Rising to the Challenge

Six Steps to Cut Global Warming Pollution in the United States

MontPIRG Education Fund

Summer 2006

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Tony Dutzik, Frontier Group
Emily Figdor, U.S. PIRG Education Fund

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Harriet Eckstein Graphic Design

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Executive Summary

Extensive scientific evidence demonstrates that global warming is real, that it is affecting us now, and that human activities—particularly the burning of fossil fuels—are the primary cause.

Science is also clear about what we need to do to address the problem: immediately and significantly reduce emissions of the pollutants that cause global warming. Avoiding the worst consequences of global warming will require the United States and other industrialized countries to stabilize emissions within the next decade and reduce them by about 80 percent by mid-century.

Achieving those reductions won't be easy, but it can be done. By improving the efficiency with which we use fossil fuels and increasing our use of clean, renewable energy, the United States can reduce its global warming emissions in the near future, while putting America on a path toward dramatically lower global warming emissions in the decades to come.

This report lists six challenging but feasible strategies that, if implemented, could achieve these reductions, while improving America's environment and our energy security.

Global warming is real, is happening now, and poses a serious threat to America's future.

- Global average temperatures increased by 1° F in the 20th century and are now increasing at a rate of about 0.36° F per decade. Sea levels are on the rise, ice and snow cover are decreasing, and hurricane intensity has increased.
- The consensus view of the scientific community is that most of the global warming that has occurred is due to human activities—particularly the burning of fossil fuels. Fossil fuel consumption releases carbon dioxide, which traps the sun's radiation near the earth's surface. Since 1750, the concentration of carbon dioxide in the atmosphere has increased by 35 percent—a rate of increase unprecedented in the last 20,000 years.
- Should the world continue on its present course, global warming emissions could triple in the next half century, with global temperatures increasing by 8° F by 2100. Sea levels would rise by one and a half feet (and

possibly more), threatening low-lying coastal areas. And the ecological balance upon which life depends would be irrevocably altered.

The United States has a responsibility to take leadership in reducing global warming pollution.

- The United States is far and away the world's largest global warming polluter, accounting for 23 percent of the world's carbon dioxide emissions.
- Should current trends continue, by 2030 the United States will emit 37 percent more carbon dioxide than it does today, increasing the likelihood of dramatic global climate change.
- To avoid the worst consequences of global warming, scientists believe that the United States needs to stabilize emissions within a decade, begin reducing them soon thereafter, and cut global warming pollution by 80 percent by the middle of this century.

The United States can achieve significant reductions in global warming pollution by improving the energy efficiency of our economy and using more renewable energy.

The United States can reduce its global warming emissions by as much as 19 percent by 2020 by taking a set of aggressive but achievable steps toward improved energy efficiency and increased use of renewable energy, within the context of mandatory limits on global warming pollution.

1) Stabilize vehicle travel.

Americans drive nearly twice as many miles per year as they did a quarter-century ago, leading to increased emissions of global warming pollutants. Americans are already cutting back on driving as a result of higher gasoline prices, but many Americans have few realistic alternatives to driving.

Through changes in public policy and development patterns, Americans can be given more transportation choices, thus reducing the growth in vehicle travel. Such changes include:

- o Encouraging the development of compact neighborhoods with a mix of land uses, where more tasks can be completed by foot, bike or transit.
- o Expanding the reach and improving the quality of transit service.
- o Supporting programs to encourage carpooling, vanpooling, telecommuting and other alternatives to single-passenger car travel.

2) Increase vehicle fuel economy standards to 40 miles per gallon and set fuel economy standards for large trucks.

The creation of federal fuel economy standards for cars during the 1970s succeeded in reducing gasoline consumption and oil imports, as well as global warming pollution. But the fuel economy of new vehicles is now lower than it was during most of the Reagan administration.

Several recent studies show that we could increase the fuel economy of new vehicles to 40 miles per gallon within the next decade using technologies that already exist or will be available soon. All types of vehicles—from SUVs to compacts—can be designed to be far more energy efficient. And most of the improvements in fuel economy can actually save money for consumers over the long term, especially with gasoline prices at nearly $3 per gallon. Similarly, major improvements in fuel economy are possible for heavy-duty trucks, which are currently exempt from fuel economy standards.

3) Replace 10 percent of vehicle fuel with biofuels or other clean alternatives.

Ethanol and biodiesel that are produced cleanly and sustainably have the potential to significantly reduce global warming emissions from transportation—especially if these biofuels are produced from plant wastes and cellulose. Other vehicle technologies—like “plug-in” hybrids, electric vehicles and fuel cell vehicles—have the potential to dramatically reduce global warming emissions in the future.

4) Reduce energy consumption in homes, business and industry by 10 percent from current levels.

Dramatic improvements in energy efficiency are possible in virtually every aspect of American life. Studies show that we could reduce our electricity consumption by as much as 20 percent at no net cost to the economy. For now, the U.S. can encourage weatherization of buildings, deployment of more efficient appliances and equipment, and efficiency improvements in industry. Soon, using new technologies such as those in zero-energy homes, we can transform the way we consume energy and achieve even larger improvements in efficiency.

5) Obtain 20 percent of our electricity from new renewable energy sources.

America has virtually limitless potential for the generation of power from natural forces. By ramping up our use of wind power, solar power, geothermal and biomass energy and other renewable forms of energy—and using much of that energy to replace power production at dirty, coal-fired power plants—the United States could dramatically reduce global warming emissions from electric power production.

6) Hold emissions from other sources to current levels.

The five strategies listed above would address the largest sources of energy use and global warming emissions in the United States But some other sources of global warming pollution—such as emissions from air travel and emissions of some non-carbon dioxide global warming gases—are projected to increase significantly in the years ahead. The United States must remain vigilant about stabilizing, and eventually reducing, global warming pollution from all sectors of the economy. Mandatory limits on global warming emissions would help to achieve that goal.

These six steps would enable the United States to reduce its global warming emissions by 19 percent below 2004 levels by 2020.

- Taking these six steps would reduce U.S. carbon dioxide emissions by about 23 percent and global warming emissions by about 19 percent by 2020. (See Table ES-1.)

Table ES-1. Global Warming Emission Impact of the Six Steps (million metric tons carbon dioxide equivalent)

Strategy	Savings $MMTCO_2E$
Stabilize Vehicle Travel	0*
40 MPG Fuel Economy and Heavy-Duty Truck Fuel Economy Standards	383
10% of Transportation Fuel from Renewables	61
10% Reduction in Energy Consumption	400
20% of Electricity from New Renewables	511
Total Savings	**1355**
2004 U.S. Global Warming Emissions	7122
Reduction Relative to 2004	**19%**

* Avoids increase in emissions resulting from projected increases in vehicle travel between now and 2020.

- In addition, taking these steps will reverse the trajectory of global warming emissions, putting the United States on a path to achieving the even greater reductions in global warming pollution that will be required in the decades to come.

The United States should adopt a series of public policies designed to quickly and significantly reduce emissions of global warming pollutants:

Cap global warming emissions. The United States should establish mandatory, science-based limits on carbon dioxide and other global warming pollutants that reduce emissions from today's levels within 10 years, by 15-20 percent by 2020, and by 80 percent by 2050.

Adopt complementary policies to reduce global warming emissions. The United States should adopt policies that would achieve the targets laid out in this report, including, but not limited to:

- Transportation policies designed to reduce growth in vehicle travel and promote alternatives to automobile travel.
- An increase in federal fuel economy standards for cars and light trucks.
- Creation of federal fuel economy standards for heavy trucks.
- A renewable fuel standard requiring a significant share of transportation fuel to come from renewables by 2020.
- Policy support for the development and introduction of plug-in hybrid, electric and fuel-cell vehicles.
- Stronger appliance efficiency standards, energy efficiency programs and other policies designed to improve energy efficiency.
- A federal renewable energy standard requiring a large and increasing share of the nation's electricity to come from renewable energy.

Encourage action at the state level. Federal action to reduce global warming pollution should promote innovative approaches at the state level and not impede individual states or groups of states from pursuing policies that go above and beyond the commitments made by the federal government.

Introduction

Global warming is the most profound environmental threat of our time. From thinning ice sheets to changes in ocean currents and from rising global temperatures to more severe storms, global warming is already affecting our environment, our economy, and our lives.

Human activities are the dominant cause of global warming. Over the past three centuries—and especially in the last 100 years—the concentrations of pollutants known to warm the climate have been increasing in the atmosphere. These increases in pollution cannot be explained by natural variables, but only by human activity.

