for those Americans working in the auto industry—and in my district we talked about Nissan, and we also have some wonderful folks at the Saturn GM plant that is in Spring Hill, we have some great innovators that are with Bodine that are working with Toyota. So the auto industry is very important to Tennessee. So let us talk about trade for just a minute, and are we going to see with our

next-generation vehicles—do you anticipate are we going to see any trade barriers with our electric vehicles and things that we are going to be trying to move into the global marketplace?

Mr. DUVALL. Any sort of policy questions related to trade I would have to refer to the U.S. Trade Rep, but I will say it has been a strong push in the administration to reduce technology barriers, particularly in the environmental and climate change area. This has been one of our huge strategies in international negotiations to try to get other countries to reduce tariffs on environmentally friendly technologies. We had had some success, but I would expect that to continue with the next administration, too, hopefully.

Mrs. BLACKBURN. Well, and we appreciate the work that has also been done on the intellectual property protections that are also a component of that.

Looking at the electric vehicles, and considering that these will be a significant part of our U.S. fleet, why don't you talk for a minute about the costs and then the improvements that are going to be needed for charging batteries, what we are going have—the burden on the grid for both at home and as people are away and traveling and trying to use these for longer distances. Can you touch on that for me?

Mr. DUVALL. Yes. This is an area obviously that the Department of Energy is probably the expert witness to talk about. I will simply say that clearly the current battery technologies have not been sufficient to obviously allow the significant penetration of plug-in hybrids. There are some signs, obviously, that that is changing. And certainly as the marketplace gets more competitive, we would expect prices to come down and the quality of these batteries to come up.

As far as the literature I have read and talked to with other folks in the administration, I think there is a lot of optimism that the balancing of the grid, off-beat charging basically can be a mechanism to ensure the stability of the electricity grid, but I would not want to go further in my testimony to opine on that.

Mrs. BLACKBURN. All right. And then how long do you think it is going to be? What year do you expect to see these electric vehicles coming into the marketplace?

Mr. DUVALL. I guess I would say to that question if fuel prices remain high, I would expect within the next few years we start to get a stronger penetration of certain vehicles. But as the Chairman noted, we are still some period away, I think, from a meaningful percentage of the auto fleet in the United States shifting to that.

The key thing at this point in time, as I said, is battery reliability and durability as well as cost. And hopefully the private sector, as was noted, is starting to invest heavily in this. That is a great leading indicator in the optimism of the private sector for these technologies. So I guess cautious optimism would be the way I would assess that.

Mrs. BLACKBURN. I will tell you, visiting with some of the innovators that are in my district working on the battery technologies and some of the different engineering applications for next-generation vehicles, I think it behooves us in Congress to pay attention to what is going to happen with the power grid, how we are going to handle our electric-generation sources, and to start to

give a little bit more forethought, if you will, than has been seen over the past 30 years as we look at fossil fuel and the application of that to the transportation fuels market.

I will yield the balance of my time.

The CHAIRMAN. The gentlelady's time has expired.

The Chair will now recognize himself for a round of questions.

Mr. Duvall, first of all, I do want to commend you and your staff at NHTSA for taking a comprehensive approach to implementing the fuel economy provision of the energy bill and making many solid updates to the model you used to calculate the standards. But let me ask you the first question. Do you think that it is reasonable to really predict that it is going to average $2.42 a gallon for gasoline in 2016?

Mr. DUVALL. Mr. Chairman, as was stated previously, I think we take the best estimates we have, and we use the best experts that we have available. In our view, the EIA is among the leaders and most accurate forecasters. They have been wrong on the upside and wrong on the downside in previous years. There is little question, obviously, given current fuel prices, that we are in a very volatile environment right now.

The proposal is a long-term proposal. If I knew what oil prices would be in 2015, I would probably be in a different job than I am in now. We have a lot of uncertainty. We use the best information we have. I will say a number of other experts who are predicting extremely high oil prices in the short term have also predicted significant declines in those prices in the longer term. I know several analysts on Wall Street had predicted, you know, $150, $200.

The CHAIRMAN. I appreciate that. See, here is the thing. You have the job; you are responsible. You personally are responsible for preparing our country for the oil and transportation status of our country 5 and 10 years from now. So it is on your shoulders because you are the responsible person.

The question is do you think it is prudent for our country as a plan to assume that the price of gasoline is going to be $2.42 in 2016 for planning purposes?

Mr. DUVALL. Mr. Chairman, before I answer, I would say obviously there are a lot of people responsible for setting——

The CHAIRMAN. You are the guy. I asked the Bush administration to send us the guy. You are the guy, so you are the person responsible. Do you think it is responsive——

Mr. DUVALL. The wife doesn't think I am the guy.

The CHAIRMAN. Well, today is my 20th anniversary. If I am not home tonight, I won't be the guy either, okay? That is a different situation for both of us.

For the purposes of this conversation, I am the guy from the Congress, and you are the guy of the Bush administration.

Mr. DUVALL. All right.

The CHAIRMAN. So as the guy from the Bush administration representing President Bush and Vice President Cheney, do you believe that President Bush and Vice President Cheney actually believe that $2.42 a gallon is what the American people will be paying for gasoline in 2016?

Mr. DUVALL. I think that, first of all, I am proud to be here representing both President Bush and Vice President Cheney, but I

think that basically all in the administration believe that the EIA is among the best and most competent forecasters of oil prices in the world, and in the face of extreme uncertainty about future oil prices, that obviously oil markets themselves have been proven to be incorrect.

The CHAIRMAN. You have a high-price scenario as well. That is a high-price scenario as well that predicts $3.14 a gallon by 2016.

Mr. DUVALL. Correct.

The CHAIRMAN. In your opinion, do you think that that would be a better planning point for the American people? You are supposed to protect the American people from becoming excessively dependent upon imported oil. That is your principal responsibility. Do you think we should plan for $2.42 in planning the mileage for vehicles to be driven in America or $3.16 a gallon by 2016?

Mr. DUVALL. Mr. Chairman, the brilliance of the rulemaking process is that we propose something, and then the public tells us what they think about the proposal, and then we take public comment and input and finalize the proposal. So we are in the phase where we are taking comments, yours among others.

The CHAIRMAN. Which would you as the expert—you are President Bush's expert on the issue. Would you use $2.46 a gallon for 2016 or $3.14? Which would you use as the expert?

Mr. DUVALL. I will not prejudge the rulemaking process. It is very important. Not to make light of this, it is very important.

The CHAIRMAN. Oh, no, you can't make light of this here.

Mr. DUVALL. Well, I am not making light of it.

The CHAIRMAN. We are in a crisis in America. The airline industry iscollapsing, Mr. Duvall. The trucking industry is collapsing. The American people are being tipped upside down at the gasoline pump every day. Bush sends his expert to testify before the Energy Independence Committee, and you are telling me you do not have a view on whether we should be planning for $2.42 a gallon for gasoline or $3.14 for gasoline in terms of what we tell the auto industry to build in as efficiencies in the vehicles in the years ahead. And so you are at a critical point here, because the next panel is going to be talking about electric vehicles and other new technologies.

Now, I personally believe that the American people will embrace them if we put in place the kind of rulemaking that will incentivize all the auto manufacturers to move in that direction. But you are the one and President Bush is the one who has to make the decision as to whether or not we are going to be basing it upon a realistic or a dream world of assessment of what the price of oil is going to be.

Mr. DUVALL. I guess I would say this is a proposal, we are taking comments, and if the comments are sufficient to inform the final rulemaking to change the proposal. I would not call the experts at the Department of Energy dreamers. I believe they know what they are doing and are among the leading in the world in this area. They are consistent with other forecasts with respect to this. The Department of Energy, in fact, is on the high side of other forecasts, not deviating substantially either from long-term market projections or——

The CHAIRMAN. Mr. Caruso from the Energy Information Agency said in testimony before our committee just 2 weeks ago that we are on the higher side of that price path right now. If you would ask me today what I would use, I would use the higher price, says Mr. Caruso from the Department of Energy.

So if the Department of Energy is saying to you, at the Department of Transportation, I would use the higher price, what weight are you going to place upon that as opposed to some testimony you might get from the oil industry or the gas industry or the automotive industry? How much are you going to rely upon your own Department of Energy, or is it just going to be ignored by President Bush, by Vice President Cheney, as every other warning has been ignored over the last decade in terms of what our planning should be?

By the way, I didn't even toss in there that the SUV marketplace has collapsed, so all of this planning was based upon a faulty premise, even though we were going up a percent and a half every single year in imported oil in our country. We have gone up from 46 percent in 1995 to 61 percent today in imported oil. So it just seems to me that there is an inexorable increase in the amount of oil we are importing and, as a result, an inexorable decline in the control we have over the price because it is more and more set by the countries that have two-thirds of the oil in the world, OPEC; and that we should plan for that as a national security reason.

So you see this testimony now by your Department of Energy; so again he felt free to be able to say, I would go on the higher side.

Mr. DUVALL. Mr. Chairman, we are in an open rulemaking, and the comments made by the Department of Energy, anybody at the Department of Energy, will be taken into account and given significant weight in the decision process.

I will say simultaneously, you have numerous Members and other commentators who are also arguing that the high prices are driven by speculation. Now, I don't know what the price of oil will be in 2015; we rely on experts to do that. But I can assure you it is an internally inconsistent argument to, on the one hand, claim that speculation is driving high oil prices that fundamentally should be lower and, on the other hand, claiming that oil price forecasts should be higher.

The CHAIRMAN. I will tell you that will drive a stake into the heart of speculation in the oil marketplace if you announce that the standard is 35 miles per gallon by 2016.

You are right, this will say, Oh, my goodness, people are going to move to electric vehicles. People are going to move to hybrids. People are going to move to biofuels.

Maybe the price of oil will finally come down. But why don't we plan for that? Why don't we take the offensive? Why don't we, rather than speculating on some low, unbelievably low price of gasoline in 2016 and 2030, why don't we as a nation, why don't you as the person responsible for it, plan for a higher price? And if we get a lower price, everybody will be happy driving around with lower-priced gasoline. But let's at least be in control.

Right now, we are on our hands and knees watching the President and Vice President go over and begging the Saudi Arabians to please produce more oil. What a sad state of affairs for our coun-

try. When President Kennedy was faced with that from Khrushchev with Sputnik floating around in outer space, he told Khrushchev we were going to put a man on the moon in 8 years, invent new metals, new forms of propulsion. And 8 years later we did it. We were going to control the skies.

Why don't we make the announcement that we are going to assume there is going to be a high price of oil in the same way President Kennedy assumed the Russians would control the skies, but we are going to do something about it? Why don't we announce that it will be 35 miles per gallon because we are going to assume the worst, and then if the best turns out, then we have an extra bonus for America because we have the technology and, plus, we have the lower energy price? Why don't we think that way, rather than this mess that the Bush administration has allowed us to get in because we put 70 percent of the oil we consume in gasoline tanks?

So if we keep assuming that where we put 70 percent of the oil—gasoline tanks—is going to be low, then of course we are going to be playing right into the hands of the countries that have two-thirds of the oil in the world. They will be setting the agenda.

Mr. DUVALL. Mr. Chairman, I guess I would say if you assume the worst and are wrong, the economic costs are significant in terms of lost jobs to the United States economy. We need to rely on experts, scientific experts——

The CHAIRMAN. We are not going to have any jobs left in the auto industry. Do you understand? We are seeing such a precipitous drop—General Motors just announced another 19,000 jobs are taking the buyout. Ford, the same way; Mr. Mulally at Ford Motor just announced last week that "We have moved permanently off the SUV and onto the smaller vehicle model."

So all of this is happening, okay, and the losses have already been absorbed; and there is more to go, but we are down to a very small handful of jobs left in America and people making automobiles. I think General Motors is down to 50- or 60,000 people making automobiles.

So Starbucks has 125,000 people making latte, and General Motors has this—it is all a sad story. And to say we are not going to set the standards higher because we are going to lose jobs, well that is why we have lost jobs. We have lost jobs because there has been an assumption that the price of oil was going to stay at these unrealistically low levels, and people—and meanwhile, we were driving deeper and deeper and deeper into this hole.

So again I say to you, Mr. Duvall, that the EIA told us 2 weeks ago that we should use the high estimate. Okay? At least they're now thinking in national security terms, at least they're now thinking in terms of energy independence terms. But it is about time that the Department of Transportation thought that way too. Ignoring it and pretending you are protecting jobs, protecting—tell the airline industry you are protecting their jobs. Tell the truckers you have been protecting their jobs. Tell the workers in all these auto factories you are protecting their jobs by using the mid and the low estimates for what the price of oil is going to be.

You didn't protect anybody. We have already lost a million jobs or more in America because of the wrong estimates. Okay? The

only way we are going to get the new job is if we create the new technologies. And that has not happened yet.

So that is your responsibility, and it is about time that we had an administration, maybe this will be the going-away present that the administration gives to the American people, that there is really a man-on-the-moon plan here, that there will be a commitment that is made to this that actually can be looked back at as a legacy, that we technologically challenged the Saudi Arabians.

But do you know what the sad thing is, Mr. Duvall? It is that on the day the President was there, begging the Saudi Arabians to produce more oil, they said they will think about it, but we want you, Mr. President, to sell us nuclear power plants here in Saudi Arabia; and he and Condoleezza Rice agreed to do that.

Now, how much more volatile a region in the world can we have than Saudi Arabia to be selling nuclear power plants? That is how pathetic our relationship is now with these volatile Middle Eastern countries, to sell us oil. And it seems to me that if the President and Secretary of State had looked up into the sky, they would have seen a broiling sun on the desert and said, No, we will sell you solar technology, we will partner with you in a new technological revolution, but we are not going to be selling you nuclear technology. You have the most oil, the most gas, the most solar.

And by the way, I remember Peter O'Toole as being kind of windblown in some of those scenes of "Lawrence of Arabia." There is a lot of wind there, too.

We shouldn't be sending nuclear power. We shouldn't be sending all these nuclear materials into the Middle East. It makes no sense whatsoever. That is how sad our state of affairs is.

So rather than have that occur year after year, again, I say to you, as the Department of Transportation, this is a geopolitical, it is a defense, it is an energy, it is economic, it is environmental, but it is a moral issue as well, that we finally stand up and say, we are going to challenge OPEC, that we are technologically going to take them on.

We have yet to make that announcement. And that would be the John F. Kennedy moment with Khrushchev for the Bush administration. And if they don't do it, then they will have missed their one great opportunity during their 8 years.

They will have sent a signal to the rest of the world that we are going to use our technological genius to solve this problem.

Let me turn and recognize once again the gentleman from New York, Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman. I concur with your remarks about the sale of or transfer of nuclear materials and technology to Saudi Arabia, which, as we remember, is in a part of the world where other countries have taken supposedly peaceful nuclear programs and diverted materials to a bomb program, Iran being the one that we are talking about most recently.

But every case of a country going from the nonnuclear to the nuclear club, it seems to be they started out with a peaceful nuclear weapons program and diverted it; and in this case, it would be the Sunni bomb to counteract what they see coming as the Shia bomb in Iran. And I think it is naive for the Secretary of Energy to state, as he did before this panel, Well, the President trusts the King,

and that is why he is not as worried about it as you are, Mr. Chairman.

But, anyway, I had another question regarding battery technology that I wanted to ask and then that is it for me for today. But, Mr. Secretary, are there any significant technological obstacles to setting up the kind of battery switching that some witnesses have described, that—Israel, for instance, has a company that is involved in developing a car that will run on electricity, and rather than charging the battery, they will just exchange it, pull into a gas station, take the battery out and put another one in, and hook the wires up, and away you go in a few seconds; as opposed to however long it takes to fill a tank or to charge a battery.