Scientists tell us that if we continue on a "business-as-usual" path, releasing more global warming pollution every year, the consequences for human beings and the planet will be dire. Scientists don't yet have the tools to tell us with certainty which areas of the planet will be most dramatically affected, but the overall picture is clear: unrestrained global warming will severely disrupt the environment and the ecosystems on which all life depends.

But there is good news in the climate science, too. The evidence suggests that if we begin to reduce emissions of global warming pollutants immediately and significantly, we still have time to avoid the most catastrophic impacts of global warming.

The United States has an indispensable role to play in reducing global warming emissions. The United States is by far the world's largest consumer of fossil fuels and emitter of global warming pollution, and thus must make a firm commitment to curbing emissions—and carry through on that commitment—in order for the world to achieve the emission reductions needed to safeguard the climate.

The road will not be easy. Climate scientists estimate that the world will need to reduce emissions of global warming pollution by more than half below current levels by mid-century if we want to avoid the worst consequences of global warming. But the technology exists to begin making that transition now.

About This Report

This report documents one pathway by which the United States could significantly reduce its emissions of global warming pollutants in the near future. We list six strategies that, combined, could reduce U.S. global warming emissions by approximately

19 percent by 2020—a significant down payment on the larger reductions we and the rest of the world will need to achieve in order to safeguard the earth's climate.

The six strategies presented here are ambitious. Some are unprecedented in their scope or the speed with which they must be implemented. Implementing these strategies will require new policy approaches, large capital investments, and determined effort by individuals, corporations and government.

But the potential payback for those efforts is tremendous—both in avoided economic and environmental impacts from global warming and in the establishment of a more secure energy future for the United States. By investing now in dramatic improvements in energy efficiency and the development of clean, renewable energy, the United States can begin to meet its obligation to address global warming while reducing our dependence on scarce fossil fuels and, in many cases, creating jobs and saving money. The result would be a cleaner, more sustainable foundation on which to build America's economy for the 21st century.

To protect our children and future generations, the United States must transition to an energy economy that releases far less global warming pollution. The six steps laid out in this document are not the only possible path to that goal. But they show that the United States can address global warming in ways that not only benefit the climate, but benefit our economy and security as well.

Global Warming: The Need for Immediate Action

Global Warming Is Happening

The first signs of global warming are beginning to appear across the United States and throughout the world. Global temperatures and sea levels are on the rise. Other changes, such as the recent increase in the severity of hurricanes, are consistent with the kinds of changes scientists expect to occur on a warming planet and are harbingers of the dramatic climate shifts that await us if global warming pollution continues unabated.

Rising Global Temperatures

Global average temperatures increased during the 20th century by about 1° F. While this increase may not seem extreme, it is unprecedented in the context of the last 1,000 years of world history.[1] Figure 1 (next page) shows temperature trends in the Northern Hemisphere for the past 1,000 years with a relatively recent upward spike. Temperatures in the past 150 years have been measured; earlier temperatures are derived from proxy measures such as tree rings, corals, and ice cores. A recent National Academy of Sciences report found that it is highly likely that the last few decades of the 20th century were the warmest in at least the last 400 years.[2]

Global warming appears to have intensified in recent years. In 2006, scientists at the National Aeronautics and Space Administration (NASA) reported that, since 1975, temperatures have been increasing at a rate of about 0.36° F per decade.[4] And 2005 was the hottest year on record worldwide.[5] Nineteen of the 20 hottest years ever recorded have occurred since 1983 and nine of the 10 hottest years have occurred since 1995.[6]

This warming trend cannot be explained by natural variables—such as solar cycles or volcanic eruptions—but it does correspond to models of climate change based on human influence.[7]

Melting Ice

The rise in global temperatures has resulted in thinning ice and decreasing snow cover. Over the last three decades, the volume and extent of ice cover in the Arctic has been declining rapidly, leading to the possibility that the Arctic could be ice-free during the summer by the end of this century.[8] Mountain glaciers around the world have been retreating, and since the late 1960s, Northern Hemisphere snow cover has decreased by 10 percent.[9] Mountain snowpack—which is a particularly important source of water in much of the parched western United States—has declined, with snowpack in the Colorado River basin below average in 11 of the last 16 years.[10]

It appears that, in some parts of the world, the decrease in ice and snow cover is accelerating. One recent study, for example, found that Greenland's glaciers are shedding twice as much ice into the ocean as they did just five years ago.[11]

Rising Sea Levels

Oceans have risen with the melting of glacial ice and the expansion of the ocean as it warms. Average sea levels have risen 0.1 to 0.2 meters in the past century.[12] Sea level rise has already helped cause the inundation of some coastal land. In Chesapeake Bay, 13 islands have disappeared entirely since the beginning of European settlement four centuries ago. Sea level in the Bay has increased by about 12 inches in the last century, with scientists estimating that global warming accounts for 2 to 6 inches of the increase.[13] Louisiana loses approximately 24 square miles of wetlands each year, increasing the destructive potential of hurricanes like Hurricane Katrina.[14] While development and land subsidence contribute to the loss of coastal land in these areas, rising sea levels also have an impact, and threaten even greater changes in coastal areas in the decades to come.

More Severe Storms

Storms throughout the middle and high latitudes of the Northern Hemisphere have been getting more intense. The increase in the frequency of heavy precipitation events arises from a number of causes, including changes in atmospheric moisture, thunderstorm activity and large-scale storm activity.[15]

In addition, hurricanes have become more powerful and more destructive over the last three decades, a phenomenon that some researchers link to increasing global temperatures.[16] The number of Category 4 and Category 5 hurricanes globally has nearly doubled worldwide over the last 35

Fig. 1. Northern Hemisphere Temperature Trends[3]

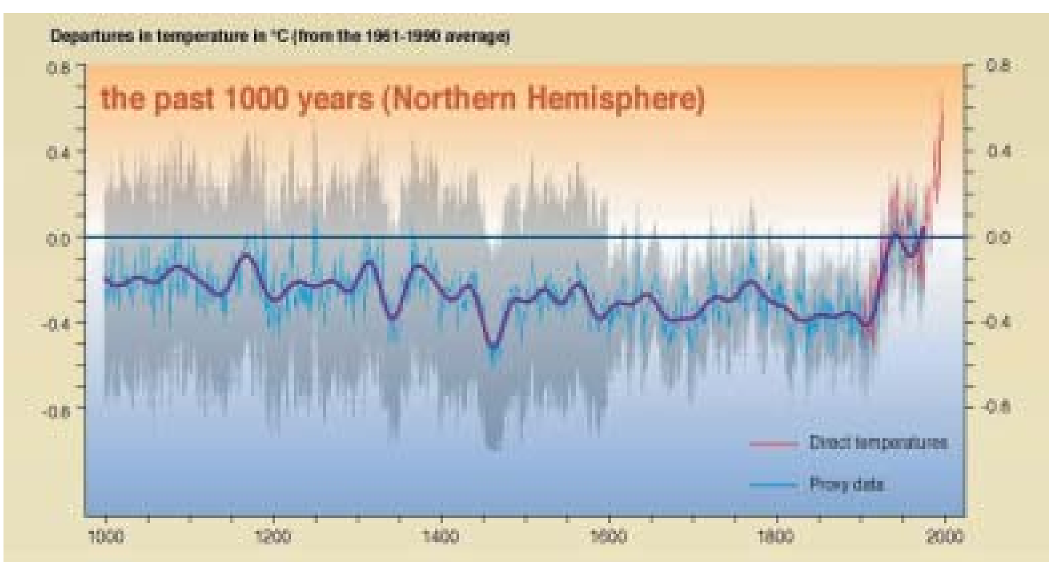
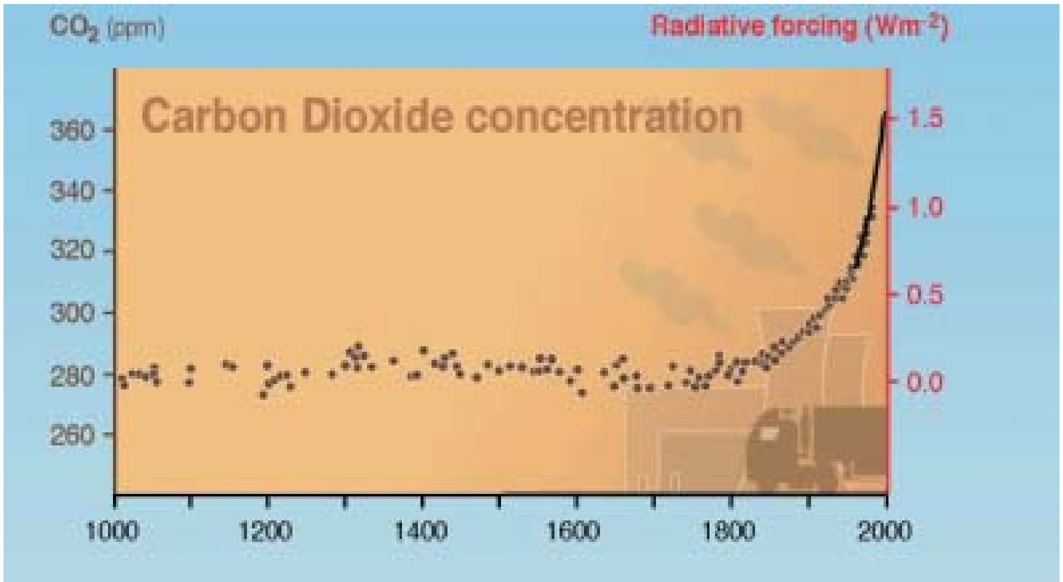