What are the obstacles technologically? What will be the most effective way for us in government to help make these stations as ubiquitous as gas stations?

Mr. DUVALL. I am going to defer to Steve on the technology impediments question. He has more to add to that than I do.

I will say, as a policy matter, clearly the regulation we are pursuing here, one of the key purposes, I think—contrary to the chairman's comments—is to really drive the technology. This is the most aggressive rulemaking that has ever been done by our Department. The costs, as I said, are enormous. But one of the benefits of this proposal will be to drive technology in a technology-neutral way.

And I think one of the key policies that we need to be careful about at the Federal level is that we are cherry-picking various technological outcomes. The history of energy policy and transportation policy has been, the government has done a fairly mediocre job, let's just say, of picking technology winners. And what you want to do is create the right market incentives for the private sector and venture capitalists to come in and develop these technologies and come in and push breakthroughs.

As a regulatory matter, this is a regulation, as I said, that imposes huge costs in a mandate, but it is done under a construct that recognizes manufacturer flexibility to deploy technologies in a neutral way or a cost-beneficial way for them.

We have a very diverse car industry. I don't think it is well understood how diversified this industry is right now. So we need to be very careful about specific technology mandates. But as far as the current technological impediments, I defer to Steve.

Mr. KRATZKE. Thank you, Mr. Congressman. The battery is the single item that is the expensive and desirable thing on these vehicles. The older battery systems had very limited range, and so they had very limited appeal to people.

One approach for getting around that could be the approach you suggested where you have a battery station every 15 miles. But in the U.S., the people who are now developing batteries are aiming for a range of about 100 miles so that people can commute roughly 50 miles to do it, because that represents where we live and where we work now.

Mr. HALL. In Israel, that is what they are aiming at also.

Mr. KRATZKE. Yes. So those really are the things that we are looking at right now.

If we can get to 100 miles as the range, then we don't really need the refilling stations everywhere. If you get a battery that does

that, then trading it out, you are giving up a very expensive thing and you are imposing either a large cost or you need some sort of bond to make sure you get the battery back.

Mr. HALL. A deposit.

Mr. KRATZKE. It is an approach. But for the most part, in the market right now, trading out the battery isn't something that looks like a viable model, but you could consider it.

Mr. HALL. Thank you.

I just wanted to remark that in the chairman's district, A123 and their subsidary, High Motion, are making an upgrade as many of you probably know, for Prius. And they are so busy making them because there is so much demand—it doubles the effect of mileage of the Prius—that they have postponed making the one for my car, the Mercury Mariner hybrid, which I read the other day is the most—the fastest car to recoup the difference between the cost of the hybrid version and the nonhybrid version.

So I am glad I made a good choice without knowing that in advance, but I would really like to be able to upgrade it.

And the city of Chicago has a fleet, I understand, of Ford Escape hybrids that they are converting to plug in hybrids. So somebody is developing batteries with deeper capacity to do this. And maybe Chicago can come here and tell us how they are doing it.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. Hall, very much.

And I am just going to conclude by saying this. In 1957, the Soviet Union had launched the first satellite into space, the Sputnik. In 1961, the Soviets sent the first man into space, Yuri Gagarin, a very important moment. And I was a boy in the United States.

Since the same rocket technologies that enabled these achievements could also be applied to building nuclear missiles that could be launched against the United States, losing the space race with the Soviets was clearly unacceptable.

President Kennedy responded to this challenge by calling on the Nation to send a man to the moon and return safely to Earth before 1970. He said, and I quote, "We choose to go to the moon in this decade and to do other things not because they are easy but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one that we are unwilling to postpone and one that we intend to win."

How hard was this going to be? President Kennedy said it would require us to "send to the moon 240,000 miles away from the control station in Houston a giant rocket more than 300 feet tall, the length of a football field, made of new metal alloys, some of which have not yet been invented, capable of withstanding heat and stresses several times more than have ever been experienced, fitted together with a precision better than the finest watch, carrying all the equipment needed for propulsion, guidance, control, communications, food and survival, on an untried mission to an unknown celestial body, and then to return it safely to earth reentering the atmosphere at speeds of over 25,000 miles per miles per hour causing heat about half that of the temperature of the sun."

He concluded by saying, "To do all this and to do it right and to do it first before this decade is out, then, we must be bold." Eight

years later, Neil Armstrong became the first man to stand on the surface of the moon.

Today we have another great political and technological challenge. It is the challenge posed by our addiction to imported oil and the danger of global warming. In order to make ourselves energy independent and stop producing the greenhouse gases that threaten to heat up our planet, we must take on these challenges, challenges that are hard, but which will organize and measure the best of our skills and our energies.

But we are not talking about putting a man on the moon. We are talking about new batteries. We are not talking about rocket science. We are talking about auto mechanics.

We can do this, and we can do it in a way that sends a very strong technological signal to OPEC and to the rest of the world that we do not intend to be dominated politically and economically by powers halfway around the world.

That is sadly where we are today. That is where President Bush and Condoleezza Rice were 4 weeks ago when the Saudi Arabians said they will send us a little more oil if we start selling them nuclear power plants. It is not a position that any American can be proud of.

Your Department, sir, has the responsibility for setting the challenge ahead. Do not use the lowest standards. Use the highest. America will respond.

We know that we are in a crisis, and we want a way out. But we need to hear the words from the highest level. And I think our industries will respond, and the American people will as well.

So we thank you for testifying here today with us. After your rulemaking is completed, we expect you to come back here, and we will talk to you again about the decisions. I thank you.

Now if the other witnesses can come up and sit at the table, I would appreciate it.

We welcome our second panel, and first we will recognize Dominique Thormann, who is the Senior Vice President of Nissan North America, where he oversees all finance, legal and business operations. He also serves as the Chief Financial Officer and Senior Vice President of Nissan Europe.

We welcome you, sir, whenever you are ready, please begin.

STATEMENT OF DOMINIQUE THORMANN, SENIOR VICE PRESIDENT, NISSAN NORTH AMERICA, INC.

Mr. THORMANN. Thank you. Good afternoon, Mr. Chairman and members of the committee. I thank you for this opportunity to appear today to present Nissan's views on gasoline prices and fuel economy and how it relates to energy independence and global warming.

At Nissan we have a culture of establishing very challenging yet achievable goals. Mr. Chairman, I believe you would understand that culture well. You have asked me to address three significant and complex issues and to do so in 5 minutes. So here I go.

In our most recent business plan, that we announced last April, we put forward three commitments that we want to achieve by 2012. One of them is to lead the automotive industry in zero-emis-

sion vehicles worldwide. Central to that commitment is our investment in the electric vehicle.

If ever there was an industry where the word "globalization" was meaningful, that would be the automotive industry. Growth in car sales is occurring in virtually every country across all continents. This is a new and recent development. The desire for mobility is universal. In the United States, there are 800 cars per 1,000 inhabitants, 600 in Western Europe and Japan, but the same ratio in China and India reveals fewer than 50 vehicles per 1,000 people.

At Nissan we have recognized the need to find a solution to cope with this apparent contradiction between the predicted global growth in car sales and energy independence and global warming. Mr. Chairman, I believe you have recognized these trends and see the issues before us are global.

Coping with global warming and energy independence goes well beyond what a single company can do. It is together, by collectively pooling ideas and investments from the private and public sectors that actionable, meaningful solutions will emerge. Nissan's views led us to intensify our research and development. We invested in technologies that would improve the efficiency of the internal combustion engine in all its forms. Our engineers are optimistic and while some innovations are significant, they are not sufficient to meet the rapidly evolving needs of our customers.

In the United States, in the face of rapidly escalating energy prices, consumers are shifting abruptly from trucks to crossovers, from large cars to small cars, from V8 engines to V6, and now four-cylinder engines. Fuel efficiency is at the top of consumers' concerns. Higher fuel prices, coupled with environmental concerns, means consumers are more willing to consider new forms of powering vehicles. This means an interest in diesel engines, flex fuels and biodiesels.

But at Nissan, we believe that a more radical change of breakthrough technology, like the electric car, is needed. Electric vehicles will not only have zero tailpipe emissions, but they will also offer more flexibility in determining the source of energy to power them.

Today, oil is the major source of energy to power a car. With electric cars, the electricity needed to charge the batteries can come from multiple sources, including, in the best of all worlds, renewable ones such as the wind, the sun or water. Clean coal furnaces and nuclear power will also be effective in combating CO_2.

Electric vehicles have always been limited by their battery as its size, driving range, cost and charge time made electric vehicles unacceptable to consumers. Nissan has been working on lithium ion batteries since 1992, and we have created a separate company which will be responsible for the manufacture and sale of batteries. We are satisfied with our advances and believe that we have the technical visibility today to bring these vehicles to market in short order.

We will bring to the market in the United States a fully electric automobile before the end of 2010. But—first, the number of vehicles will be relatively small, but we plan to have a truly mass market vehicle available in the United States by 2012.

These electric vehicles will be cars that consumers will be happy to drive. They will have a range that will get them comfortably to

work and back home with all the comfort and features that they are used to today. They will handle highway speeds and permit drivers to comfortably merge into highway traffic. The acceleration will surprise many and make the vehicles fun to drive. As the market grows, different types and sizes of vehicles will be launched.

Nissan looks forward to working with Congress, regulators and government agencies in making this technological breakthrough a reality. The electric vehicle will transform the value chain of our industry as we know it today.

In partnership with private industry, public policy will need to address the new infrastructure requirements, and we will need to work together in adapting the rules that govern the use of automobiles to this new reality and create the conditions of success.

Mr. Chairman, I thank you and the committee for the opportunity to testify today. And I will be happy to answer your questions.

The CHAIRMAN. Thank you, Mr. Thormann, very much.

[The statement of Mr. Thormann follows:]

Testimony of Dominique Thormann

Senior Vice President

Nissan North America, Inc.

Before the

Select Committee on

Energy Independence and Global Warming

U.S. House of Representatives

June 26, 2008

Mr. Chairman and Members of the Committee:

I thank you for this opportunity to appear before you today to present Nissan's views on gasoline prices and fuel economy and how it relates to energy independence and global warming.

At Nissan, we have a culture of establishing very challenging yet achievable goals. Mr. Chairman, I believe you would understand that culture well. You have asked me to address 3 significant and complex issues and do so in 5 minutes!

In our most recent business plan announced last April, we put forward three commitments that we want to achieve by 2012. One of them is to lead the automotive industry in zero emission vehicles worldwide. Central to that commitment is our investment in the electric vehicle.

If ever there was an industry where the word "globalization" was meaningful, that would be the automotive industry. Growth in car sales is occurring in virtually every country across all continents. This is a new and recent development. The desire for mobility is universal. In the United States, there are 800 cars per 1,000 inhabitants; 600 in Western Europe and Japan, but the same ratio in China or India reveals fewer than 50 vehicles per 1,000 people. At Nissan we have recognized the need to find solutions to cope with this apparent contradiction between the predicted global growth in car sales and energy independence and global warming.

Mister Chairman, I believe you have recognized these trends and see the issues before us are global. Coping with global warming and energy independence goes well beyond what a single company can do. It is together, by collectively pooling ideas and investments from the private and public sectors that actionable, meaningful solutions will emerge.

Nissan's views led us to intensify our research and development. We invested in technologies that would improve the efficiency of the internal combustion engine in all its forms. Our engineers are optimistic and while some innovations are significant, they are not sufficient to meet the rapidly evolving needs of our customers.

In the United States, in the face of rapidly escalating energy prices, consumers are shifting abruptly from trucks to crossovers and from large cars to smaller ones, from V8 engines to V6s and now four cylinder ones. Fuel efficiency is at the top of customers' concerns.

Higher fuel prices, coupled with environmental concerns, mean consumers are more willing to consider new forms of powering vehicles. This means an interest in diesel

engines, flex fuels and biofuels. But at Nissan, we believe a more radical change, a breakthrough technology like the electric car is needed.

Electric vehicles will not only have zero tailpipe emissions but they will offer more flexibility in determining the source of energy to power them. Today, oil is the major source of energy to power a car. With electric cars, the electricity needed to charge their batteries can come from multiple sources, including, in the best of all worlds, renewable ones such as the wind or the sun or water. Clean coal furnaces and nuclear power would also be effective in combating CO_2.

Electric vehicles have always been limited by their battery as its size, driving range, cost and charge time made electric vehicles unacceptable to consumers. Nissan has been working on lithium ion batteries since 1992. We have created a separate company which will be responsible for the manufacture and sale of batteries. We are satisfied with our advances and believe we have the technical visibility today to bring these vehicles to market in short order.

Our goal is to bring to market in the United States a fully electric automobile before the end of 2010. At first, the number of vehicles will be relatively small but we plan to have a truly mass market vehicle available in the US by 2012. These electric vehicles will be cars the consumer will be happy to drive. They will have a range that will get them comfortably to work and back home with all the comfort and features they are used to today. They will handle highway speeds and permit the driver to comfortably merge into highway traffic. The acceleration will surprise many and make the vehicles fun to drive. As the market grows, different types and sizes of vehicles will be launched.

Nissan looks forward to working with Congress, regulators and government agencies in making this technological breakthrough reality. The electric vehicle will transform the value chain of our industry as we know it today; in partnership with private industry, public policy will need to address the new infrastructure requirements and we will need to work together in adapting the rules that govern the use of automobiles to this new reality and create the conditions of success.

Mr. Chairman, I thank you and the committee for the opportunity to testify today. I am happy to answer questions.

The CHAIRMAN. Our second witness is Shai Agassi. He is the founder and CEO of Project Better Place, a company working directly with governments and the finance community, the automotive manufacturers and technology companies to develop saleable and sustainable personal transportation systems.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF SHAI AGASSI, FOUNDER AND CHIEF EXECUTIVE OFFICER, PROJECT BETTER PLACE

Mr. AGASSI. Thank you, Mr. Chairman.

Mr. Chairman, thank you for your leadership on this critical issue for inviting me to testify in front of you today, and I request my full written statement to be made part of the hearing record.

The CHAIRMAN. Without objection, so ordered.

Mr. AGASSI. The electrification of the automobile is inevitable. I didn't say that. Neither did my friend here from Nissan. It is Bob Lutz of GM. And, in reality, on January 21, 2008, it happened in Israel.

We had, for the first time, the CEO of Renault/Nissan standing up and saying, We will make electric cars, we will make them fun to drive, and we will make them in high volume enough for the entire country to switch.

We had Project Better Place stand up and declare that we will put a network, ahead of time, of charging infrastructure across the entire country. That network of infrastructure will include 500,000 charge spots that will be put in parking lots at work, at downtown, before the first car shows up. It will include swap stations that enable us to swap batteries as we go through the freeways, and it will include scheduling software that enables us to charge these cars without needing to bring down the grid every time everybody connects to the grid.

We also had a policy by government that decided to push this switch, this change from oil to oil independence, within less than a decade, a President who stood up and said, We will get off oil within this decade; and a policy that was put in place to actually make that happen faster than 10 years.

The electric car has a secret. The secret is, you have to separate between the battery and the car if you want to make consumers adopt it faster. The battery is not part of the cost of the car. The battery is a consumable that is equivalent to crude oil. If you separate between the car and the battery and you put the infrastructure in place to charge, you open a menu of sources to generate the electricity, the energy required for that car.

The battery is a consumable, plus the electricity for the car gets you to a price of 6 cents per mile. That is cheaper than the price you called absurd right now by the administration. It actually is relatively around the range of about $1.50 a gallon.