Fig. 2. Atmospheric Concentration of Carbon Dioxide[23]



years.[17] And the Atlantic hurricane season of 2005 was the worst ever recorded with the most named storms (28), the most hurricanes (15), the most Category 5 hurricanes (4), the most major hurricanes to hit the United States (4), the costliest hurricane (Katrina, which caused more than $80 billion in damage), and three of the six strongest hurricanes recorded (Wilma, the strongest ever, plus Katrina and Rita).[18] Recent research suggests that higher sea surface temperatures caused by global warming had a large role to play in triggering the destructive 2005 hurricane season.[19]

Human Activities Are Causing Global Warming

The changes described above are consistent with the kinds of widespread climatic shifts scientists believe will occur as a result of global warming. They are also signs that human activities have already begun to affect the climate through the release of pollutants (known as greenhouse gases or global warming pollutants) that exacerbate the earth's natural greenhouse effect.

In 2001, the Intergovernmental Panel on Climate Change, the global body charged with assessing the scientific record on global warming, concluded that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations."[20]

The Greenhouse Effect

Global warming is caused by human exacerbation of the greenhouse effect. The greenhouse effect is a natural phenomenon in which gases in the earth's atmosphere, including water vapor and carbon dioxide, trap radiation from the sun near the planet's surface. The greenhouse effect is necessary for the survival of life; without it, temperatures on earth would be too cold for humans and other life forms to survive.

But human activities, particularly over the last century, have altered the composition of the atmosphere in ways that intensify the greenhouse effect.

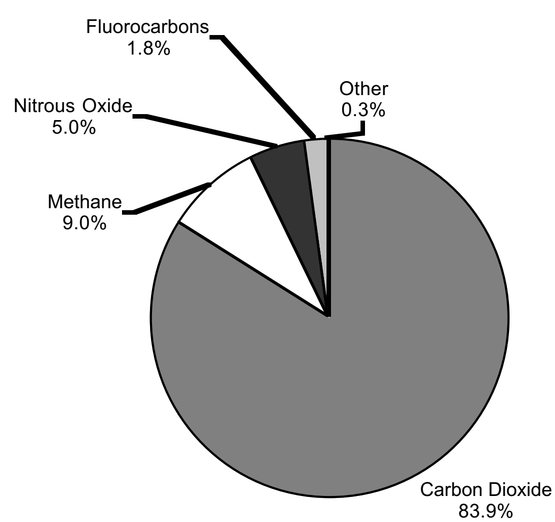
Since 1750, for example, the concentration of carbon dioxide (the leading global warming pollutant) in the atmosphere has increased by 35 percent as a result of human

Global Warming Pollutants

Human activities result in the release of many pollutants that are capable of altering the global climate. The main pollutants that contribute to global warming are the following:

- **Carbon dioxide** – Carbon dioxide is released mainly through the combustion of fossil fuels. Carbon dioxide emissions are the leading contributor to global warming and the leading global warming pollutant released in the United States. In 2004, carbon dioxide emissions represented approximately 84 percent of America's annual contribution to global warming.[24]
- **Methane** – Methane gas escapes from garbage landfills, is released during the extraction of fossil fuels, and is emitted by livestock and some agricultural practices. Methane represents about 9 percent of U.S. global warming emissions.
- **Nitrous Oxide** – Nitrous oxide is released in automobile exhaust, through the use of nitrogen fertilizers, and from human and animal waste, and is responsible for about 5 percent of America's contribution to global warming.
- **Fluorocarbons** – Used in refrigeration and other products, many fluorocarbons are capable of inducing strong heat-trapping effects when they are released into the atmosphere. However, because they are generally emitted in small quantities, fluorocarbons are responsible for only about 2 percent of America's contribution to global warming.
- **Sulfur Hexafluoride** – Sulfur hexafluoride is mainly used as an insulator for electrical transmission and distribution equipment. It is an extremely powerful global warming gas, with more than 20,000 times the heat-trapping potential of carbon dioxide. However, it is released in very small quantities and is responsible for only a very small portion of the nation's global warming emissions.
- **Black Carbon** – Black carbon is a product of the burning of fossil fuels, particularly coal and diesel fuel. Recent research has suggested that, because black carbon absorbs sunlight, it may be a major contributor to global warming, perhaps second in importance only to carbon dioxide. Research is continuing on the degree to which black carbon emissions contribute to global warming and it is difficult to judge exactly how large of a role black carbon emissions might play in causing global warming.[25]

Fig. 3. U.S. Global Warming Emissions by Pollutant (carbon dioxide equivalent)[26]



activity.[21] The current rate of increase in carbon dioxide concentration is unprecedented in the last 20,000 years.[22] Concentrations of other global warming pollutants have increased as well. (See Fig. 2.)

Global Warming Emissions Are Rising

The United States produces more global warming pollution than any other nation in the world. U.S. emissions of carbon dioxide—the leading global warming pollutant—have increased by more than one-third since 1983 and are projected to increase dramatically in the years to come.[27] Such an increase in emissions, were it to occur, would make it impossible for the world to achieve the emission reductions needed to prevent the worst repercussions of global warming, since carbon dioxide and other global warming pollutants can stay in the atmosphere for a century or longer.

The United States was responsible for nearly one-quarter of the world's carbon dioxide emissions in 2003. (See Fig. 4.) On a per-capita basis, the United States emits twice as much carbon dioxide as Great Britain or Japan, nearly three times as much as France, seven times as much as China, and 20 times as much as India.[28]

Since World War II, U.S. carbon dioxide emissions from energy use have increased at a rate of just under 2 percent per year.[30] (See Fig. 5.) The U.S. Energy Information

Fig. 4. Carbon Dioxide Emissions by Country, 2003[29]

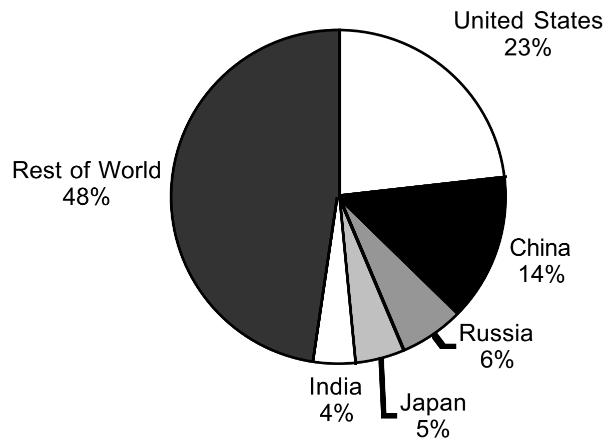


Fig. 5. Historic and Projected Emissions of Carbon Dioxide, United States[32]