If you build it in the right way, you build a service company that sits in between, almost like a mobile company—think of Verizon or Sprint for cars. That company can actually provide both the infrastructure and the cars, and as a mobile company, what we sell effectively is miles.

That company can also provide rebates for the car, and as it happens in Israel and happens in other countries, the rebate structure

makes the electric car so affordable that we can actually offer these cars for free to the consumer. When you offer free cars with zero emission with zero oil to consumers, they usually go for that car.

The question is, how much do you need to put in the ground in order to make that infrastructure happen and how fast can it happen? And the reality of the numbers is that it costs you about $500 per car to put that infrastructure in the ground.

In a sense, if we wanted to do this in the U.S., that is $100 billion of infrastructure, the equivalency of 2 months of oil imports, would get us off the addiction, 2 months of oil imports most of which would actually go as jobs. $80 billion will go as jobs in installing the infrastructure in the ground, jobs we cannot outsource outside this country.

How fast can we do this is a question of policy in the country. Denmark, which is another country that adopted this model, had put a policy that sets the price of a car, gasoline-based cars, at 180 percent tax to get off gasoline and a zero-emission car at zero. Hence, you get asked, do you want to buy a gasoline-based car at $60,000 or get an electric car pretty much close to free?

And I think if you choose the $60,000, they actually would like you to leave the country. You failed the IQ test in that case.

Every year we wait costs us $500 billion of oil imports and $300 billion of the wrong cars coming onto our streets; that is, $800 billion is the cost of prolonging the decision of shifting to electricity.

So the question that we have ahead of us right now is, would we actually want to shift off cars? Do we want to put that energy to play?

$100 billion of infrastructure, $500 billion of generation—solar, wind, wave—would actually get us off oil forever. The cost of 1 year of oil would get us off oil forever.

All government has to do is let business do what it needs to do, go back 100 years and let us do what Edison and Westinghouse did when they built the electric grid in this country. Cut away the red tape. Put in the incentives to actually accelerate this plan and probably call Detroit again.

The Congresswoman from Michigan, who is not here with us right now, said it correctly: We owe a debt to Detroit. In 1942, the President called them up and said, Please stop making cars and start making tanks. Maybe it is time the President called Detroit again and said, Stop making tanks; please make the right cars.

If we did it, and we put the right investment in place, and we opened up for businesses like Project Better Place and others to put this infrastructure in the ground, we could get the American public to drive on electricity and save our country from oil.

Thank you.

The CHAIRMAN. Thank you, Mr. Agassi.

[The statement of Mr. Agassi follows:]

Testimony by

Shai Agassi

Founder & Chief Executive Officer

Project Better Place

United States House of Representatives

Select Committee on Energy Independence and Global Warming

Hearing on

"$4 Gasoline and Fuel Economy:
Auto Industry At a Crossroads"

Thursday, June 26, 2008

Introduction

Mr. Chairman, Congressman Sensenbrenner and other Members of the Committee: Thank you for your leadership on this critical issue. And thank you for inviting me to testify before you today.

This Committee meets at a moment when the United States and its elected representatives stand at a crossroads. We face two starkly different paths, and a moment of profound choice for our energy and transportation future. The choice that is made will answer the question of whether this young century will be another American century, as was the last.

The world needs that answer to be "yes". The essential step towards ensuring that it is lies in ending the complete dependence of our transportation system - and thereby our economy as a whole - on oil.

Because of this dependence, during the next President's first term, we will spend some $3 trillion on oil - nearly as much as the entire federal budget. This year, by some estimates, we will also export some $400 billion for oil - about two dollars spent on oil for every three dollars we will spend on national defense.

Because of this dependence, we are also affecting a wealth transfer of historic proportions - giving away an enormous chunk of our economy every year. Some of that money flows back into our economy, but some in the form of sovereign wealth funds scooping up stakes in our major companies and some of our most iconic assets, New York's Chrysler Building being but the latest. The next such purchase could well be Chrysler itself. In fact, the U.S. will spend more on imported oil this month than the market value of its entire automobile industry.

But our citizens still need to get to work, and still need to take the kids to school. So they pay $4 per gallon - and if Europe is our guide, they will pay $9 if they must. That

leaves them substantially less money to spend on other things that drive our economy, and we know that the consequence of the driving they do is more and more tons of CO_2 in the atmosphere.

Better Place sees a different path – one that makes a rapid transition from gasoline cars to zero-gas, zero-emissions ones very practical. And since we no longer have time for science experiments, our path invents nothing new – it is based on integrating proven technologies that are here and now.

At the heart of this plan is breaking the stranglehold that gasoline fuels have on the vehicle market today. Instead, we create a platform for cars to operate on much more efficient electric power, capturing enormous savings over the life of the vehicle. Then, we ask the driver to continue to pay in electricity charges what they are already paying for gasoline – and in fact we refund a large part of those savings up front. In some instances, that refund can pay for the whole car.

Therefore, we rely not on a premium-priced new car model available only to a small part of the driving public. Instead, we offer a free or nearly free car and charge

current operating costs on an ongoing basis - enabling all car owners to make the gasoline to electricity transition.

For the price of two months worth of oil, some $100 billion, we can put in place the infrastructure needed to power the nation's cars and end this oil dependence. Of that $100 billion, moreover, some $80 billion will go into jobs that, by their nature, can only be performed in the United States - the construction of the infrastructure itself.

For the price of one year's worth of oil, some $500 billion, we can go even farther - creating fully renewable electrical generation sufficient to power all of the nation's vehicles. In so doing, we will again create jobs that can only be performed in this country, and we will give a much broader stimulus to the renewables energy market.

The Better Place Solution

This is not a moment for incrementalism, but for transformative thinking. Instead of exclusively oil, let's enable our cars to run on electricity generated from a diversity of sources - and at the same time enable much greater flexibility in the grid by growing energy storage

4

that can bridge intermittent renewable sources like solar, wind and tidal.

How do we make these diverse energy sources relevant to transportation? We find a formula to get our automobiles onto the grid.

The operating cost of an electric car, including the depreciation of the battery, is now about 6 cents per mile. The average American, getting 25 miles per gallon and paying $4 per gallon, is paying 16 cents per mile. Those getting less than 25MPG pay more; those in Europe pay two to three times that amount.

So if our operating cost is a third or less than that of gasoline-powered cars, why hasn't an industry taken off? Just as gasoline cars would be useless without ubiquitous distribution of refined gasoline, and cell phones would be useless without towers and network operators, so it is with electric vehicles. Electric cars are not relevant to the public until there is a battery charging infrastructure in place that makes them a practical and convenient choice.

Better Place proposes to take the burden of battery cost and management upon itself by deploying a ubiquitous network of charging spots. We will bring the "plug" that

last, essential mile to the car – whether it is parked at home, at work, at retail or downtown. That makes the electric vehicle relevant to our everyday driving. In fact, based on this infrastructure alone, of the average 2.6 cars per U.S. household today, there is no reason that one of them can't be all electric for use on every trip of 120 miles or less.

Better Place will also deploy range extension for long trips in the form of battery exchange stations — automated, mechanical battery swap points – on major arteries linking urban areas. That makes the electric vehicle just as relevant for our longer driving trips.

Finally, Better Place will bring an entirely new business model to the area of car ownership, one that will have the effect, in some cases, of making the cars themselves free. That will ensure that electric vehicles are not only relevant to all of our driving needs, but are affordable as well.

By solving the consumer's concerns — how much will it cost? Will it be convenient to use? -- we will be able tilt the market away from oil towards a rapid changeover to electric cars.

Allow me to retrace briefly how Project Better Place arrived at this point. Three years ago, I was told I was to become the next CEO of SAP, the largest enterprise software company in the world. SAP had bought a company I had founded several years earlier, and becoming SAP's CEO was what I thought was my dream and my destiny.

Something funny happened on the way to the CEO suite. I was inspired by my peers in the Young Global Leadership of the World Economic Forum to think of how to make the world a better place. Quickly I found the biggest problem to solve: oil.

The world's transportation system is almost entirely dependent on oil. As all of you know, the emissions from burning this oil in billions of vehicles pollutes our air and can impair our health, and now we understand it also causes the planet to warm, endangering our very survival.

What's more, many of the governments to which oil revenues flow actively oppose many of the free world's values – and as the price has risen we are witnessing an unprecedented transfer of wealth from developed countries to these governments.

After spending many months researching and speaking with experts, I felt that I had the basis of a framework that could move a country's transportation industry entirely off of oil in relatively short order. I wrote a paper describing my idea and shared it with officials from many governments.

Shimon Peres, who was not yet President of Israel, called me. He said he was intrigued. He said he thought the plan was workable. But he also said he thought it required private industry to be the catalyst, not the government. When I said he should find someone to start a company, he challenged me to abandon one dream and start another. When I recognized the consequences of allowing this problem to go unsolved for the world I would leave to my children, I announced my resignation from SAP.

Within six months, I had raised $200 million from private investors to form Project Better Place. Three months later, on January 21, 2008, Israel's Prime Minister announced that country's intention to be free of oil within a decade using our model. Standing with him were Carlos Ghosn, representing the manufacture of 8 million cars per year through the two companies he runs, Renault and Nissan, and myself. Two months after that this scene played out

again in Denmark, where Better Place, Renault/Nissan and DONG Energy are partnered to create an electrical vehicle infrastructure powered by wind energy.

So what is the Better Place formula? I can tell you it is not an invention. There is no time for science experiments. Our plan takes existing, proven ingredients, and integrates them in a new way.

It is best thought of as an analogy to the cellular phone industry. Who would have predicted 20 years ago that the phones that dominated our lives so soon thereafter would be mobile devices? Entrepreneurs, from sheer imagination, have brought us this new world of cellular communications.

We intend to build the first company that will be the equivalent of a mobile operator for cars. What does that mean? It means that electric cars are cheaper to manufacture, and orders of magnitude cheaper to operate. But one thing has prevented their widespread adoption: the lack of infrastructure. We will build and operate that infrastructure, allowing customers to purchase "miles" from us just as they do "minutes" from cell phone operators.

What is this infrastructure? It has three parts.

The first is batteries. Batteries are proven, but they are an expensive up-front cost that car companies have been afraid to ask their customers to bear. We solve that problem by owning the batteries ourselves. For the first time, we treat the battery not as part of the car, but as part of the infrastructure.

The second is ubiquity of electric charging. This means allowing cars to plug in wherever they are parked, enabling every trip to have a range of about 120 miles.

The third is distance. For those drivers for whom extended trips are either a necessity or desire, we will develop exchange stations for batteries that allow drivers to swap a used battery for a fresh one in less time than it takes to refill a tank of gas.

For the subscriber, just as with cell phone calling programs, there will be a menu of plans to suit different driving habits.

Let us consider for a moment the commuting class, generally consisting of people who drive long distances daily to reach their jobs downtown from the affordable ex-burbs. These drivers often travel 20,000 miles per year or more, and sometimes drive old, very inefficient vehicles. At $4

per gallon, assuming 20 miles per gallon, they are now

paying 20 cents per mile, or about $350 per month. If they

continued to pay that $350 to us, and signed a contract of

five or six years, there will come a point where we can

actually give them the car for free.

Our Progress to Date

Zero gas. Zero emissions. A subscription model in which the

driver pays not for gas, but for the electrical charge

needed to travel the miles he or she needs or wants to

drive. And – just as cellular handsets are now largely a

commodity sold at drastically reduced prices in order to

attract subscribers – we drastically lower, possibly to

zero, the cost of vehicles to the consumer.

So what has been the response to the Project Better Place

proposition?

As I have mentioned, the governments of Israel and Denmark

have already announced their intentions to adopt the Better

Place model. Both are confident that they will turn over

their vehicle fleets from gas to electricity within a

decade.

We are in active discussions with more than 30 other

countries, and with dozens of regions, provinces, states

and large cities. Many of those discussions, both in the US and globally, are well advanced.

We anticipate that four to six other countries or regions will – in the coming months – announce their intentions to take up the Better Place model, just as Israel and Denmark have done.

There is no doubt that this progress has been helped along by the anxieties arising from the spike in oil prices. But our progress is not dependent on high gas prices. The Better Place model happens to have even greater appeal in a world of $4-per-gallon gas. But the model works – even when prices are drastically lower.

And just as it will work for Israel, Denmark and the other regions and localities we expect to come on line soon, it will work for the United States. Across this country, countless localities and regions present the same characteristics that make the model an appropriate fit elsewhere: density of population, reliance on personal vehicles, mature traffic infrastructures, all leading to in-built congestion. And as these localities and regions are built out, connecting them into a truly national grid becomes more and more feasible.

12

Security and Environmental Benefits

In addition to working economically, the Better Place model

holds the prospect of decisive improvements in two areas

critical to the nation's, and the world's, future:

greenhouse gas emissions and energy security

While we have focused so far on the short-term economic

questions entailed in building out Better Place in the

U.S., the real value of such change lies in the massive

reduction in greenhouse gas emissions that will be

achieved. An average car produces 4 tons of CO_2 every year.

Certain high-traffic fleets (such as taxis or delivery

vehicles) can produce 20-40 tons per vehicle.

The developed economies seek to mitigate these numbers

through the use of new catalytic converters and other

emissions control technologies. But the emerging middle

classes in China and India are racing towards the chance to

buy their own first car, especially as car prices in those

markets fall dramatically. These cheaper cars will not use

the latest engine improvements, will drive on increasingly

congested roads, and, in so doing, will raise average

vehicle CO_2 emissions across the world, as well as NOX

levels in major population centers.

Just as importantly, we will shift the transportation energy market from dependency on fossil fuel reserves that are present only in certain locations around the world to a footing in which energy can be manufactured anywhere in the world, using renewable resources. Doing so fundamentally shifts the trade balance across countries and regions; some of that shift will be away from governments that are not fully democratic, do not share our values, and have used their oil wealth in ways that harm our interests.

Some oil-producing countries have begun to realize that recent price increases do not reflect simply one more cycle in the oil boom, and that this is most likely the last such boom the industry will experience for a very long time. While it may take time for the market to tip (on the order of 10-15 years), some governments have already started to invest their current windfall in a diversified, post-oil portfolio of economic growth drivers. The United Arab Emirates, for example, still has abundant oil, but all of its oil profits are re-invested in industries such as tourism, financial services, media, education and alternative energy.

All of these are important drivers of modernization and sustainable growth. And unlike oil, these new industries

14

are largely local in nature. They require local inputs in order to succeed. The post-oil era will stimulate an array of new – or in some cases newly invigorated – industries and services. This brings me to my final point: the broader economic benefits to the United States of the oil-to-electricity shift.

Economic Benefits Derived From Better Place

While the US has a large domestic oil production, much of our consumption is paid for in dollars that flow out of the US economy. Not spending that money on oil, and instead driving that money back into the local economy, can only affect it positively. And the Better Place model is intrinsically local.

It will depend on electricity generated in reasonable proximity to where it is used, driving electrical generating capacity demand across the full range of sustainable generating sources: solar, wind, water, and wave. It will necessitate a local infrastructure of battery-recharging and replacement stations in place of the existing infrastructure of gas stations.

In fact, the first-mover advantage in this market for early adopting car makers, component manufacturers, electrical

grid operators, and indeed countries, may be as big a prize as has ever been seen in the history of economic development. The first car maker to field a workable electric vehicle at scale will enjoy benefits that dwarf the success of the Prius for Toyota. Countries that develop local expertise will see new companies emerge that positively affect their economy for decades, in a manner similar to Nokia's effect on Finland.

Our Recommendation

With these benefits in mind, what can public policymakers do to help secure this paradigm shift?