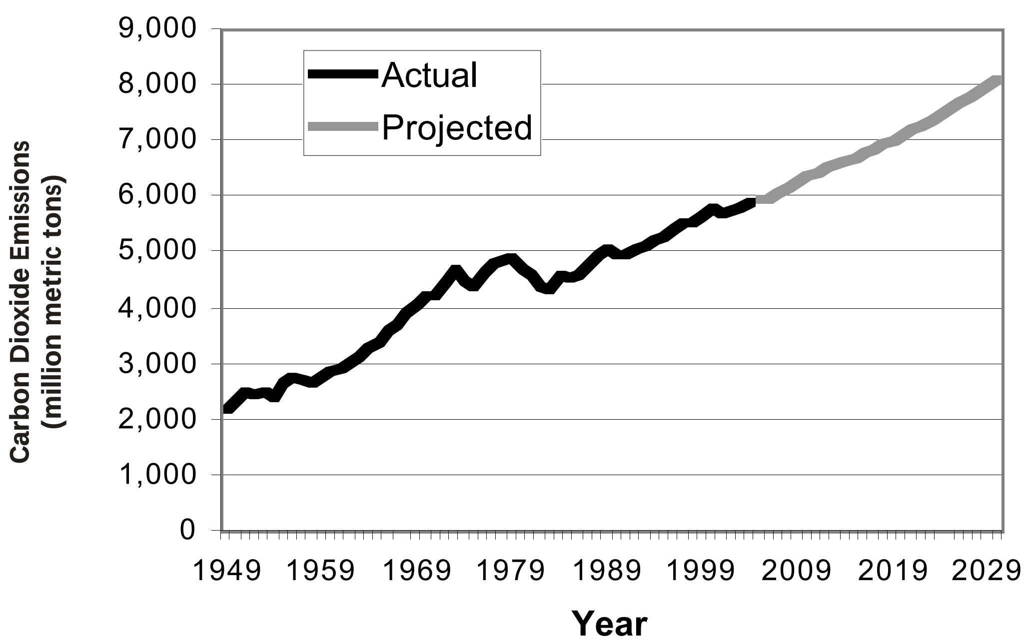
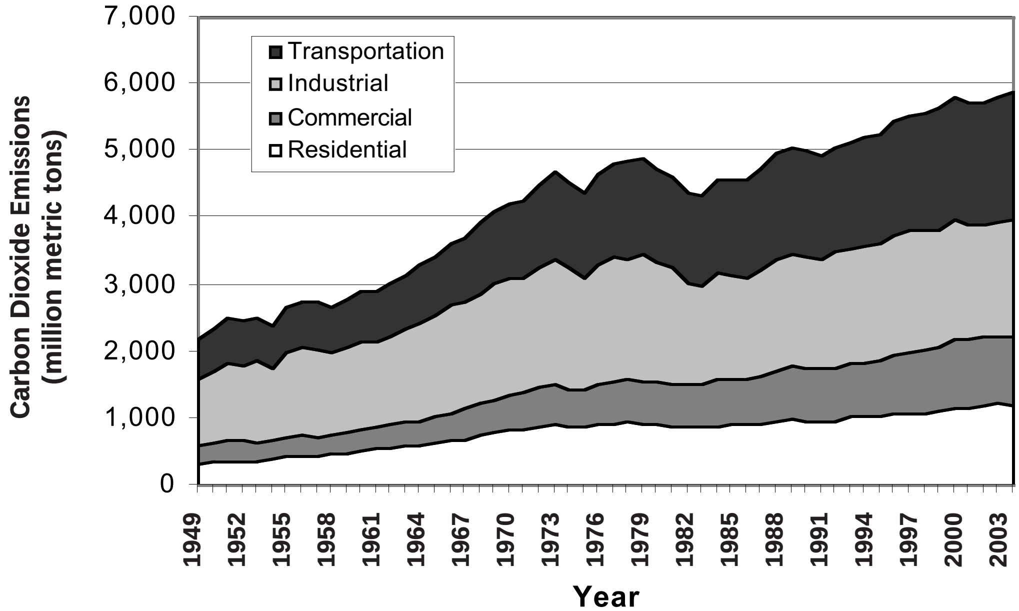
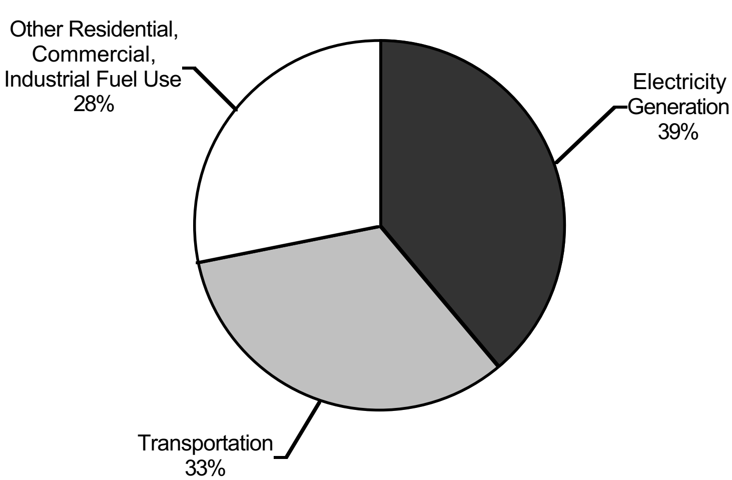


Fig. 6. U.S. Carbon Dioxide Emissions by End-Use Sector[33]



Administration (EIA) projects that U.S. emissions will continue to rise by an average of 1.2 percent per year between now and 2030.[31] Should this occur, in 2030 the United States will release 37 percent more carbon dioxide than it does today.

Fig. 7. Sources of Energy-Related Carbon Dioxide Emissions in the United States[35]



Americans use fossil fuels to heat and light our homes, to power computers and industrial machinery, and to fuel our cars and trucks, among other things. Transportation energy use is the biggest source of carbon dioxide in America, but this hasn't always been the case. In 1950, for example, transportation accounted for only slightly more than a quarter of U.S. carbon dioxide emissions; today it accounts for nearly one-third. (See Fig. 6.)

Figure 6 assigns carbon dioxide emissions from electricity production to the various economic sectors that consume that electricity. However, electricity generation is a major contributor to global warming in its own right. Nearly 39 percent of the United States' carbon dioxide emissions come from electric power plants, with the rest resulting from the direct consumption of fossil fuels in homes, businesses, industry and vehicles.[34] (See Fig. 7.)

The large volume of global warming emissions from electricity generation is mainly the result of America's reliance on carbon-intensive coal for electricity. Coal-fired power plants produce about half of

America's electricity, but they produce about 82 percent of the global warming pollution resulting from electricity generation.[36]

Global Warming Will Have a Severe Impact—Unless We Begin to Act Now

Climate scientists warn that the world faces dire environmental consequences unless we find a way to quickly and rapidly reduce our emissions of global warming pollutants.

Many scientists and policy-makers (such as the European Union) recognize a 2° Celsius (3.6° Fahrenheit) increase in global average temperatures over pre-industrial levels as a rough limit beyond which large-scale, dangerous impacts of global warming would become unavoidable.[37] Even below 2° C, significant impacts from global warming are likely, such as damage to many ecosystems, decreases in crop yields, sea level rise, and the widespread loss of coral reefs.[38]

Beyond 2° C, however, the impacts of global warming become much more severe, including some or all of the following impacts:

- Eventual loss of the Greenland ice sheet, triggering a sea-level rise of 7 meters over the next millennium (and possibly much faster)[39];
- A further increase in the intensity of hurricanes;
- Loss of 97 percent of the world's coral reefs;
- Displacement of tens of millions of people due to sea level rise;
- Total loss of Arctic summer sea ice;
- Expansion of insect-borne disease;
- Greater risk of positive feedback effects—such as the release of methane stored in permafrost—that could lead to even greater warming in the future.[40]

At temperature increases of 3 to 4° C, far more dramatic shifts would take place, including all of the above changes, plus:

- Increased potential for shutdown of the thermohaline circulation, which carries warmth from the tropics to Europe;
- Increased potential for melting of the West Antarctic ice sheet, triggering an additional 5 to 6 meter rise in sea level;
- Major crop failures in many parts of the world;
- Extreme disruptions to ecosystems. [41]

In addition, the more global temperatures rise, the greater the risks of abrupt climate change increase. The historical climate record includes many instances in which the world's climate shifted dramatically in the course of decades, even years—with local temperature changes of 10° C or more within 10 years.[42]

Should the world continue on its current course, with fossil fuel consumption continuing to rise, temperature increases of well above 2° C are likely to occur. The Intergovernmental Panel on Climate Change, in its 2001 Third Assessment Report, laid out a scenario in which population, economic output and fossil fuel consumption continue to grow dramatically. Under that scenario, the concentration of carbon dioxide in the atmosphere in 2100 would be nearly three-and-a-half times its preindustrial level, global average temperatures by the end of the century would be 4.5° C higher than in 1990, and temperatures would continue to rise for generations to come.[43]

On the other hand, if the world acts quickly and aggressively to reduce global warming emissions, there is a much greater chance of staving off the worst impacts of global warming. To have a reasonable chance of keeping global temperatures from rising by more than 2° C, the atmospheric concentration of carbon dioxide must be held below 450 parts per million (ppm)—about 60 percent higher than pre-industrial levels and about 18 percent higher than today.[44] Holding concentrations below 400 ppm would be even more effective.

To stabilize carbon dioxide levels at 450 ppm, however, the world will need to halt the growth of global warming pollution in this decade, begin reducing emissions soon, and slash emissions by more than half by 2050.[45] Greater reductions would be required to limit carbon dioxide levels to 400 ppm. Because the United States is the world's largest global warming polluter, the degree of emission reductions required here will be greater.

The good news is that there are many technologies and practices that could be put into place *today* that would lead to significant reductions in global warming pollution. The six steps detailed here are not easy, nor are they the only available paths to reducing global warming emissions. But they demonstrate the feasibility of achieving significant reductions in global warming pollution in the United States within the foreseeable future, while at the same time resulting in other far-reaching, positive changes.

Six Steps to Reduce Global Warming Emissions

Achieving major reductions in global warming pollution in the United States will be challenging, but it can be done. Many of those reductions can be achieved by improving energy efficiency and expanding the amount of energy we derive from clean, renewable sources—measures that aren't just good for the climate, but are good for our economy and national security as well.

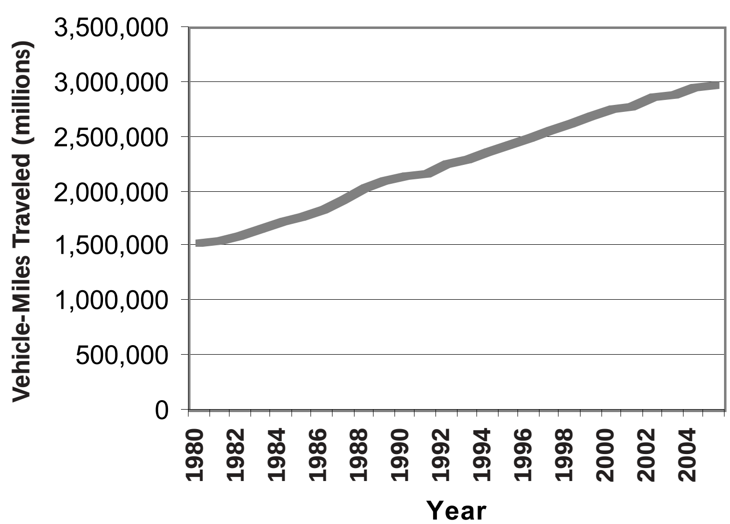
The six steps detailed in this section can, if implemented immediately, reduce America's emissions of carbon dioxide, the leading global warming pollutant, by about 19 percent by 2020. Such a reduction would be a significant step toward the long-term emission reductions the nation and the world must achieve to prevent the worst impacts of global warming.

Step 1: Stop growth in vehicle travel

Americans spend more and more time in their cars each year. Since 1980, the number of miles driven on America's roads has nearly doubled, to just shy of 3 trillion miles in 2004.[46] (See Fig. 8.) Combined with the stagnating fuel economy of vehicles, the dramatic rise in vehicle-miles traveled (VMT) is largely responsible for the rapid increase in global warming emissions from cars and light trucks in the United States.

Vehicle travel has accelerated at a far faster pace than population growth. In

Fig. 8. Vehicle-Miles Traveled in the United States[47]



1980, the number of vehicle-miles traveled per capita was just over 6,700 per year.[48] In 2004, for the first time, per-capita VMT surpassed the 10,000 mile per year mark.[49]

Why are Americans driving so much more today than they did 25 years ago? The reasons are complex and interrelated, but include:

- Sprawling development patterns, which have resulted in housing and jobs being pushed away from center cities and into distant suburbs and exurbs that are accessible only by car.
- Demographic shifts, including an increase in the number of dual-worker households and the movement of the "baby boomers" through the prime driving-age 25 to 54-year-old age bracket.[50]
- Massive public investment in highways, coupled with insufficient investment in public transit, rail travel, bicycling and pedestrian infrastructure and other transportation alternatives. In 2004, capital expenditures for highways totaled $70 billion across all levels of government, compared with $9.3 billion for transit infrastructure.[51]
- Relatively inexpensive gasoline in the 1990s. In inflation-adjusted terms, gasoline prices in the late 1990s (1994 to 1999) were the lowest of any five-year period since at least 1948.[52]

The United States will not succeed in significantly reducing its emissions of global warming pollutants without curtailing the growth of vehicle travel. Petroleum use in the transportation sector accounts for one-third of U.S. carbon dioxide emissions, with light-duty vehicles (such as cars, SUVs, minivans and pickups) consuming more than 60 percent of the petroleum used in the transportation sector.[53] The U.S. Energy Information Administration (EIA) projects that gasoline consumption in light-duty vehicles will increase by 23 percent between 2005 and 2020.[54] Eliminating future VMT growth will avoid this increase in energy consumption and the coincident increase in global warming pollution.

The first step in reducing growth in vehicle travel is to expand the availability of alternatives—high-quality transit service, car- and vanpooling, telecommuting, and bicycle and pedestrian facilities. Encouraging new patterns of land use that rely less on the automobile is also important. While even these changes will leave many Americans dependent on cars, expanding the availability of alternatives will give more people the option to leave their automobiles at home more often, thus reducing demand for petroleum and emissions of global warming pollutants.

Can it Be Done?

Given the rapid rise in vehicle travel over the past few decades, stabilizing the number of miles driven in cars and trucks would appear to be a challenging task. But recent evidence suggests that many Americans are already cutting back on driving as a result of higher gasoline prices. And a large body of research suggests that making reasonable changes in our transportation system and the way we build our communities can lead to significant decreases in driving.

Higher gasoline prices have already led many Americans to cut down on driving where they can and to use alternatives where they are available. In 2005, vehicle-miles traveled increased by approximately 0.1 percent, the slowest rate of increase since 1980.[55] Only the fast-growing south-central and western regions of the country experienced increases in vehicle travel during 2005. Over the first four months of 2006, vehicle-miles traveled increased by about 0.9 percent versus a year ago—higher than the annual rate for 2005, but still lower than the annual rate of increase for any other year in the last two decades.[56] In addition, a May 2006 poll found that nearly two-thirds of Americans claimed to be cutting back on driving as a result of high gasoline prices.[57]

While the slow growth in vehicle travel in 2005 was driven in part by higher gasoline prices, it is part of a longer-term trend toward slower travel growth. Since 2000, vehicle miles traveled have increased at an annual rate of 1.6 percent, compared to 2.5 percent during the 1990s.[58]

As the growth in vehicle travel has been moderating, transit ridership has been increasing. Ridership on public transit increased nationwide in 2005, with the number of light-rail trips up nearly 6 percent and commuter rail trips up nearly 3 percent.[59] Between 1995 and 2003, the number of transit trips increased by 22 percent—a faster rate of growth than vehicle-miles traveled.[60]

Anecdotal evidence suggests that the use of other transportation alternatives has increased as well. Bicycle sales in 2005 were strong, and many transit agencies reported strong interest in carpool and vanpool programs.[61]

Achieving zero growth in vehicle travel, however, remains difficult. Many Americans do not have convenient alternatives to driving. Trips for work, shopping, school or recreation may be too long to carry out on foot or by bike. Public transportation service is often inconvenient, unreliable, expensive or altogether unavailable. Expanding access to these transportation choices can give Americans more ways to both save money at the pump and to reduce the nation's emissions of global warming pollution.

Numerous studies have shown that expanding access to transit, encouraging compact, vibrant communities with a mix of land uses, and promoting transportation alternatives—among other measures—can significantly reduce VMT growth.

- Residents of cities with robust rail transit networks drive 12 percent less each year on average than residents of cities with smaller rail networks and 20 percent less than residents of cities with bus transit only.[62]
- Residents of higher density urban areas make approximately 25 percent fewer automobile trips than the national average. Further, residents of higher density suburbs make about 25 percent fewer trips than residents of lower density, auto-dependent suburbs.[63]
- Residents of areas with a mix of land uses (for example, homes, shops and offices) and good transit service tend to walk, bike and use transit more than residents of areas with good transit service alone. Per-capita VMT in mixed use neighborhoods with good transit is about 26 percent less than per-capita VMT in single-use neighborhoods with good transit.[64]
- Individuals who telecommute (work from home) travel 53 to 77 percent fewer miles on telecommuting days than on non-telecommuting days.[65]
- Efforts by employers to promote the use of transportation alternatives by their employees can get results. Washington State's landmark commute-trip reduction program removes about 20,000 vehicles from roadways every morning, reducing congestion, oil consumption and pollution.[66]
- Even such simple measures as improving sidewalks, storefronts and other pedestrian amenities can lead to significant reductions in vehicle travel.[67]

Expanding transit networks and creating communities that allow for a variety of transportation options is a long-term project requiring substantial financial investment and committed work on the part of individuals, communities and government at all levels. But there are signs of progress—from the thriving new light-rail networks in cities such as Salt Lake City and Dallas to new compact, transit-centered developments in cities across the country. And there is much that can be done quickly to promote alternatives such as carpooling, vanpooling, telecommuting, walking and biking, without major new capital investments.