We want to emphasize that our model stands on its own without government support. However, the active involvement of the public sector can greatly accelerate the transition away from oil-burning cars. For example, the governments of Israel and Denmark promised us no financial support in building the infrastructure. They did, however, lock in place a policy which essentially excuses zero-emission vehicles from their already quite high excise taxes on new vehicles. Since the US has not severely taxed either cars or gasoline in the past, the levers at your disposal are fewer. However, given that there is a vested public interest in accelerating the deployment of the

infrastructure to support mass adoption of electric cars, both because of its ability to move us off of imported, polluting oil and because of its ability to create domestic employment, it might be sensible to guarantee loans needed to support that infrastructure build out. With the government's balance sheet to fall back upon, we could borrow capital and vastly lower cost, and therefore deploy the infrastructure at a much faster clip.

Another possibility would be to offer tax credits to the purchasers of zero-emission cars. France recently adopted a "fee-bate" program that costs the government nothing, but uses taxes on the highest emitting vehicles to fund rebates on the lowest. And at zero emissions, the vehicles that our model would use are clearly in that latter category.

Other ways for you to engage in this vision do not directly involve our effort, but center around two of our partner industries - cars and batteries. There is no need for me to remind you about the very difficult situation our domestic automobile industry finds itself today. We think if the right strategy was pursued, the US auto industry could successfully remake itself for the coming electric revolution. In Renault and Nissan, under the leadership of Carlos Ghosn, we see a company making the investments to

lead this industry. There is no reason US automakers could

not do the same — and if their efforts were aided by the

Federal Government, there is every reason to believe they

could return to their former greatness, and again play a

central role in stimulating rapid economic expansion in the

decades ahead. But for that to happen, the right

incentives have to be offered from Washington, and the

right decisions have to be made in Detroit.

Finally, the US is in danger of moving from dependence on

Middle East crude oil to dependence on Chinese Lithium Ion

batteries. As with so much else, economics are driving the

manufacturing of advanced batteries to China — even for

companies which have innovated here in the US. If our view

of the world is right, the battery industry will be one of

the central economic drivers and it is certainly worth an

investment in the right type of incentives to keep some of

that manufacturing capacity here at home. All of you are

in a much better position to evaluate how to do that than I

am.

We stand ready to work with this Committee and the entire

federal government to determine what the right policy mix

should be, and we encourage the Congress to be bold in its

thinking. There has been enough talk about ending America's

oil dependence.   The Better Place model presents an actual blueprint for doing so. It can save our environment, strengthen our national security, and retool our economy to a post-oil era of truly sustainable development. It can help to ensure that this young century is, in fact, an American century. And it is ready to roll today.

*   *   *

The CHAIRMAN. And next we are going to hear from Torben Holm. He is a consultant with DONG Energy A/S, one of the leading energy groups in the Scandinavian region.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF TORBEN V. HOLM, DONG ENERGY A/S

Mr. HOLM. Thank you very much, Mr. Chairman. Thank you for giving me the opportunity to appear here today on the dual challenges of oil dependency and climate change.

I am coming from Denmark, one of the countries that were hardest hit when the oil got its first set of wake-up calls regarding oil dependency back in the 1970s. At that time, Denmark was almost totally dependent on imported fuel, and 94 percent of fuel consumed was oil.

In order to offset the risks associated with this delicate situation, numerous programs were started. As a result, we are now in a situation where we are a net exporter of oil, we run some of the world's most efficient power plants, fueled partly by coal, partly by biomass; and close to 20 percent of our electricity production is based on windmills.

Finally, a good number of activities have been initiated with a view to save energy.

Over the last 20 years, Denmark has achieved an increase in GDP of about 75 percent with almost no corresponding increase in energy consumption. But within this overall positive picture, one sector, namely transportation, stands out by showing a constant growth in energy consumption and CO_2 emissions. That curve has to be broken both from an energy security point of view and in order to make sure that Denmark can meet its international climate policy obligations. And this is where Project Better Place comes into the picture.

Denmark's transportation system is organized in a way that ought to be mentioned. As Shai said, we have a realistically high density of private cars, and that is in spite of heavy car registration tax. We also have a comparatively high gasoline cost, also as a result of taxation. Both owning and driving a conventional car are, therefore, blessings you have to share to a high degree with the rest of society. On the other hand, we are in a situation where electric vehicles are enjoying a quite beneficial tax treatment. And, finally, all of the electrical power needed to fuel the car fleet could come from renewable sources.

As I mentioned, Denmark was an early mover on wind energy and has now one of the highest ratios of wind to other energy sources in the world. To put these matters in correct proportions, we have estimated that one medium-sized 2-megawatt windmill can, on average, supply the energy needed for 3,000 cars.

In a country——

The CHAIRMAN. Can you say that again?

Mr. HOLM. One medium-sized 2-megawatt windmill can, on average, supply the energy needed for 3,000 cars.

The CHAIRMAN. Thank you.

Mr. HOLM. In a country with 5.4 million inhabitants and some 2 million passenger cars, the entire passenger car fleet could, thereby, run on electricity produced by less than 750 windmills.

The CHAIRMAN. Say that again.

Mr. HOLM. It is correct. In a country with 5.4 million inhabitants and some 2 million passenger cars, the entire passenger car fleet could thereby run on electricity produced by less than 750 windmills.

The CHAIRMAN. And what is the megawattage of those windmills?

Mr. HOLM. Two megawatts apiece.

The CHAIRMAN. So that would be 750 times 2? Is that what you are saying?

Mr. HOLM. Yes 1.5 gigawatt.

The CHAIRMAN. Would power the entire automotive fleet for how many vehicles?

Mr. HOLM. Two million passenger cars. On top of that, we have another 500,000 lorries and vans.

The CHAIRMAN. Please continue.

Mr. HOLM. Wind is not always blowing, so we have also estimated that even if all the electrical charging of cars were sourced from coal-fired power plants, net CO_2 emissions will still decline by half because electric motors are three to four times more efficient than either gasoline or diesel ones. However, the more wind power we have and our production makes at any given time, the higher the CO_2 emissions improvement will be.

An additional benefit will come from the fact that most charging will take place at night when wind power is in excess supply. This means that Denmark will be able to use wind energy that otherwise would have to be exported to neighboring countries, typically at relatively low prices.

Finally, we have made calculations on what this would mean for the individual driver. Based on conservative estimates of the anticipated cost of both vehicles and batteries, the results are that consumers who migrate from gas to electric cars can expect to enjoy substantial savings. This is in terms of total cost of both owning and driving a car, and it comes without sacrifice of convenience and without sacrifice of driving experience.

In summary, we see this project as one with very big upside potential and very little downside risks, both from a consumer and from a public perspective, and both from an energy security point of view and in relation to reduction of CO_2 emissions. We, therefore, hope and ask for all the support we can get from everybody involved, that is from car manufacturers to policy makers.

Our contribution, on the other hand, is to roll out the necessary infrastructure, and to that we are fully committed. Thank you, Mr. Chairman; and I will now be happy to address any questions you might have.

The CHAIRMAN. Thank you, Mr. Holm, very much.

[The statement of Mr. Holm follows:]

Testimony by

Torben V. Holm

DONG Energy A/S

United States House of Representatives

Select Committee on Energy Independence and Global Warming

Hearing on

"$4 Gasoline and Fuel Economy: Auto Industry At a
Crossroads"

Thursday, June 26, 2008

Introduction

Mr. Chairman, Congressman Sensenbrenner and other Members

of the Committee: Thank you for your leadership on this

issue. And thank you for the opportunity to describe the

efforts of my company, DONG Energy, to help address the

twin challenges of climate change and oil dependence,

including through our partnership with Project Better

Place.

DONG Energy is one of the largest integrated energy groups

in the Nordic region. We produce oil and gas from the North

Sea, are Denmark's largest power generator with a

production portfolio where some 20% of total capacity is

based on renewable energy (mostly wind), and we distribute

power, heat and gas to more than 1 million customers across Denmark, Germany, Sweden and The Netherlands. DONG Energy is majority owned by the Kingdom of Denmark. The remaining shares are currently held by municipalities and local utility companies, but a public offering of shares is about to happen whenever conditions in the stock market as a whole are determined to be right.

Let me begin by placing DONG Energy's climate change efforts in context. The commitments of my home country, Denmark, to address these climate change concerns take place within the broader framework of commitments undertaken by the European Union as a whole. The EU has committed to achieving, by the year 2020, a 20% cut in greenhouse gas emissions compared to 1990 (30% if international agreement is reached); a 20% increase in energy efficiency; and a 20% share of renewable energies in energy consumption.

However, Denmark's national climate change commitments also reflect our own longstanding dedication to the highest possible levels of environmental protection. In many areas, Denmark's commitments exceed those of the EU. In the EU burden-sharing process, Denmark has received CO_2 reduction targets that substantially exceed the EU average (i.e. 21%

2

compared to 1990 emissions versus an EU average of 8%, and 20% compared to 2005 emissions in 2020 for the sectors not covered by the EU emissions trading system versus an EU average of 10%). Likewise Denmark's national target for renewable energy is set at 30% renewable energy in 2020, thus exceeding the average EU target by 50%. In addition, Denmark is the first country in the world to commit itself to actually reducing overall energy consumption, aiming for a 2% reduction by the year 2011.

Over the last 20 years, Denmark has achieved an increase in GDP of about 75%, with almost no corresponding increase in energy consumption. This improvement in energy efficiency has been achieved through gradual technological improvements in many sectors across the economy, ranging from upgrading of power plants to the highest possible efficiency standards to better insulation of buildings and active campaigning for change to more energy efficient appliances.

But within this overall positive picture, one sector stands out, and helps to explain our interest in the Better Place model: transportation.

The transportation sector in Denmark has shown a constant, steady increase in energy consumption. And if this cycle is

not broken, Denmark will be unable to meet its international climate change obligations.

At DONG Energy, we believe that the overall solution to the climate challenge will come from a mixture of complementary initiatives. So we are pressing ahead on several different fronts.

We are a partner in seven of the 10 largest offshore windfarm projects in the world, and due to constant trimming of our portfolio of conventional power plants we now operate some of the world's most energy-efficient units with energy utilization rates approximately 30% higher than the EU average.

In the transportation sector, we are committed to the development of second generation bio-ethanol as a means of improving fuel efficiency in the existing car fleet. And we are a shareholder in a company jointly owned with Project Better Place, whose objective is to convert the vehicles driven in Denmark from gasoline to electrical power as quickly as possible.

The Denmark/Better Place Fit

What are the factors that led DONG Energy, as well as the Danish government, to conclude that the Better Place model would work in Denmark? There are several.

First, there is one key historical reason. At the time of the first oil shock of 1973, Denmark was totally dependant on imported fuel, and 94% of fuel consumed was oil. That shock had a profound impact on Denmark, underscoring for us the inadequacy of relying on energy sourced from unreliable suppliers and regions, and prompting a commitment to energy self-sufficiency. Because of that shock, Denmark was one of the first countries to commit to wind energy. Within 20 years, the country was also a net exporter of oil.

Second, Denmark's transportation infrastructure has several notable features, which taken together make Denmark an excellent testbed for efforts to convert today's gasoline-based transport system: a heavy reliance on having one's own vehicle, irrespective of the fact that car purchase and ownership of conventional gasoline or diesel cars is massively taxed; a vehicle transportation grid constrained by geography in how much it can grow; not surprisingly, consistent and growing traffic congestion; and a

comparatively high gasoline cost, a large portion of which is made up of taxes.

Finally, and perhaps most importantly, one key pillar of the Better Place model is that all of the electrical power needed by the car fleet could come from renewable sources. As I have mentioned, Denmark was an early mover on wind energy, and retains one of the highest ratios of wind-to-other energy sources in the world. In 2007, wind energy contributed about 19% to total power production. But as old, small and now comparatively in-efficient wind mills are now being retired and replaced with bigger and more powerful ones, this ratio will increase even further. And in this environment cars represent an almost ideal customer profile for this extra capacity.

We have estimated that one 2MW windmill (a medium-sized turbine, typically positioned offshore) can, on average, supply the energy needed for 3,000 cars. In a country with 5.4 million inhabitants and some two million passenger cars, the entire passenger fleet could run on electricity produced by less than 750 windmills or 1,500 MW wind capacity installed.

In 2006 the installed wind capacity in Denmark was 3,135 MW, 423 MW of this being offshore wind turbines. With the

6

measures decided in the recently approved Danish energy plan, wind capacity is expected to increase with an extra 1300 MW (i.e. about 40%) until the year 2012.

Benefits to Denmark From the Changeover to Electric Cars

So we have a very high degree of confidence that this model can and will work in Denmark. We have also very high – but we believe quite realistic – expectations of the benefits this model will bring, for emissions, energy efficiency and individual consumers.

We have estimated, for example, that even if all of the electrical charging of cars was sourced from coal-fired power plants, net CO_2 emissions would still decline by half because electric motors are 3-4 times more efficient than either gasoline or diesel ones. The more wind power we have, the higher the CO_2 emissions improvements will be.

We also expect there to be cost efficiencies as well, since most vehicle charging will take place at night, when wind power is in excess supply. In fact, by charging the cars at night Denmark will be able to use wind energy that otherwise would have to be exported to neighboring countries, typically at relatively low prices. Moreover, because there will an electrical grid operator who can

aggregate energy storage across the grid, that energy can
be sent back to the grid during peak hours. This optimizes
the use of Denmark's wind capacity, and improves the
ability to increase the share of renewable energy in the
production portfolio

We also believe there will be substantial cost savings to
the individual driver. Based on even conservative estimates
of the anticipated cost of both vehicles and batteries, we
believe that consumers who migrate from gas to electric
cars can enjoy immediate savings of some 15-20% per month,
and quite considerably more if in fact the subscription
model drives down the price of vehicles in the manner that
we expect.

Electric cars will thus contribute substantially to
reaching the Danish and European long-term goals of
independence from fossil fuels, and will correspondingly
lessen the energy dependence on countries led by
politically unstable regimes, a situation that has not
improved much since the last oil crisis.

The Challenges That Remain

For these reasons, both DONG Energy and the Danish
government strongly support efforts to transform our

transportation infrastructure from gasoline to electricity. There are, of course, supply constraints at present both from the auto manufacturing industry and amongst battery producers that we are working to address. There is also work underway to ensure that Denmark's public policy framework works in favor of - or at least not counter to - this model.

But we believe these challenges are surmountable. Indeed, we believe they must be surmounted if we are to break free from our oil dependency and secure the environmental, security and consumer benefits that this transformation can bring.

*   *   *

The CHAIRMAN. And our final witness is Mr. Jeffrey Holmstead. He heads the environmental strategy section at Bracewell and Giuliani. He was the head of the EPA Office of Air and Radiation from 2001 to 2005 during the administration of President Bush.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF JEFFREY R. HOLMSTEAD, PARTNER AND HEAD OF THE ENVIRONMENTAL STRATEGIES GROUP, BRACEWELL AND GIULIANI

Mr. HOLMSTEAD. Thank you very much for having me. As you mentioned, I am—my name is Jeff Holmstead. I am a partner in the law firm of Bracewell and Giuliani, but today I am not appearing on behalf of my firm or any of the law firm's clients. I am here in my personal capacity as a former EPA official who has spent almost 20 years working on climate change and air quality issues.

I feel kind of like I am on the wrong panel. I am not a technology expert, but I do know a fair amount about regulatory policy and regulatory programs. And I want to make just a few observations about that.

As you well know, last year Congress passed an energy bill that will require a substantial increase in fuel economy for motor vehicles, an increase of at least 40 percent by 2020. NHTSA estimates that during the first 5 years that this lies in place it will save approximately 55 billion gallons of fuel and reduce greenhouse gas emissions by over 500 million metric tons. Not surprisingly, there is a significant upfront cost that must be paid to achieve these improvements.