Many Americans are looking for convenient and affordable alternatives to higher gas prices and frustrating commutes. By investing in a range of transportation options and designing our communities so as to reduce automobile dependence, we can halt the growth of vehicle travel—thereby curbing global warming pollution, reducing our growing dependence on oil, and creating clean and efficient new ways of getting from place to place.

Step 2: Increase fuel economy standards to 40 MPG and create fuel economy standards for heavy-duty trucks

Establishing minimum fuel economy standards for automobiles in 1975 was one of the most effective steps ever taken to reduce oil consumption in the United States. Between 1975 and 1987, the average fuel economy of new cars and light trucks increased by nearly 70 percent—from 13.1 miles per gallon (MPG) to 22.1 MPG.[68] By 1978, gasoline consumption began to fall. Oil imports fell, too. Not until 1993 would the United States again use as much gasoline as it did in the late 1970s.[69]

Over the last two decades, however, the fuel economy of America's vehicle fleet has not only stalled, but has actually declined. In 2004, new cars and light trucks achieved only 20.8 MPG on average, a lower fuel economy average than the new vehicle fleet achieved in 1982.[70]

The amount of global warming pollution released from cars and light trucks depends on three factors: 1) the type of fuel used, 2) the number of miles driven, and 3) the efficiency of the vehicle in making use of fuel. The recent decline in fuel economy, therefore, has helped lead to a significant increase in global warming pollution from transportation.

Setting a 40 MPG fuel economy standard for both cars and light trucks would lead to a significant reduction in global warming pollution. By phasing in such a standard beginning in 2009 and ending in 2018 (along with stabilizing vehicle travel), the United States could reduce fuel consumption for cars and light trucks by about 20 percent by 2020, reducing carbon dioxide emissions by about 307 million metric tons—representing about a 5 percent reduction in total U.S. carbon dioxide emissions compared to 2004 levels.[71] Even greater reductions would occur after 2020 as older, less-efficient vehicles are retired from the vehicle fleet.

Significant reductions in global warming emissions are also possible from heavy-duty trucks, which are currently exempt from vehicle fuel economy standards. Setting fuel economy standards that would increase the fuel economy of heavy-duty trucks by 50 percent would reduce carbon dioxide emissions by approximately 76 million metric tons, or 1.3 percent of U.S. carbon dioxide emissions in 2004.

Can it Be Done?

A variety of analyses over the past several years have found that dramatic improvements in fuel economy and per-mile global warming emissions are both technologically feasible and cost-effective.

Car and Light Truck Standards

The Union of Concerned Scientists (UCS) has concluded that average vehicle fuel economy of 40 MPG is attainable within a 10-year timeframe, even without the widespread use of hybrid technology. In addition, UCS concluded that such standards would provide a net savings to purchasers of more-efficient light trucks, even given a relatively conservative estimate of gasoline prices ($1.75 per gallon).[72] Similarly, the Consumer Federation of America concluded that a 50 MPG standard would be both feasible and cost-effective by 2030, assuming gasoline prices of $3 per gallon, using technologies that are either currently available or projected to be available soon.[73]

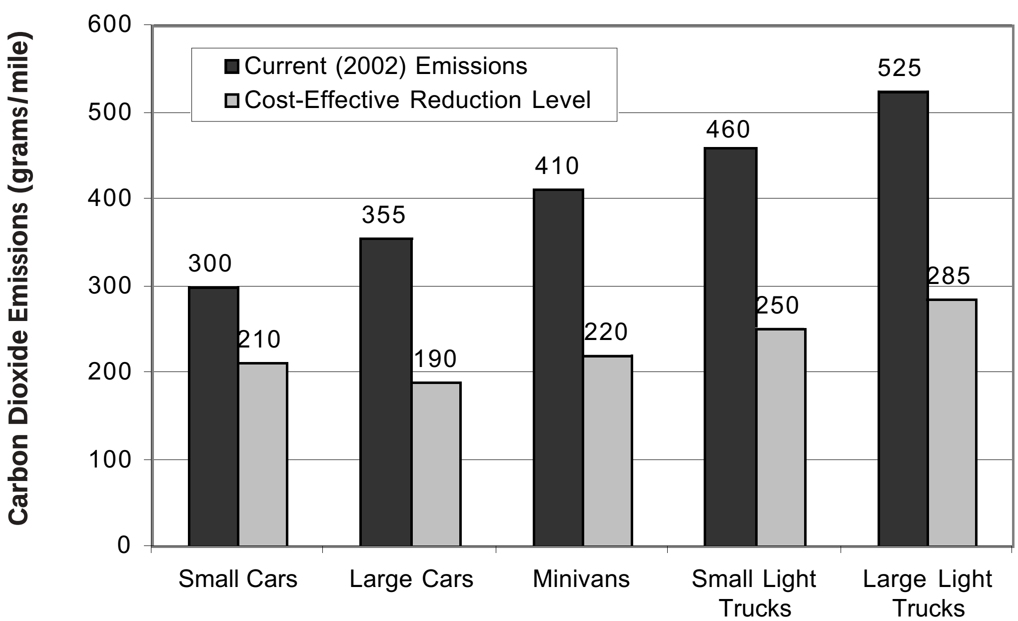
A 2004 study by the Northeast States Center for a Clean Air Future found that carbon dioxide emission reductions of up to 45 percent would be cost effective for most vehicle classes at gasoline prices of $2 per gallon, using a variety of technologies currently in use or projected to be available soon.[74] These reductions translate to a near-doubling of vehicle fuel economy from today's levels.

A similar study by the Union of Concerned Scientists found that light-duty vehicles could produce 20 percent less global warming pollution using technologies available today and 40 percent less pollution using technologies to be developed within the next decade.[76] The analysis did not include hybrid-electric vehicles, but another UCS study found that using hybrid technology would eventually allow the fleet to achieve an average fuel economy of 50 to 60 MPG.[77]

Most of the technologies used to achieve the fuel economy improvements and global warming pollution reductions described above are neither new nor exotic. Technologies such as six-speed automatic transmissions, continuously variable transmissions, turbocharging and cylinder deactivation are already finding their way into growing numbers of vehicles. Other more advanced technologies, such as improved electrical systems and idle-off (in which the gasoline engine is shut off during idling), can also significantly reduce emissions.

Unfortunately, American consumers have had very limited choice of fuel-efficient vehicles. According to the EPA, there were only 42 model year 2006 vehicle

Fig. 9. Cost-Effective Reductions in Carbon Dioxide Emissions (grams/mile)[75]



models that achieved 30 MPG combined city/highway mileage or greater (compared with more than 400 models that achieved less than 20 MPG combined). Of those 42 vehicles, 27 were compacts, subcompacts or other small cars. Only three mid-sized cars, no mid-sized station wagons, and six SUV models achieved 30 MPG or greater.[78]

The experience of the 1970s and 1980s demonstrates that automakers can make more fuel-efficient vehicles if they get a push from government. China, Japan and the European Union have all adopted fuel economy or global warming pollution standards for automobiles that, while not directly comparable with U.S. standards, surpass them on paper.[79] (See Table 1.) And automakers currently have access to a wide variety of technologies that can significantly improve fuel economy and curb global warming emissions.

A 40 MPG fuel economy standard, achieved over the course of a decade, would challenge automakers to use their technical know-how to help solve two of our greatest problems: global warming and dependence on oil.

Heavy Truck Standards

Heavy-duty trucks are major consumers of fuel. Large tractor-trailers consumed about 14 percent of the fuel used by all highway vehicles in 2004, and fuel consumption by large trucks has been increasing by more than 4 percent per year since the early 1990s.[81] As is the case with the light-duty vehicle fleet, fuel economy among the largest trucks has also been declining, dropping 5 percent between 1997 and 2002.[82]

Heavy-duty trucks are exempt from federal fuel economy standards. But significant increases in fuel economy for these trucks are possible at a net lifetime savings to vehicle owners. A 2004 study conducted by the American Council for an Energy-Efficient Economy (ACEEE) found that fuel economy improvements for tractor-trailers of 58 percent are achievable and cost-effective. The study also identified cost-effective improvements in fuel economy for other types of large trucks.[83] Calculations of cost-effectiveness were based on diesel fuel prices of $1.41 to $1.60 per gallon, well below the recent prices of $2.80 and higher charged recently at pumps across the

Table 1. Fuel Economy and Global Warming Emission Standards in the United States, Other Countries[80]

	Standard (MPG or MPG equivalent)	By Year	Notes
Japan	48.0	2010	
European Union	44.2	2008	(a,b)
China	36.7	2008	
U.S. Clean Cars Program	35.6	2016	(b,c)
Australia	34.4	2010	(a)
United States	**24.9**	**2007**	

(a) Voluntary standard
(b) Standard is a carbon dioxide standard, not a fuel economy standard. MPG equivalent is approximate.
(c) Has been adopted by 11 U.S. states: CA, CT, MA, ME, NJ, NY, PA, OR, RI, VT, WA.