Again, NHTSA estimates that in model year 2015 new car buyers can expect to pay between about $650 and $2,000 more for a car and between about $1,000 and $1,400 more for a new light truck because of the new CAFE program. It is important to note that buyers will more than recover these costs through greater fuel savings, but even so, they will have to pay more upfront when they want to purchase a new car or light truck. This is the price that must be paid to achieve greater energy security and reductions in greenhouse gas gases.

As you are all aware, the new CAFE program was extensively debated in Congress and the final product passed with large bipartisan majorities in both Houses. This law represents a careful balancing of regional and ideological differences. For example, the CAFE law was carefully drafted to ensure that safety would not be jeopardized by mandating an attribute-based system. This law also ensures that other economic factors such as job loss, consumer choice and market demand would also be considered in designing and implementing a new fuel economy standard.

As I understand it, compromise agreements were also reached to protect union jobs in the manufacturing sector and to extend the flex-fuel credit until model year 2019.

Notwithstanding the extensive debate in Congress and the compromises reached between many competing interests in order to secure passage of the new CAFE program, there are now a number of advocacy groups who argue that Congress did not intend the new CAFE program to be the final word on fuel economy. In their view, provisions added to the Clean Air Act back in the 1970s actu-

ally require a much more aggressive fuel economy program than the one that Congress designed and adopted last year.

I, as someone who has spent more than 5 years at EPA, have enormous respect for EPA officials in their ability to develop effective regulatory programs, but it seems odd to me that Congress would debate a contentious national policy issue like fuel economy for many years, reach a compromise on an approach that garners broad support, and then expect EPA to immediately develop a completely separate program which makes that compromise entirely irrelevant.

Supporters of the view that EPA in California should be setting policy in this area argue that CAFE is about fuel economy and that the Clean Air Act is about emissions. But Congress certainly understood, at least by 2007, that when it comes to CO_2 emissions, they are exactly the same thing.

As I think you know, NHTSA is responsible for implementing the CAFE program, and how does NHTSA determine whether car companies are meeting the program's fuel economy requirements? Well, they do it by having EPA measure the CO_2 emissions that come out of those cars. As a matter of basic science, there is no difference between fuel economy and CO_2 emissions. You can control CO_2 emissions by regulating fuel economy, or you can control fuel economy by regulating CO_2 emissions; but no one should pretend that they can be viewed as two different things.

I would think that most Members of Congress would find it troubling to have EPA or California or both establish their own regimes for regulating fuel economy because neither EPA nor California is required to conform their programs to the CAFE system that was so carefully designed by Congress. For example, California is clearly under no legal stricture to adopt an attribute-based system as Congress commanded NHTSA to do, and under the Clean Air Act, EPA does not have to balance the competing interests of fuel economy, safety and jobs.

Considering the costs of the new CAFE law, I think it is legitimate to ask if it is wise to have EPA also regulate fuel economy or, in some States, have California rules compete with Federal rules. It just doesn't make any sense to have two separate Federal agencies, NHTSA and EPA, governed under two separate statutes, the Energy Policy and Conservation Act and the Clean Air Act regulating the exact same activity, fuel economy or CO_2 emissions, which are the same things. It makes even less sense when you add a separate California program which may then be adopted by any other State that chooses to follow it rather than following either EPA or NHTSA.

This afternoon, I simply would like to urge the members of this committee to be sure that Congress sets clear, uniform national policy and does it in a way that is sensible for the manufacturing sector and for American consumers.

Thank you very much. I would be happy to answer any questions:

The CHAIRMAN. Thank you Mr. Holmstead.

[The statement of Mr. Holmstead follows:]

Testimony of Jeffrey R. Holmstead
Before the
House Select Committee on Energy Independence and Global Warming
June 26, 2008

Mr. Chairman, my name is Jeff Holmstead. I am a partner in the law firm of Bracewell and Giuliani and the head of the firm's Environmental Strategies Group. This afternoon, however, I am not appearing on behalf of my law firm or any of my firm's clients. I am here solely in my personal capacity as a former EPA official who has spent almost 20 years on working on climate change and air quality issues.

As you know, last year Congress passed an energy bill that will require a substantial increase in fuel economy for motor vehicles – an increase of at least 40 percent by 2020, which will result in a 30 percent reduction in greenhouse gas emissions from motor vehicles. NHTSA estimates that, during the first five years this law is in effect, it will save approximately 55 billion gallons of fuel and reduce greenhouse gas emissions by 521 million metric tons.[1]

Not surprisingly, there is a significant up-front cost that must be paid to achieve these improvements. NHSTA estimates that, in model year 2015, new car buyers can expect to pay between about $650 and $2000 more for a car and between $1000 and 1400 more for a new light truck because of the new CAFE program.[2] All told, NHTSA calculates that consumers will pay between $36.5 billion and $67.9 billion more to purchase the vehicles regulated under its proposed rule to implement the CAFE increase.[3]

It is important to note that buyers will more than recover these costs through greater fuel savings. But even so, they will have to come up with a bigger down payment when they want to purchase a car or light truck, or take out a bigger loan. This is the price that must be paid to achieve greater energy security and reductions in greenhouse gas emissions.

As the Members of this Committee are aware, the new CAFE program was extensively debated in Congress, and the final product passed with large bipartisan majorities in both houses. This law represents a delicate balancing of regional and ideological differences. For example, the CAFE law was carefully drafted to ensure that safety would not be jeopardized, by mandating an attribute-based system. This law also ensures that national economic factors, such as job loss, consumer choice, and market demand would be considered in designing and implementing the new fuel economy standard. As I understand it, compromise agreements were also reached to protect union jobs in the manufacturing sector and to extend the flex fuel credit until model year 2019.

Notwithstanding the extensive debate in Congress, and the compromises reached between many competing interests in order to secure passage of a new CAFE program, there are a number of advocacy groups who argue that Congress did not intend the new CAFE program to be the final word on fuel economy. In their view, provisions added to the Clean Air Act back in 1977 actually require a much more aggressive fuel economy program than the one adopted by Congress last year.

I have enormous respect for EPA officials and their ability to develop effective regulatory programs. But it seems odd to me that Congress would debate a contentious national policy issue like fuel economy standards for many years, reach a compromise on an approach that garners broad support, and then expect EPA to develop a completely separate regulatory program which makes that compromise entirely irrelevant.

Supporters of the view that EPA (and California, pursuant to a Clean Air Act waiver) should be setting policy in this area argue that CAFE is about fuel economy and that the Clean Air Act is about emissions. But Congress well understood, at least by 2007, that when it comes to CO_2 emissions, they are exactly the same thing. NHTSA is responsible for implementing the CAFE program. And how does NHTSA determine whether car companies are meeting the fuel economy requirements of that program? By having EPA measure the CO_2 emissions that come out of those cars. As a matter of basic science, there is no difference between fuel economy and CO_2 emissions. You can

control CO2 emissions by regulating fuel economy, or you can control fuel economy by regulating CO2 emissions. But no one should pretend that they can be viewed independently.

I would think that most Members of Congress would find it troubling to have EPA or California (or both) establish their own regimes for regulating fuel economy/CO2 emissions because neither EPA nor California is required to conform their programs to the CAFE system that was so painstakingly designed by Congress. For example, California is under no legal stricture to adopt an attribute-based system as Congress commands NHTSA to do. Moreover, under the Clean Air Act, EPA does not have to balance the competing interests of fuel economy, safety and jobs.

Considering the huge cost of the new CAFE law, it is legitimate to ask if it is wise to have EPA also regulate fuel economy, or in some states, have California rules compete with federal rules. If NHTSA was refusing to implement the will of Congress, perhaps such a situation would be appropriate. But that is not the case. In this instance, NHTSA's average 4.5 percent a year increase in stringency has surpassed what is required under the new energy bill.

Mr. Chairman, it just doesn't make any sense to have two separate agencies (NHTSA and EPA) governed under two separate statutes (the Energy Policy and Conservation Act and the Clean Air Act), regulating the exact same activity (fuel economy/CO2 emissions). It makes even less sense when you add a separate California program, which may then be adopted by any other state that chooses to follow it, rather than following either EPA or NHTSA.

---

[1] 73 Fed. Reg. 24,456 (May 2, 2008).
[2] NHTSA, *Preliminary Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2011-2015 Passenger Cares and Light Trucks*, April 2008, page. IX-13.
[3] 73 Fed. Reg. 24,479 (May 2, 2008).

The CHAIRMAN. Mr. Holmstead, do you think it is wise for the Department of Transportation to use $2.40 a gallon by 2016 as a basis for what they are planning on using in their cost-benefit analysis for new vehicles by 2016?

Mr. HOLMSTEAD. I am not qualified to predict fuel economy, and I think what you have to do is depend on people who are the experts in this area. So if that is what EIA says the price is expected to be, then I don't know that NHTSA really has any choice.

But, again, I don't know very much about this.

The CHAIRMAN. The Energy Information Agency actually recommends that we use a much higher level, but the Department of Transportation uses a midlevel $2.40 a gallon. And I don't know how much of an expert you have to be in order to predict that gasoline won't be at $2.40 a gallon 8 years from now.

Mr. HOLMSTEAD. The law that was passed today, how much is that predicted to reduce the price of a barrel of oil? I have heard very significant predictions; through the antispeculation bill, some people are saying 50 percent.

Again, I don't know about that, but I know there are lots of people looking at those issues.

The CHAIRMAN. We don't have to worry about it, because the President is promising to veto it. So it is not anything that is actually likely to happen since the President isn't going to sign it.

So what I am saying is, given all of the things that have happened, doesn't it make sense to plan for the worst?

And, Mr. Agassi, you are working in Israel. They seem to be planning for the worst in Israel, that is, planning for a world in which oil is used as a weapon against Israel and against the rest of the world. So what is their response in terms of planning, going forward into the future?

Mr. AGASSI. Well, the assumption in Israel is that, given the right infrastructure, given the right pricing, the consumer will actually make the choice to go with no oil. And so I think they are planning for the best in that sense; that all of us, given the opportunity to disconnect from oil and connect to electricity, we will choose to do the right thing. I think the American consumer will do the same.

The CHAIRMAN. Well, that is not an assumption, however, that has been made inside the Bush administration. They don't plan for the worst, but they also, taking your comment in quotes, they also don't plan for the best. They don't plan for the American people to respond to the challenge in the same way that President Kennedy expected the American people to respond to the challenge of the Soviets in outer space with this nuclear capacity attached to it. So I think that is still a real problem in our country.

So you heard what Mr. Holm said about the amount of wind that would have to be generated in order to provide for all of the electricity for the vehicles in his country.

And, by the way, last year in the United States, we actually installed 5,400 new megawatts of wind in the United States. Now what would 5,400 megawatts of wind mean in your country, Mr. Holm, in terms of your automotive industry?

Mr. HOLM. It is a matter of simple math: 4500 megawatts. That is three times the amount I mentioned, so it is 6 million cars.

The CHAIRMAN. Six million cars can be powered?

Mr. HOLM. Yes. Provided that you had the same wind pattern here as we have in my country.

The CHAIRMAN. We will assume—we will accept the challenge—that we will at least be able to match your country in terms of the efficiency of our wind system.

Mr. Agassi, can you extrapolate that for the United States of America? What would you think might be possible here in our country looking at what Mr. Holm is talking about, looking at what the Israelis are planning? What could happen in the United States if your vision took hold?

Mr. AGASSI. I think if you looked at the U.S., roughly at a cost of any source, the average source—wind, solar, wave—of about $2,500 per car, we would be able to install capacity that would drive that car for the next 6 years without a single molecule of CO_2 coming into the atmosphere and without a single drop of oil coming into our system.

In effect, if you took the U.S. and you put 200 gigawatts of generation in any source, in any mix, over the next, let's say, 10 years, the 200 gigawatt being 200,000 megawatts, we would get every car in the U.S. going forever. And we could do that at a cost of about $500 billion spread over the next 10 years of which 80 percent is labor that stays in America.

So we can replace oil imports with jobs at a scope of about 1 year of oil imports. We could get off oil.

The CHAIRMAN. Now, right now, President Bush is threatening a veto of a bill that would extend the wind and solar and other renewable tax breaks that generate electricity in our country, hopefully, in the years ahead. And at the same time, I hate to say this, but it is the Republicans in the Senate that blocked our passage just by one vote of legislation that would have established a minimal goal for new renewable electricity generation by 2020 in our country.

Could you comment upon that, Mr. Agassi, in terms of long-term planning? And where do you think we should be going in terms of nonpolluting electricity being used by nonpolluting automobiles that the American people could rely upon?

Mr. AGASSI. I think one of the critical issues that people have to remember is putting cars on the grid, putting cars on the road that have batteries in them, creates a different economic model for renewable generation. Cars park 22 hours in a day; they drive 2 hours in a day. When they are parked, the batteries are available to absorb electricity that comes from renewable sources. So if you have a lot of cars, if you have 200 million batteries parked most of the day, you can take a lot of electricity that come from renewable sources, especially wind.

Wind is a great example because wind blows mostly at night. So the perfect appliance that matches to wind generation is a car, because a car is parked mostly at night. If you put the two together and you actually replace oil with wind, that is the only way to replace oil with wind.

We talk a lot about taking oil out of the equation and putting renewable sources, if we don't put the electric wire that connects the two, we won't be able to get there.

The CHAIRMAN. When I was a boy, I worked my way through Boston College driving an ice cream truck. So I would get the truck in the morning, fill it up with Popsicles and Fudgesicles, but then when I got home at night, I had to plug it into the side of the house so that I would be using the electricity overnight to keep all of my Fudgesicles and Popsicles very, very cold, so I could sell them all day long.

Now, that is essentially what the American people will be asked to do. And maybe you, Mr. Thormann, can talk about how much less expensive it is to use electricity overnight trying to, as you recharge your battery either for ice cream or to drive the vehicle, rather than in the middle of the day. That is a concept a lot of people don't quite understand, how it is less expensive if you use it when most people are not, in fact, using electricity.

Mr. THORMANN. I think Mr. Agassi quoted a number. The working assumption order of magnitude between peak hours and off-peak rates currently would be a factor of——

The CHAIRMAN. What does that mean for ordinary people? When you say "peak" and "off-peak" hours, what does that mean in laymen's terms?

Mr. THORMANN. Day and night. Very simply.

The CHAIRMAN. Day and night. If you are using electricity during the day——

Mr. THORMANN. It is expensive.

The CHAIRMAN. And if you use it from midnight to 6:00 a.m.?

Mr. THORMANN. It is cheap.

The CHAIRMAN. It is cheap. And how long would it take to charge one of these batteries?

Mr. THORMANN. Less than you sleep at night.

The CHAIRMAN. And how much less expensive is it to use it at night rather than during the day?

Mr. THORMANN. Well, I have numbers that would show that it would be a factor of one to seven. So it would be seven times cheaper to take electricity from the grid at night when people sleep than in the daytime when——

Mr. HOLMSTEAD. How it would be affected if the demand for nighttime goes up? Would those numbers stay roughly similar if, all of a sudden, there are 200 million cars that are using electricity at night?

Mr. THORMANN. A lot of it is going to depend.

Mr. Agassi made a good point. If it comes from wind that blows at night, it is wasted energy, and you can't store it anywhere, and the car serves as sort of a reservoir. It is like a big tank where you would store oil; our automobile becomes just a receptacle to store energy, and it becomes available for the driving needs during the day, which is when most of the driving occurs.