United States.[84] As a result, the ACEEE estimates of cost-effective savings are likely conservative.

Imposing federal fuel-economy standards designed to increase the fuel economy of tractor-trailers by 50 percent would significantly reduce global warming pollution from the fast-growing freight transportation sector. The increase would be sufficient to raise the average fuel economy of heavy-duty trucks from approximately 5.7 MPG to about 8.5 MPG. The United States should also devise strategies to reduce fuel consumption and promote energy-efficient technologies in all medium- and heavy-duty trucks.

Step 3: Replace 10 percent of vehicle fuel with clean biofuels or other clean options

Shifting away from fossil fuels and toward renewable energy can significantly reduce America's contribution to global warming. Across the country, states have pressed forward with ambitious initiatives to increase the use of wind, solar, geothermal and other forms of renewable energy for the generation of electricity. (See Step 5.)

Using renewables to fuel our transportation system is trickier, however. America's cars and trucks are built to run on liquid fuels, particularly gasoline and diesel. For renewables to play a part in the powering of America's cars and trucks will require either using renewable liquid fuels (like cleanly produced ethanol or biodiesel) or augmenting or replacing liquid fuels with other sources of energy, such as renewably generated electricity.

Renewable fuels, such as ethanol and biodiesel, are made from crops such as corn and soybeans, and could soon be manufactured from specialized "energy crops" like switchgrass. While some fossil fuels are expended in the production of ethanol and biodiesel, the energy value of the crops exceeds the energy used to grow them. And both ethanol and biodiesel generally produce less global warming pollution than their fossil fuel equivalents, though the degree of emission reductions depends on how the fuels are produced. (See "Making Biofuels Sustainable," page 27.)

Cars that are partially or fully powered by electricity, meanwhile, produce less global warming pollution than conventional vehicles and could eventually reduce a large share of the nation's petroleum consumption. Electric motors are far more energy efficient than internal combustion engines. Improvements to hybrid-electric vehicles that allow them to run entirely on electricity for short distances using power from the electric grid are technologically feasible today. And advances in battery and fuel-cell technologies could allow vehicles to break their dependence on petroleum entirely.

Were America to replace 10 percent of vehicle gasoline use with ethanol and 10 percent of transportation diesel use with biodiesel, it would reduce vehicle carbon dioxide emissions by approximately 61 million metric tons in 2020, or about 1 percent of America's 2004 carbon dioxide emissions.[85] Replacing large amounts of vehicle fuel with electricity—particularly if that electricity were to come from renewable or low-carbon sources—would lead to even steeper emission reductions.

Can it Be Done?

Expanding the use of renewable fuels in America's transportation fleet would require an expansion of the infrastructure for growing, processing, and distributing plant-based fuels. Achieving a goal of 10 percent ethanol use for gasoline-powered vehicles would require annual production of about 17 billion gallons of ethanol.[86] Fuel ethanol production in the United States nearly doubled between 2002 and 2005, to a total of 4 billion gallons annually.[87] An additional 2 billion gallons of capacity is currently under construction.[88] Virtually all of this capacity is to produce corn-based ethanol.

Great potential exists for future production from ethanol from cellulose, which requires fewer fossil energy inputs and therefore delivers greater reductions in global warming pollution. A 2004 study by a group of academics and non-profit organizations laid out a pathway for obtaining 1 billion gallons of ethanol annually from cellulose by 2015, with production increasing by 30 percent annually thereafter.[89] Such a scenario would result in the production of about 3.7 billion gallons of cellulosic ethanol annually by 2020. Combined with the 7.5 billion gallons of ethanol required annually by 2012 under the renewable fuel standard in the 2005 Energy Policy Act, this would bring annual ethanol production to at least 11 billion gallons by 2020. The remainder of the ethanol needed to satisfy 10 percent of gasoline use could be obtained from continued incremental growth in corn ethanol production beyond 2012 or faster growth in cellulosic ethanol production.

Achieving a 10 percent standard for biodiesel use would require annual production of about 4 billion gallons of biodiesel by 2020.[90] In 2005, approximately 75 million gallons of biodiesel were produced in the United States, triple the amount of the year before.[91] The U.S. Department of Energy has identified the potential for 10 billion gallons of biodiesel production annually by 2030, while the 2004 study referenced above identified the ultimate potential for 16 billion gallons of production of Fischer-Tropsch fuel (a substitute for diesel) as a co-product of cellulosic ethanol production.[92]

Achieving a 10 percent ethanol/biodiesel goal will also require investments in infrastructure, particularly related to ethanol. Policy initiatives will be needed to encourage the deployment of infrastructure capable of transporting and distributing E85 to a broader segment of the public.

It is important to note that greater percentages of biofuels are possible in the decades ahead as the cellulosic biofuels industry grows. The 2004 study by academics and non-profit environmental organizations, for example, laid out a pathway by which more than 41 billion gallons of cellulosic ethanol could be produced by 2030.[93]

Production and use of ethanol and biodiesel should be managed so as to provide the greatest environmental benefit. (See "Making Biofuels Sustainable," page 27.) But biofuels are not the only alternative to petroleum that can reduce global warming emissions. Vehicles that are powered by electricity—either obtained from the electric grid or generated in a hydrogen fuel cell—could be even more effective options for reducing the global warming impact of transportation.

"Plug-in" hybrid vehicles are perhaps the closest such vehicles to market readiness. Plug-in hybrids are similar in most ways to advanced hybrid vehicles like the Toyota Prius. But there are two main differences: plug-in hybrid vehicles are capable of running for significant distances on electricity alone, and their larger on-board batteries are recharged in part using power from the electric grid. While current hybrid technologies can reduce global warming emissions by 28 percent per mile compared with conventional vehicles, plug-in hybrids can achieve 40 percent reductions per mile, with even greater reductions in areas of the country that generate less of their electricity with carbon-intensive coal.[99] Eventually, plug-in hybrids could be paired with engines running primarily on biofuels such as ethanol to create vehicles with a small fraction of the global warming impact of vehicles on the road today.

Plug-in hybrids still face obstacles of cost and automaker acceptance, but numerous plug-in hybrids are currently traveling the roads in demonstration projects, and Ford,

Making Biofuels Sustainable

Ethanol, biodiesel and other biomass-based fuels can make a significant contribution to reducing global warming pollution—if they are produced sustainably. However, environmental damage can result if the transition to biofuels is managed poorly. Indeed, under some circumstances, production and use of biofuels could lead to greater global warming emissions than the petroleum products they are designed to replace.

To maximize the environmental benefits of biofuels, policies must be in place to ensure that they are developed sustainably.

- **Protect air quality** – Low concentrations of ethanol in gasoline (such as E10) can result in increased emissions of smog-forming pollutants.[94] Motor vehicle air pollution standards should be revised to ensure that the use of ethanol does not result in overall increases in urban smog. In addition, public policy should encourage the use of ethanol fuels in higher blends (such as E85), which do not pose a threat to air quality.
- **Ensure sustainable production** – The way biofuels are produced has a large impact on their ultimate environmental benefits. Some agricultural methods for producing biomass can contribute to environmental problems such as eutrophication (nutrient enrichment) of waterways and soil erosion.[95] Under some production methods, biofuels can provide negligible global warming benefits or even result in higher global warming emissions. For example, the high price of natural gas has led some ethanol producers to use coal as a fuel for their plants, a change that could reduce, or even eliminate, the global warming benefits of ethanol use.[96] Some biomass production methods can also lead to increases in global warming emissions from land use that reduce or cancel out the benefits from reducing consumption of fossil fuels.[97] Finally, increasing production of feedstocks for biofuels could encourage negative agricultural practices (such as broader use of genetically modified crops or applications of toxic pesticides) or the conversion of ecologically important areas to "energy crops."