Not predicting, of course, what prices would be when supply and demand——

Mr. HOLMSTEAD. But the other key factor that I think all of us are aware of—and certainly the chairman is—to get the wind energy to where we need it, we are going to need a fair amount of new transmission, aren't we?

Mr. AGASSI. Actually, one of the studies by the administration that was put out today, without any changes to transmission, no

changes to the grid, and effectively no changes to generation, we could drive 86 percent of the cars in America on zero change, zero infrastructure investment.

The grid in America is actually designed for the high-end peak, not for average peaks, not for average consumption. So we could actually—especially if you use overnight, you could effectively, with today's infrastructure, with today's grid, you could drive probably about 150 to 170 million electric cars in America.

Now you would then be using coal. What we are proposing is that, as you make that change, you also make the change to clean generation, because you are effectively removing the usage of $140 barrel of oil. Instead of saving the last cents on using coal, put the last cent in and use wind, use solar, use renewable sources.

Mr. HOLMSTEAD. That is my point about transmission. The places where you have good wind and good solar resources are not the places where we have transmission infrastructure.

Mr. AGASSI. We have 20 million cars in California. We can put solar plants in the Mojave Desert, and you will lose less than 3 percent in transmission of those electrons from the desert to every major metropolitan area in California. That is 10 percent of cars.

You look at Texas; we have a lot of wind and a lot of sun. The beauty of wind and sun is usually, if you have a lot of sun, you can use that; and if you don't have sun, you usually have a lot of wind. So the mix is very much in place for both of them.

In some places, as one of the Congresswomen here mentioned, they have nuclear. A nuclear plant, to put it in perspective, can drive 3.5 million cars, if you already built that nuclear plant. So France, as an example, could actually turn off every single car to electrons and not need to add any single source of generation and drive all their cars on their nuclear plant infrastructure today, what they have today.

The CHAIRMAN. So, Mr. Agassi, thank you so much. We had United States President Kennedy could rely upon Wernher von Braun to help him with the space program. And we can rely upon you to help us solve this technological problem here in the United States.

So—Mr. Holmstead has already stipulated he is not a technologist, so a lot of this depends upon kind of the game-changing aspect of technology. So if we get the regulation correct, then everything else changes, you know, in a very dramatic way.

So—AT&T in the year 1980 predicted we would have 1 million people using cell phones in the United States in the year 2000, so AT&T was off by a lot because they missed a whole bunch of other decisions that got made from 1980 on that changed everything. And they were right; some people would probably not walk around with something that weighed 4 pounds and required them to have a direct view of some cell phone tower or satellite in order to deliver a message.

So you have to basically have a little bit of confidence in the technology.

So what Mr. Agassi is saying and Mr. Holm and Mr. Thormann is saying is that if we use the electricity that is wasted in the middle of the evening, overnight, we are actually taking an unused resource; we are charging the batteries, and we are not affecting the

grid during the day when it is needed in order to keep businesses going and industry churning. So you have that as an asset.

And I think what Mr. Agassi is saying is that if you move to wind and solar—let's just say for the sake of discussion that the 5,400 megawatts that we installed in 2007 in the nascent part of this industry—by the way, Mr. Holm, 2,500 new megawatts of wind in Texas in 2007, that would power every vehicle, all 2 million vehicles in Denmark, just what was installed in one State in 1 year.

So obviously something big is happening here. And experts predict that we will have a minimum of 100,000 megawatts of wind by the year 2016.

So now let's go to—and give me your analysis—let's go to our first panelist again.

The Department of Transportation and President Bush have to make a decision by 2016 on what kind of standards we can establish for the vehicles that we drive. And if we want to use that decision to enhance our technological superiority, break our dependence upon imported oil, and create more jobs in our country, now—if we factor in that 100,000 new megawatts of wind will be constructed in our country, most of it not used overnight—give us a little vision of what might be possible in terms of the miles-per-gallon standard established for the average of the vehicles in our country that year.

Mr. AGASSI. One of the factors I would plug in, maybe, instead of focusing on the number before the miles per, we focus on the gallon. If we get off the gallon, we get to infinity—which might have actually the reason the Nissan called their high-end brand Infiniti. We need to get to a point where we are driving on infinity miles per gallon because we are not using any gallons whatsoever.

I think the assumption that we need to put in place is that oil is not going to become cheaper, it is not going to become more abundant. I don't see any new sources showing up. The sources that are showing up will take a long time before we drill into them. I think the reality of the number is pretty fixed in front of us right now.

Given that number, we are looking at $4 to $5 per gallon right now, and we are seeing that electricity, including all costs, all loaded costs, are at $1, $1.50. That means unless we suddenly find oil that we can bring out of the ground at $10 a gallon, electricity is here to stay. That trend line has happened.

This is like trying to fight the Internet by sending letters faster. It is not going to happen. We are going to electrons, and in the transition, we are sort of going between the world of physical atoms, like sending letters around, to the world of sending e-mails.

We had this very short period in which we turned molecules into electrons and called it fax and turned it back into molecules at the other end; that is the hybrid model. We had a hybrid model, and it is a short period of time in which hybrid models survived.

But then when you get to full electrons, nobody comes back from full electrons. It doesn't happen. In every industry in our history we went from physical molecules to electrons.

It happened in the early 20th century when we converted light——

The CHAIRMAN. Say that again? You went from what to what?

Mr. AGASSI. From molecules to electrons. Oil went to zero historically after it was very expensive. Oil was discovered to light up houses; it was kerosene. When we discovered oil, it was used mainly to light up houses; and then Edison and Westinghouse put lights made out of electrons in every house, and kerosene was useless and oil became useless; and we effectively had a period of time in which oil was pouring into rivers and nobody would put it into barrels because barrels were more expensive than oil.

We have to go back to that model.

Today, if we stop using oil for cars, oil will become useless again. The price will go down below $10 a barrel. The world will be safer. We will be independent.

The CHAIRMAN. In the same way we didn't have to go out and kill those whales anymore for their oil. Let them out there, swimming along, don't need their oil.

And wouldn't that be a great day? Wouldn't it be a wonderful day if the United States could say to Saudi Arabia, we don't need your oil any more than we need your sand?

You can keep it all over there, just be a wonderful, wonderful day.

So Mr. Thormann, can you talk here a little bit about what Mr. Agassi was mentioning, about going all electric we will go through the hybrid period and hit the all electric period. What is Nissan planning?

Mr. THORMANN. We have, simply put, we are planning for the ultimate stake which is the all-electric vehicle. The hybrids that we know of today are transitioned between internal combustion engine and all-electric vehicle.

One factor that you must remember is that the requirements or that the measures that have been put forward by the IPCC to reduce CO_2, so by 2050, so that global warming has a chance of stopping. We have to reduce current output by 80 percent, CO_2 output of automobiles by 80 percent. The only way we know how to get there is by the electric vehicle. Hybrid cars will not allow you to do that. And if we put an electric car at the end of the renewable source of energy that we just talked about, we achieve that goal.

So you have an economic factor, your oil independence and so our car, our proposition is that you kill 2 birds with one stone. We get off of the oil and the dependency of a single source of energy, and at the same time, you accomplish the second goal, which is obviously critical to future generations, which is to reduce CO_2 and prevent global warming. And that the electric car allows you to envisage that future.

The CHAIRMAN. A lot of this requires us to get the policies correct in the United States. We have to create the wind power, solar power, the LJ power. We have to go through the whole thing, the wave power, we are creating the electricity. But once we create that, this automotive technology is moving along, the batteries will follow. The vehicles will be put together. The system can be put in place in order to accomplish this goal.

Back in 1993, basically all cell phones were analog, and it cost about $0.50 a minute, at $0.50 a minute we probably won't have a lot of people using cell phones in the United States. I was the chairman of the subcommittee with jurisdiction over it, I was able

to move over 200 megahertz of spectrum for a third, fourth, fifth and sixth license in every community in the United States.

Now those third, fourth, fifth and sixth licenses could not be bid on by the first two licensees that were analog, the big companies. And what did the new companies do? They all went digital.

And within a couple years they all dropped their price down to $0.40, 0.30, 0.20, 0.15, 0.10 cents a minute and lower and everyone said this is great. What the first two companies do? They moved to digital and they started lowering their prices. So by 1996, 1997 everyone is walking around with a phone because they moved over to this better technology, this lower cost and very affordable. But you had to change the policy.

In 1996, again something on the telecommunication sub-committee we were able to create a dynamic where not one home in America at that point had broadband technology, not one home in America. So we had to change the policies so that we could create a brand new telecom world. So that if we moved from this old, again, analog world to a broadband world. Once we passed the 1996 Telecommunications Act by 2000, 2001 we were in a world of Googles, of Amazons, of thousands of companies who no one ever heard of before because broadband is going into all these people's homes. And we become a YouTube world that no one would have ever envisioned 10 years ago because now the technology is unleashed. Not that it hadn't already been invented.

You know, the broadband had already been invented as the DSL in the laboratories of the Bell Laboratories 15, 20 years before. So here we have to get this policy right because it will turn all the economists thinking on their head, because all they can use is the old models. But if you put the technologists in charge and you say to them, you know, ah, now the conditions are there where I can deploy my new technology and sell it to consumers, then things change more rapidly than anyone would have ever thought. We have seen it happen over and over and over again with technology in American society.

So Mr. Agassi, could you just tell us a little bit about what the Israelis said when they made their announcement about breaking their dependence upon oil and why they did it.

Mr. AGASSI. The policy they set was extremely simple, it was so simplistic everybody could get it. They basically set a deferential tax on buying a new car. They said a gasoline car will cost 72 percent more than the cost of making it and the electric car will cost 10 percent tax. And then they said if we see a lot of people switching to the electric car, we will shift both prices up, but we will keep it always 60 percent delta until 2019.

So they created a visibility of 10 years out and are basically telling people, the more people will shift to electric, the more expensive it will get, but gasoline will also get expensive. Then they said we will create standards and force you, Better Place, to abide by open standards so that you can't block people from coming into this market. You can't block everybody to buy just one type of car from one maker. Open standards using plugs that are made standards by the ISO organization.

Then they basically said, we are going to put regulations so that there is competition in the market. Just like you said, we are going

to make it so that you are competing. And then they told me in the back room, we hope you are very, very successful, because we are going to tax you. The more successful you are, the more we are going to tax you. Well, first we want you to be successful. Now I think we need to do the same thing here. You said it absolutely correctly, this is like the mobile industry.

The CHAIRMAN. I think we are going to go from Mobil, ExxonMobil to Mobil. And if we do then we have a whole new era.

Mr. AGASSI. Absolutely. We need to do auction and basically come up and say we want to put this infrastructure in the ground. The auction will give you a build or lose type of agreement just as you said before. If you don't build this network up front, we are going to take away your rights to build a network in that region, give it to number 2. And then make that happen within a very short time span.

If we don't have the wire connecting the grid to the parking lot, nobody will be able to plug. And so put these wires in by companies that are running very, very fast, much faster than government organizations would run, auction it off and then tell them. When you start to make profit, we are going to tax you.

The CHAIRMAN. Now again, tell us why the Israelis said that they wanted to do this, what is the reason?

Mr. AGASSI. Well, in Israel, it is pretty obvious, Israel is a transportation island surrounded by countries that have oil. Israel has no oil. Israel knows viscerally that getting off oil it is not a question of when but how fast can you do it.

So when you talk to the President of Israel, President Peres, his only question is do you think you can really do it, and is there anything else in the world that could be more important. Now, from their perspective, it is a topic that touches on geopolitical security, environment, budget. Israel pays $7 billion a year to import oil. So those $7 billion disappear off the country. They don't even come back and buy anything in Israel, it is just $7 billion that disappears.

In our country in the U.S. we send out $50 billion a month to buy oil, it comes back to buy us. So we sent President Bush to ask for more oil and the next month we sent Secretary Paulson to bring the money back and to buy some U.S. companies with it. So we are in kind of a situation today where we have to figure out in Israel they figured out they want to get off oil as quickly as possible. I think in the U.S., we have to figure out the same model.

The CHAIRMAN. We are in a situation, not quite like Israel, Israel has almost no oil and has to import it all.

In the United States we have 2 percent of the world's oil reserves, but we consume 25 percent of the world's oil on a daily basis.

Mr. AGASSI. Right.

The CHAIRMAN. That is not quite as bad as Israel, but it is pretty bad in terms of our long-term prospects. You can't ever find 25 percent of the world's oil on 2 percent of the world's oil reserves, that is just a mathematical and geological impossibility.

Now many people, including the White House are now saying let's drill, drill, drill our way to energy independence, but again it doesn't add up. You can never get up to that 25 percent of the oil

in the world in terms of the percentage that we need in order to say we are energy independent.

So what you are proposing here is something that we are either going to have to do sooner or we will wind up doing later anyway, because it is just a finite amount of resources that we have in America. And there is no geologist that says all of a sudden we will end up with 5 percent or 10 percent of the world's oil reserves. That is all we have and it is just a geological misfortune the same way Israel's is, but at the same time, both countries have a technological capacity.

Mr. AGASSI. That's right.

The CHAIRMAN. To be able to create this independence.

Mr. AGASSI. There is one more interesting point here, and that is if we know that it is inevitable that we are going to get off oil and get on to the electric car, we need to look at whether we want to be leaders or followers in this market. And if we follow, that means the entire supply chain, including the batteries, will probably not happen in the U.S.

Now all things remaining equal as they are right now, that supply chain will most likely migrate either to Europe where gasoline is priced at $9 a gallon, or to China and Japan where the expertise in building the batteries are right now. That is where most of these batteries are made right now.

And so if we wait and not stimulate this industry, we are actually going to find ourselves off addiction to oil from one country and on addiction to lithium ion batteries from a different country. I think we are in an interesting period where if we did the right things in the U.S. and stimulated this industry so the incentives drive the factories to Boston where A 123 is and other companies around this Nation, we may find ourselves off the addiction completely and not getting addicted to some other substance that we can't bring in from this country.

The CHAIRMAN. I could not agree with you more. You know the Bush administration will testify before us and they will say that we have the capacity to produce rockets that can be shot at 2:00 a.m. in the morning on a moment's notice because a Russian incoming missile is coming towards the United States, and going 10,000 miles an hour, and in 3 minutes, reach, hit and destroy the incoming Soviet missile in order to protect the United States of America. They say we can do that technologically.

Then if you turn to the very same people and say do you think we can invent a way that we increase the fuel economy standards of the vehicles that we drive? They say, oh, that is not rocket science, that is auto mechanics, we can't do that. That is almost too simple for them to try to figure out because they don't attach the same level of urgency to it. But the reality is that the constant increase in our addiction to oil undermines our national security and undermines our defense posture just as surely as the deployment of Soviet nuclear weapons. The problem is that we are sinking deeper and deeper into the hole.

Mr. Thormann, what do you think is a reasonable goal for Nissan in terms of the production of electric vehicles in the years ahead without divulging any proprietary information for your company?

Mr. THORMANN. Our intention is not to—this is not a PR gim-mick, this is real business, it is a real business proposition. We will satisfy the mandates that we have in California and a number of States to have a certain number of zero-emission vehicles in 2010. In 2012 we will mass market them, which means that we have to come with an object, a vehicle and a series of vehicles that will meet several different needs and different requirements and dif-ferent driving circumstances.

So the adoption, depending on the speed at which consumers adopt these vehicles, will depend on how many we can sell, but we are preparing to sell many thousands of them.

The CHAIRMAN. And Mr. Holm, let me ask you this, do you think that it is inevitable that the United States goes down this route and it is no longer a question of if, but when?

Mr. HOLM. I would certainly hope that the United States will fol-low this route and go electric.

You had a comment before where you have a reference back to what happened in the mobile industry here in the United States, and I would like to use that analogy a little further. Both the origi-nal NNT system, which was an analog system and DTSM system was born out of relatively small economies in Europe. And we built up the mobile industry significantly faster than it happened over here.

The difference between the mobile industry and what we talk about here is that the small countries in Europe cannot create a market that will make the auto makers change rapidly. We need big markets to pull this. And for that reason, I would certainly hope that the United States would jump on the bandwagon and start pulling.

The CHAIRMAN. And Mr. Homestead, you have heard all the tes-timony today from these technologists. Do you think we should jump on this bandwagon?

Mr. HOLMSTEAD. It certainly sounds fabulous, it has been inter-esting to be on the panel. I guess the only question I have sort of given everything we have heard is given the economic case for this, why do you need a government mandate? If you can do electric cars at roughly equivalent to a buck 50 a gallon and gasoline is now 4 bucks a gallon. As a regulatory policy guy, I say why do you need a more stringent CAFE standard?

The CHAIRMAN. I can tell you the answer.

Mr. HOLMSTEAD. Look at the mobile phone industry. I don't think that came about because of government mandates, it came about because of market demands.

The CHAIRMAN. No, no, no, not at all. Not at all. It came about because—amongst other things, I was completely frustrated with the fact that the two incumbent companies were moving so slowly, the price was so high, the technology was so clunky that we needed a new policy. The only way to do it is to allow the third, fourth, fifth and sixth companies, that is Mr. Thormann, Mr. Agassi, Mr. Holm, whomever, everyone who is not AT&T, everyone who is not the big company to come in and start to innovate. And once that innovation happened then you had the big change.

The same thing is true with narrow band versus broadband. If you have only got Verizon and Comcast and they are dividing the market in half, then they don't have any real incentive.

Mr. HOLMSTEAD. I still don't see how the mandate was involved.

The CHAIRMAN. Well, there was no mandate that you had to go——

Mr. HOLMSTEAD. You just had to let people——

The CHAIRMAN. It was basically that I kept having hearings where everyone would say digital is the key word. And the two cell companies would say, well, we are analog and we are not changing because it will be too expensive to change and it was. And it was at $0.50 a minute because they divided the markets in half all across America. But somehow or another, it lowered down to $0.08 or $0.09 a minute and they lost their entire market to the four digital companies, somehow or other they could then afford to move over to digital.

So the same thing is true and happened in broadband. Once we reshifted the market, which we did in the 1996 Telecom Act in order to have—what you have to create is a paranoia inducing Darwinian set of market conditions. Once that happens, you can get out of the way, the innovation will happen. But as long as the whole thing is controlled by a couple of companies, they are never going to change, because the inexorable investment of time and career are already made in the old idea is a very hard thing to dislodge.

So what you have to get are the new players on the field, and the only way that happens is if policymakers find a way to create the aperture whereby the smaller are out there and they are able to thrive. So without our help, that as policymakers, you are not going to see massive wind and solar electricity development across the country that really makes what Mr. Agassi and Mr. Thormann and Mr. Holm were talking about affordable, and something that is compatible with the global warming agenda as well that we have for our country.

A CEO of an existing company does have that responsibility. We accept that. I accept the fact that Exxon, I accept the fact that Chevron are the big auto manufacturers, that is not their job. It is our job to set the national plan. So to have a national plan to back out all the oil or cut the greenhouse gases by 80 percent, that is our job sitting here. We are the board of directors for America, so we have to set that plan. Then we say to the private sector go and do it. And here is the new playing field, and it is wide open to you, and it is going to have a lot of wind and solar and biomass, it will have a lot of electric/gas stations all across America that you are going to be able to switch batteries at and then whatever happens, happens. Otherwise we will just stay right where we are, and dig the hole deeper and deeper. We are in violation of the first law of holes, when you are in one stop digging. And every year we go another percent and a half deeper into this hole of imported oil dependence.

That is after 32 years on in Congress, that has been my experience if you want the technological change. If you want to move from the black rotary dial phone era that lasted 80 years, you have to break up AT&T because they will sell you a black rotary dial

phone. They had each of us renting it at $3 bucks a month. My mother paid $1,200 bucks for that black rotary dial phone. And she couldn't go down to another store to buy another phone that was white and only costs 90 bucks because it wouldn't go into the phone jack. Right? Well, what happened once you changed the laws, well, black rotary dial phone just went away in about 3 or 4 years. Everyone moved on to the new technologies, but it took the government to do it.

Mr. HOLMSTEAD. It is opening new markets. I still don't understand the role that a government mandate played with respect to mobile or broadband. I don't think Congress ever mandated those. It just allowed the competition to flourish to develop those technicians.

The CHAIRMAN. Right.

Mr. HOLMSTEAD. I just wanted to make sure.

The CHAIRMAN. But once we passed the 1996 Telecom Act, if you were still selling narrowband, then you weren't going to be a company anymore. We are not going to tell Nissan or General Motors or Ford or anyone else exactly what they have to do after this. But once we make it possible for this to happen, once we create a new policy, then I have every confidence it will happen. In fact, my own opinion is this is the last revolution, that we had the telecommunications revolution. We finally broke up AT&T and unleashed that revolution that was sitting there with young people and technologists all across America and across the planet.

This is the same kind of revolution that will be unleashed. We will create millions of jobs. We are going to revolutionize the prize of energy. The sources from which it comes. It is all out there ready to be unleashed, but we need to put the new policies on the books and then we just have to get out of the way. But the overarching goal has to be to say to OPEC we are looking at you in a rearview mirror. This is too unhealthy for our country to have aircraft carriers floating around over in the Middle East to protect the flow of oil coming into our country. It is a very unseemly for our country to be in that situation. So it is a national security context too. Maybe think of it that way.

I am going to give each one of you to a minute and a half to summarize what you want our committee to remember from your testimony as we are going forward trying to put together a national energy policy in our country. We will begin with you, Mr. Holmstead.

Mr. HOLMSTEAD. Well, I thank you again for allowing me to participate. And my thought is, and this conversation has been very interesting, is we need to make sure that there is an availability for all of these technologies to compete on a level playing field. I do think we need to do it in a way that was done before, which is to remove regulatory barriers to innovation as opposed to having additional government mandates.

The CHAIRMAN. Mr. Holm.

Mr. HOLM. I would simply reflect a little bit on the fact that what we have been talking about this afternoon is nothing about new inventions. It is about meeting together existing technologies a new way in order to achieve something big. I would certainly hope that your committee and the House and the Senate can find ways to support that.

The CHAIRMAN. So unlike President Kennedy who said we had to discover new alloys, new metals, new forms of propelling these missiles in outer space, here we don't have to invent anything, it is all there.

Mr. HOLM. The basics are all there.

The CHAIRMAN. It is all ready to go.

Mr. Agassi.

Mr. AGASSI. I think Mr. Holm was right, we took 8 years. Over the last 8 years, we found all the science that is required to go over to electric. I think now it is time to put it all together with the right policy. I think that we're here in Project Better Place, we are available to your committee, we stand ready to work with you and determine the right policies.

There has been a lot of talk about ending our addiction to oil. I think it is time to take a model like Better Place, scale it to the needs of the Nation, save our environment, work on our national security, retool Detroit, bring this as an opportunity not as an end of Detroit but actually as an opportunity to grow Detroit and bring more jobs back to America. And I think we can ensure this would be the project of our generation, the one that we will remember forever as the one that put America back on a leading track as technologists and the economy will be a force in the next century.

The CHAIRMAN. Thank you, Mr. Agassi.

Mr. Thormann.

Mr. THORMANN. Mr. Chairman, I would like to, first of all, thank you because representing a company that is 7 percent of the car market in the United States, I am very honored by the faith that you put in us and in our testimony today and I would like to thank you for the words that you spoke just a few minutes ago about creating conditions of success. We will do our part, and I commit to you that our company is very focused on this project and it is something that we will deliver for you.

The CHAIRMAN. I thank you, Mr. Thormann. And I agree with Mr. Agassi, this is a tremendous opportunity for the American automotive industry. There is going to be a huge transition that takes place over the next 10 years. My father always said it is better to start out where you are going to be forced to wind up anyway, it is a better place to be. We are heading there, it is inevitable. This happened in Denmark, it is happening in Israel and it is better for us to be the leaders.

By the way, I think the world wants us to be the leader, not the lagger. They want American technology, they want us to give that leadership. And hopefully, we can do this in a way that creates those additional millions of jobs here in America that are creating these products, exporting them around the planet rather than importing them and having the jobs be overseas. I think its our great challenge and I think our country will respond. I thank each of you for your excellent testimony today. This hearing is adjourned.

[Whereupon, at 4:08 p.m., the committee was adjourned.]

QUESTIONS FOR THE RECORD
FOR THE HONORABLE TYLER DUVALL
ACTING UNDER SECRETARY FOR POLICY
U.S. DEPARTMENT OF TRANPORTATION
JUNE 26, 2008 HEARING
SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING
U.S. HOUSE OF REPRESENTATIVES

QUESTION 1: How is fuel economy measured for compliance purposes? Isn't it based on the vehicle's CO_2 output?

RESPONSE: Fuel economy is measured in a laboratory by placing the test vehicle on a dynamometer and using a test procedure that is defined by statute. The amount of CO_2 emitted from the vehicle's tailpipe during the test procedure is measured and converted into miles per gallon for CAFE compliance.

QUESTION 2: Does NHTSA's proposed rule for model year 2011-2015 cars and light trucks take into account CO_2 emissions and global warming generally?

RESPONSE: NHTSA's proposal takes CO_2 emissions and global warming into account by placing a monetary value on CO_2 emissions, and conducting analyses under NEPA of the impacts on CO_2 emissions, climate and the physical environment and then considering the results in order to balance the statutory criteria to set standards. However, most of the monetary benefits of setting standards that both increase fuel economy and decrease CO_2 emissions are derived from the value of the saved fuel.

QUESTION 3: What are the resource implications of doing a CAFE rulemaking? Is this a resource-intensive activity for NHTSA? What goes into it?

RESPONSE: In 2008, NHTSA had a budget of $1.9 million for CAFE standards. An additional $3.3 million was reprogrammed from other NHTSA activities to fund the increased work load, for a total of $5.2 million. These funds will be used for a variety of required activities under EISA. These include conducting a study of medium duty and work truck CAFE standards, establishing a new consumer rating program and developing another consumer program to educate the public about fuel economy and eco-driving.

QUESTION 4: After putting these resources in, how do you feel about letting California write fuel economy rules that make the NHTSA process obsolete and irrelevant? Do you think NHTSA should continue to have to do these rulemakings if the federal government intends to let California go forward with its own program?

RESPONSE: Since fuel economy standards have a national impact, both with regard to the economy and to the environment, the responsible and prudent way to establish such standards and programs is to base them on a national assessment of benefits and costs. That is precisely the way in which we have established the CAFE standards.

Similarly, we have implemented the CAFE standards on a nationwide basis. The CAFE standards require each manufacturer to ensure that its nationwide mixes of cars and light trucks meet the levels of national average fuel economy specified in those standards. In contrast, each state that adopts the California standard controls only the average fuel economy of the mixes of cars and light trucks sold in that state. We note that this state-by-state balkanization of each manufacturer's nationwide fleet will make it more difficult for the manufacturers to meet consumer demand across the country and will drive up consumer costs.

QUESTION 5: I have seen in the Federal Register that NHTSA asked for comments regarding an Environmental Impact Statement. Are you preparing an EIS? What is the timeframe? Will it cover global warming effects and CO2 generation as part of the CAFE rulemaking process? What level of resources is being devoted to this effort?

RESPONSE: In its original decision in Center for Biological Diversity v. NHTSA, 508 F.3d 508 (9th Cir. 2007), the 9th Circuit ordered the preparation of an Environmental Impact Statement (EIS) in connection with the CAFE standards that the agency set in a 2006 final rule for model years 2008-2011. Subsequently, NHTSA published a draft EIS June 18, 2008 for the standards it proposed for model years 2011-2015, and held a public hearing August 4, 2008. Over 40 people presented their views at the hearing. The period for written comments ended August 18, 2008, with over 500 submitted comments.

On that same day, the Ninth Circuit issued an opinion vacating and withdrawing its original order for the agency to prepare an EIS (Center for Biological Diversity v. NHTSA, No. 06-71891, slip op. (9th Cir. filed Aug. 18, 2008), vacating, withdrawing and replacing 508 F.3d 508 (9th Cir. 2007)). The court concluded that the record for the 2006 final rule is insufficiently complete for it to order the immediate preparation of an EIS and remanded the case to NHTSA to prepare a revised EA or, as necessary, a complete EIS. In reaching this conclusion, the court noted: "In connection with EISA, NHTSA has already begun preparation of a complete EIS to inform the 'NEPA analysis relating to the CAFE standards for MY 2011-2015 automobiles,' including light trucks. … The information developed in preparation of the EISA-based EIS would undoubtedly inform NHTSA's decision as to the necessity of an EIS in this case."

The agency is continuing to prepare a final EIS.

The analysis for the draft EIS extensively discusses global warming and its effects. It includes modeling of climate impacts resulting from the reductions in CO2 that would be produced by the proposed CAFE standards and by a range of alternative standards. Seven full time agency staff are working on the EIS. In addition, a budget of $1.7 million is being spent on contract support.

QUESTION 6: Why did NHTSA recommend to Congress that we change to an attribute-based system instead of a flat number?

RESPONSE: An attribute-based standard (which varies according to the mix of vehicles sold by a manufacturer) has a number of advantages over a flat standard (which does not vary from manufacturer to manufacturer).

First, attribute-based standards increase energy savings. The energy-saving potential of flat standards is limited because only a few full-line manufacturers would be required to add fuel-saving technologies. Under attribute-based standards, which account for size differences in product mix, virtually all manufacturers are required to use additional fuel-saving technologies to achieve compliance.

Second, attribute-based standards reduce the potential for adverse safety consequences. A flat standard would create an incentive to comply by downsizing vehicles. Research at NHTSA has shown that this has negative safety implications. Attribute-based standards discourage downsizing of vehicles as a CAFE compliance strategy because, as vehicles become smaller, the fuel economy target for them becomes more stringent.

Third, attribute-based standards are more equitable for different vehicle manufacturers. Under flat standards, the cost burdens and compliance tasks would be placed almost exclusively on the full-line manufacturers. Attribute-based standards distribute these burdens and tasks more evenly.

Finally, attribute-based standards are more market-oriented because they more fully respond to changes in economic conditions and consumer preferences. Attribute-based standards do not force vehicle manufacturers to adjust their fleet mixes toward smaller vehicles. Instead, they allow the manufacturers to adjust the mix of their product offerings so that they can offer consumers the vehicles they want to buy.

QUESTION 7: What effects on domestic employment would you anticipate should California and other States be granted approval to pre-empt the Federal standard?

RESPONSE: California's flat standard approach favors manufacturers who produce predominantly small vehicles. Full line manufacturers such as Ford and GM would pay a disproportionate amount of the compliance costs under a flat standard. In addition, the aggressiveness of California's standard could have costs under a flat standard. The National Academy of Sciences (NAS) said in its 2002 report on CAFE that: "policies that reduce the number of vehicles manufactured in the U.S. or rapidly and significantly reduce the scale of an industry central to a regional economy could have at least temporary regional employment impacts." The NAS Committee further said that "if implemented too aggressively, any of the policies could greatly increase the cost of vehicles or their use and thus have the potential for harming employment."

QUESTION 8: What are the resource implications of doing a CAFE rulemaking? Is this a resource-intensive activity for NHTSA? What goes into it?

RESPONSE: In 2008, NHTSA had a budget of $1.9 million for CAFE standards. An additional $3.3 million was reprogrammed from other NHTSA activities to fund the

increased work load, for a total of $5.2 million. These funds will be used for a variety of required activities under EISA. These include conducting a study of medium duty and work truck CAFE standards, establishing a new consumer rating program and developing another consumer program to educate the public about fuel economy and eco-driving.

QUESTION 9: How is fuel economy measured for compliance purposes? Isn't it based on the vehicle's CO_2 output?

RESPONSE: Fuel economy is measured in a laboratory by placing the test vehicle on a dynamometer and using a test procedure that is defined by statute. The amount of CO_2 emitted from the vehicle's tailpipe during the test procedure is measured and converted into miles per gallon for CAFE compliance.

QUESTION 10: The Department has developed a rule that is "attribute based" or what some call a reformed CAFE standard. Is this a more productive way to set fuel efficiency standards than just setting a flat standard like some others have recommended?

RESPONSE: An attribute-based standard (which varies according to the mix of vehicles sold by a manufacturer) has a number of advantages over a flat standard (which does not vary from manufacturer to manufacturer).

First, attribute-based standards increase energy savings. The energy-saving potential of flat standards is limited because only a few full-line manufacturers are required to add fuel-saving technologies. Under attribute-based standards, which account for size differences in product mix, virtually all manufacturers are required to use additional fuel-saving technologies to achieve compliance.

Second, attribute-based standards reduce the chances of adverse safety consequences. A flat standard approach creates an incentive to comply by downsizing vehicles. Research at NHTSA has shown that this has negative safety implications. Attribute-based standards discourage downsizing of vehicles as a CAFE compliance strategy since as vehicles become smaller, the fuel economy target for them becomes higher.

Third, attribute-based standards are more equitable for different vehicle manufacturers. Under flat standards, the cost burdens and compliance tasks are placed nearly exclusively on the full-line manufacturers. Attribute-based standards distribute these burdens and tasks more evenly.

Finally, attribute-based standards are more market-oriented because they more fully respond to changes in economic conditions and consumer preferences. Attribute-based standards do not force vehicle manufacturers to adjust their fleet mixes toward smaller vehicles. Instead, they allow the manufacturers to adjust the mix of their product offerings so that they can offer consumers the vehicles they want to buy.

QUESTION 11: The CAFE law mandates that NHTSA set a fuel economy standard under an "attribute-based" system. How does this new method of regulating fuel economy ensure that my constituents can buy the vehicle they choose?

RESPONSE: Attribute-based standards are more market-oriented because they more fully respond to changes in economic conditions and consumer preferences. Attribute-based standards do not force vehicle manufacturers to adjust their fleet mixes toward smaller vehicles. Instead, they allow the manufacturers to adjust the mix of their product offerings in response to changes in economic conditions and consumer preferences and thus offer consumers the vehicles they want to buy.

QUESTION 12: Congress changed the way fuel economy is regulated, replacing the "flat" standard with an "attribute-based" standard. The attribute-based standard was originally adopted by the Bush Administration in its 2006 light truck rule. What are the safety benefits of the attribute-based system over the flat standard?

RESPONSE: Attribute-based standards are better for safety. A flat standard approach creates an incentive to comply by downsizing vehicles. All other things being equal, smaller, lighter cars get better fuel economy than larger, heavier cars. Therefore, producing smaller cars to "average out" larger cars was a method used to comply with flat CAFE standards. Research has shown that this has negative safety implications – smaller, lighter cars do not fare as well in crashes as larger, heavier cars. An attribute based approach greatly reduces this incentive – smaller vehicles must get higher fuel economy. Under the attribute-based approach, there is no compliance benefit for building smaller cars.

QUESTION 13: What are the overall proposed standards for MY 2011-2015? Are you well on the way to meeting the 2020 standards prescribed by EISA?

RESPONSE: The proposed standards are well on their way to meeting the prescribed goal. EISA defines a minimum CAFE requirement of 35.0 mpg by 2020. The proposed standards reach 31.6 mpg by 2015. This is an average annual growth rate of approximately 4.5 percent. The annual rate of growth for model years 2011-2020 required to achieve 35.0 mpg in 2020 is only 3.3 percent.

QUESTION 14: How did DOT decide how to set the levels of its proposed CAFE standards for 2011-2015?

RESPONSE: NHTSA assessed what fuel saving technologies would be available, how effective they are, and how quickly they could be introduced. This assessment considered technological feasibility, economic practicability and associated energy conservation. We also considered other standards to the extent captured by EPCA and environmental and safety concerns. This information was factored into a computer model used by NHTSA that set the standard by applying technologies to vehicles until it was no longer cost-effective to add more.

QUESTION 15: How does the fuel savings from this proposal compare to the fuel savings from past CAFE rules?

RESPONSE: Fuel savings from the 2005-2007 light truck rule are 3.6 billion gallons over the lifetime of the vehicles regulated in those years. Fuel savings from the 2008-2011 light truck rule are 7.8 billion gallons over the lifetime of the vehicles regulated in those years. Fuel savings from the proposed 2011-2015 rule are 54.7 billion gallons over the lifetime of the vehicles regulated in those years.

QUESTION 16: The CAFE law exempts auto manufacturers who produce 10,000 vehicles or less worldwide. Which automakers qualified for this exemption last year, and how many vehicles did they sell in this country?

RESPONSE: In 2006, NHTSA granted Spyker Cars' petition and established an alternative standard of 18.9 mpg for model years 2006 and 2007. Spyker Cars estimated that its production would be 77 vehicles in 2006 and 112 vehicles in 2007. In June 2008, NHTSA proposed to exemption Mosler Automotive and establish an alternative CAFE standard for it of 22.1 mpg for model years 2008 through 2010. In those three years, Mosler Automotive estimated that it will sell a total of 150 vehicles.

QUESTION 17: If a new automaker from China or India sought to sell their vehicles in this country, could they be exempted under CAFE because they are "new" or if they agree to limit their sales?

RESPONSE: Manufacturers, regardless of their location, can be exempted from CAFE standards only if they sell 10,000 vehicles or fewer worldwide. If a Chinese or Indian manufacturer sold these limited few vehicles worldwide, it could petition for an exemption. If a manufacturer produces large volumes outside the United States, it cannot qualify for an exemption from this agency by limiting its sales in the United States.

QUESTION 18: How many more highway-related deaths and injuries would there be in "CARB", and associated economic costs, if the California Air Resources Board's fuel economy/greenhouse gas regulations go into effect if the California waiver is granted?

RESPONSE: NHTSA has not evaluated whether there would be an increase in highway fatalities under the CARB proposal.

Answers to Follow-up Questions by
Shai Agassi
Founder & Chief Executive Officer
Project Better Place

United States House of Representatives

Select Committee on Energy Independence and Global Warming

Hearing on

"$4 Gasoline and Fuel Economy:
Auto Industry At a Crossroads"

1.   You say the US has the appropriate characteristics to
utilize your service. These characteristics are: density of
population, reliance on personal vehicles, and mature traffic
infrastructures. However, these characteristics describe only a
few areas of the country, such as the East Coast and coastal
California. Isn't your service more of a regional possibility
than a national one?

The Better Place model is a repeatable framework that can
not only be scaled to meet the needs of countries like the
United States, but it is the only way to end the United States'
dependence on oil from the Middle East in the next ten years as
proposed by Senator Barack Obama.

The areas most attractive for initial deployments have high
population densities and commuter traffic. Ideally they are
relative transportation "islands." In smaller states or

1

countries, Better Place can complete system deployment to support electric cars nation/statewide. For larger countries, Better Place will begin in the dense urban areas and expand from there. This deployment methodology is very similar to that employed by mobile operators.

All Better Place needs are two pluggable parking spots per car that conservatively cost $200 each. That's $400 per car. Then we need one battery exchange station, at $500,000, for each 5,000 cars. That's $100 per car. So $500 per car times 200 million cars in the U.S. is $100 billion to lay the infrastructure for the whole United States – equal to about two months worth of crude oil costs. 80% of that cost is installation, which makes it effectively a $80 billion job stimulus package – paid for by the private sector, although government guarantees would accelerate adoption. With the political will and support, this could be done within a single presidential term.

2. What time frame are you talking about for deploying a ubiquitous network of charging spots for car batteries?

The Better Place model is the only way to meet the goal, as articulated by Senator Barack Obama, to end the United States' dependence on oil from the Middle East in the next 10 years.

Israel has already started that journey. Better Place and Renault-Nissan plan to have hundreds of test cars, thousands of charge spots and several swap stations ready by late 2009. By the end of 2010, we will have pre-production cars in circulation, as well as more than 100,000 charge spots and dozens of swap stations in place. And by the end of 2011, electric cars will be in mass production with more than 500,000 charge spots and more than 100 swap stations. Truly, Israel will be well on its way to achieving its stated goal of oil independence by 2020.

In Denmark, Renault-Nissan's electric cars will be among the first to be on Danish roads by the middle of the next decade.

We have not yet entered the U.S. market. Therefore, we cannot make any predictions about a timeframe. However, we believe that with the support of our partners—car manufacturers, utility companies and investors—and government guarantees, we can set up a sustainable transportation solution in the United States within a single presidential term.

The Better Place model is the only way to free the U.S. from imported oil from the Middle East in the next ten years. With the political will and support, setting up the infrastructure could be done in less than a decade.

3.   You say in your testimony that $100 billion would be needed to build battery charging infrastructure. How would this money be raised?

As we are a for-profit company, the money will be raised in the form of equity and debt from private sources. However, government-sponsored loan guarantees or other mechanisms could lower the cost of capital and make it possible to deploy resources much more quickly toward our goal of replacing oil for surface transport.

In addition, governments, automakers, utility companies and individuals are recognizing the need to end oil and embrace the sustainable transportation of the electric car. Many of them have joined Better Place as partners in this cause. With their support, we will put the infrastructure in place that will free us from dependence on foreign oil.

80% of the cost for infrastructure is installation. This job stimulus package of $80 billion dollars is paid for by the private sector and will only need government guarantees to accelerate adoption.

4.   If the monthly contract for vehicle from Project Better Place is equal to what consumers are currently paying in

**monthly gas bills, what incentive is there to purchase your
service?**

The short answer to your question is, cars that are deeply
discounted or even effectively free. How is that possible?

It is important to understand that 30% of the cars drive
70% of the miles and therefore use 70% of the oil and produce
70% of the emissions. For that category of driver, signing a
long-term contract with us will bring a large rebate check on
day one — under some circumstances approaching the cost of the
car. That is certainly true for cabs, for example. Ask a cab
driver if they would still pay $80 a day for gas, and sign for 4
years, if they knew the cost wouldn't go up, that they could
drive unlimited miles — and if they would get a clean, very cool
new car for FREE. For the rest of the public, the other 70% of
drivers, many will adopt to escape the volatility of gas prices,
to drive a zero emissions car, or just for the experience.

**5.   You state, "The Better Place model happens to have
even greater appeal in a world of $4-per-gallon gas." Is this
model competitive if gas prices would fall?**

The operating cost of an electric car, including the
depreciation of the battery, is now about 6 cents per mile. The
average American, getting 25 miles per gallon and paying $4 per

gallon, is paying 16 cents per mile. Even at $3 per gallon, the average American would still be paying 12 cents per mile, twice as much as the operating costs of an electric car.

6.   Does Project Better Place have any immediate plans to enter the Chinese or Indian markets?

Better Place is in active negotiations with approximately 25 countries, many of the major automakers and local partners in each target market. Better Place is unable, however, to name those entities due to confidentiality agreements currently in place.

7.   Do you support nuclear power to generate electricity?

Better Place does not tell countries how to generate their electricity, however it purchases only carbon free electric. Nuclear is carbon free electric, and therefore we would purchase nuclear electricity, but we leave it to utility operators and policy makers to determine what the best long-term generation strategy is for their country.

8.   What incentives should the Federal government offer US automakers to manufacture electric cars?

The Better Place model can be implemented without immediate government support; however the rate of consumer adoption

depends on government policy. Government can put in place consumer friendly policies and incentives that reduce the price of the total cost of the electric car for early adopters.

In addition, putting in place the infrastructure will effectively generate a $80 billion job stimulus package paid for by the private sector. Combined with loan guarantees for the infrastructure, our model can contribute substantially to economic growth in the coming years.

We also think if the right strategy was pursued, the U.S. auto industry could successfully remake itself for the coming electric revolution. And if their efforts were aided by the Federal Government, there is every reason to believe they could return to their former greatness, and again play a central role in stimulating rapid economic expansion. However, incentives offered from Washington need to coincide with the right decisions made in Detroit. Thereby, rewarding innovation as well as research and development is as fundamental as acknowledging the political, economic and environmental benefit of carbon-free technologies.

9.   What incentives should the Federal government offer to battery manufactures to develop batteries in the US?

If our view of the world is right, the battery industry
will be one of the central economic drivers and it is certainly
worth an investment in the right type of incentives to keep some
of that manufacturing capacity at home. Key is not only the
support and reward of innovation and research and development,
but the recognition of environmentally friendly technologies and
their contribution to long-term, sustainable economic growth.

Answers to Follow-up Questions by

Torben V. Holm
Dong Energy A/S

United States House of Representatives

Select Committee on Energy Independence and Global Warming

Hearing on

"$4 Gasoline and Fuel Economy:
Auto Industry At a Crossroads"

1. You state in your testimony, "One key pillar of the
Better Place model is that all of the electrical power needed by
the car fleet could come from renewable resources." Yet you say
that nearly 20% of DONG energy production is from renewable
energy. What comprises the remaining 80% of DONG's power
production?

It is coming from Danish power plants fired with coal,
biomass (i.e. straw and wood-pills), oil and gas (with coal as
the dominant component) plus import of energy from abroad
produced by hydro-power in Norway and nuclear power in Sweden as
the biggest contributors.

2. You say Denmark's entire passenger fleet could run on
electricity produced by less than 750 windmills or 1,500 MW wind

capacity. However, the number of passenger cars in Denmark is around 2 million and the U.S. has several hundred million passenger cars. Is this a realistic model for the U.S.?

My statement was focused on the situation in Denmark only. My calculation is based on the wind power available in this part of the world. I have no insight neither into wind patterns in various parts of the U.S., nor into the ability to transport wind power produced in one part of the States to cars, roaming around in other parts of the U.S.

3. You say that nearly 20% of DONG energy production is from renewable energy. What comprises the remaining 80% of DONG's power production?

Please see answer to question 1

4. In your testimony, "We believe that consumers who migrate from gas to electric as can enjoy immediate savings of some 15-20% pr month." How did you calculate the cost savings?

I based my calculation on the assumption that electric cars and conventional cars of the same class will be sold by

manufacturers for the same price. Moreover, I assumed that the current tax-regime will remain in force.

Accordingly, electric cars are completely free from registration tax until 2012 and liable to a relatively modest tax of approximately US$4.000 from 2013 and onwards. That is to be compared with a registration tax of 105 percent on conventional cars for the first approximately US$14.000 and 180 percent on car prices in excess of that: Finally, I assumed that the price of a battery pack will be in the neighborhood of US$12-13.000.

5. Do you think the Better Place model could be used in the more rural areas of the world or is it more or urban areas?

On the one hand, the higher your driving need is the better of choice is the electric car. On the other hand, a certain density of cars is needed in order to make investments in battery change stations economically feasible. Commuters living in some distance from metropolitan areas, taxi-drivers, sales-people and others might thereby represent good, but very different markets to address.