  A sustainable biofuels strategy must recognize these challenges and ensure that the agricultural and industrial processes used to produce biofuels do not cause unintended harm to the environment or the climate.
- **Don't substitute biofuels for efficiency improvements** – Biofuels can provide an important supplement to fossil fuels, but they are no substitute for using energy more efficiently. The "dual-fuel" loophole in U.S. automobile fuel economy standards, for example, gives automakers credit toward their fuel economy goals for the production of vehicles that are capable of running on alternative fuels such as E85, even though the vast majority of dual-fuel vehicles are operated entirely on gasoline.[98] Public policy should drive *both* improvements in fuel economy and sustainable expansion of biofuels in order to reduce fossil fuel use and achieve reductions in global warming pollution.

among other automakers, is considering the technology.[100]

Vehicles fully powered from the electric grid and those powered by hydrogen fuel cells may be somewhat further off. Both types of vehicles have been produced for demonstration projects (and several thousand pure electric vehicles were sold in California in the late 1990s and early 2000s), but both face significant technological hurdles—limited driving range, long recharging times and high cost for electric vehicles, and range, fuel storage and cost issues for hydrogen fuel-cell vehicles. Both technologies, however, have the potential to drive significant reductions in global warming emissions—particularly if the electricity or hydrogen used to fuel the vehicles comes from clean, renewable sources.

Government should consider measures—such as the zero-emission vehicle program pioneered by the state of California—to ensure the eventual integration of high-technology vehicles into the U.S. fleet.

The Importance of Mandatory Global Warming Pollution Limits

Improving the energy efficiency of America's economy and expanding the use of renewable energy give the United States a golden opportunity to reduce its emissions of global warming pollution. Instead of facing constant pressure to build new power plants to serve ever-growing demand, the nation would have the ability to finally replace its oldest and most polluting sources of electricity.

To take full advantage of that opportunity, however, the United States must pair smart energy strategies that promote energy efficiency and renewables with mandatory limits on global warming pollution.

A strong, mandatory cap on global warming pollution would encourage the shut-down of the dirtiest forms of electricity generation (such as older, coal-fired power plants) and their replacement with forms of generation that have less impact on the climate. Such a program can take the form of a "cap-and-trade" system—similar to a program recently agreed upon by eight northeastern states—in which companies that make emission reductions can sell their pollution permits (or "allowances") to other firms, thus delivering emission reductions at the lowest aggregate cost to the economy.[103]

To illustrate the potential global warming impact of a cap on global warming emissions, we compiled a second set of estimates for global warming emission reductions resulting from reducing electricity consumption by 10 percent by 2020. Instead of assuming that 75 percent of the energy saved is used to reduce demand for coal-fired power, we assumed that the same amount of energy is used to displace high-efficiency natural gas combined cycle power plants. In that case, a 10 percent reduction in electricity consumption would result in only 118 million metric tons of carbon dioxide emission reductions, as opposed to 284 million metric tons if efficiency improvements are used mainly to reduce coal-fired generation.

Mandatory limits on global warming pollution are central to any strategy to reduce the U.S. contribution to global warming, and should be adopted alongside the clean energy strategies discussed in this paper.

Step 4: Reduce energy consumption in homes, businesses and industry by 10 percent

Energy consumption in homes, businesses and industry accounts for two-thirds of U.S. emissions of carbon dioxide (including emissions resulting from the generation of electricity for residential, commercial and industrial use).[101] Reducing consumption of oil, natural gas and electricity in these sectors can lead to significant reductions in global warming pollution in the United States.

The impact of energy conservation and efficiency on global warming emissions depends in part on the form of electricity generation that is displaced. Electricity in the United States is generated from sources that produce huge volumes of global warming pollution (older coal-fired power plants), sources that produce less global warming pollution (modern natural gas-fired power plants), and sources that produce little or no pollution (renewable power).

For the purposes of this scenario, we assume that 75 percent of the electricity saved through efficiency and conservation is used to offset generation from existing coal-fired power plants, with the remaining 25 percent used to offset generation from nuclear power plants, many of which are nearing the end of their operating licenses.[102] Such a reduction in coal-fired power generation would likely only occur in the presence of a strong federal policy designed to reduce carbon dioxide emissions. (See "The Importance of Mandatory Global Warming Pollution Limits," page 28.)

Based on those assumptions, reducing oil, natural gas and electricity consumption by 10 percent below today's levels would reduce carbon dioxide emissions by about 400 million metric tons from 2004 levels—or about 7 percent—by 2020.[104]

Can it Be Done?

The electricity savings required to meet the 10 percent goal amount to 380 million Megawatt-hours (MWh) of electricity in 2020 compared to 2004 generation levels. Compared to the U.S. Energy Information Administration's 2020 projected generation levels, savings of 1,400 million MWh, or about 29 percent of projected generation, would be required. On the natural gas side, reductions of about 3.7 quadrillion BTU versus projected levels, or about 21 percent, would be needed by 2020.[105]

A 2004 review of 11 energy efficiency studies by the American Council for an Energy-Efficient Economy (ACEEE) found a mean economic potential for energy efficiency improvements (i.e., efficiency savings that would be cost-effective) of 20 percent for electricity and 21.5 percent for natural gas.[106] The dramatic increase in natural gas and electricity prices in some parts of the country in the years since the studies were conducted could result in the cost-effective energy efficiency potential being even higher today.

Achieving a 10 percent reduction in energy use by 2020 is, therefore, a very ambitious goal, requiring the United States to reap virtually all currently economic energy-efficiency opportunities, continue to develop new energy-saving technologies, and begin to deploy next-generation technologies that can transform the way Americans use energy in their homes, offices and factories.

Current Energy Efficiency Opportunities

Virtually every aspect of American life has the potential to be more energy efficient—often in ways that not only reduce global warming pollution, but that save money as well.

The potential for quick, dramatic reductions in energy use was demonstrated in California during that state's 2000-2001 energy crisis. Faced with the possibility of rolling blackouts during the summer of 2001, the state of California launched an unprecedented energy conservation effort that coupled stronger energy efficiency standards, public education efforts and financial incentives. The drive resulted in California slashing its electricity consumption by 6.7 percent within a single year, while curbing summer peak electricity demand by 14 percent.[107]

Such bold, comprehensive energy efficiency and conservation efforts have rarely been attempted elsewhere in the United States. The American Council for an Energy-Efficient Economy (ACEEE) reports that spending on state and utility-run energy efficiency programs is less than it was a decade ago, totaling only $1.35 billion in 2003.[108] Federal energy efficiency programs continue to face severe budget pressure; President Bush's proposed fiscal year 2007 federal budget slashed core energy efficiency funding by about $100 million, representing a 32 percent cut from fiscal year 2002 levels.[109]

There are plenty of options for developing America's "strategic reserves" of energy efficiency. The options below may or may not be sufficient to achieve the 10 percent reduction goal—indeed, the United States will almost certainly need to develop new policies, programs and technologies to achieve that target. But these options are illustrative of the types of energy efficiency opportunities that are available today.

Space heating – Space heating is the largest source of energy consumption in homes and businesses.[110] Despite dramatic improvements to the energy efficiency of the average American home since the energy crises of the 1970s, opportunities to reduce energy consumption for space heating still exist.

Comprehensive weatherization can cut energy consumption in single-family homes by 12 to 23 percent or more.[111] Air sealing, insulation and window replacements can reduce energy consumption by 20 percent.[112] High-efficiency residential furnaces, such as those meeting the federal government's Energy Star standards, can reduce fuel use by about 20 percent compared to furnaces meeting the government's minimum furnace efficiency standard, and by 40 percent or more compared to older furnaces.[113] Considering that about one-quarter of all homes have furnaces that are 20 years old or older, the opportunity for energy savings is large.[114]

On the commercial side, comprehensive retrofits that include heating, lighting and other uses of energy have been shown to achieve energy savings on the order of 11 to 26 percent.[115]

Air conditioning – Air conditioning accounts for 16 percent of residential electricity consumption and 26 percent of commercial electricity consumption.[116] New federal standards for residential and commercial air conditioners will improve efficiency for new units by 30 percent and 26 percent, respectively.[117] However, air conditioners currently exist that exceed the new federal standard by 15 percent or more.

Appliances – Many household and commercial appliances can be made vastly more energy efficient than they are today. Refrigerators, for example, consume 14 percent of residential electricity.[118] Refrigerators meeting Energy Star efficiency standards are 10 to 15 percent more efficient than average models.[119] Many other household and commercial appliances are available in more energy-efficient models or could be made to be more energy efficient using technologies available today.

In addition, many household appliances—from televisions and VCRs to computers and telephones—consume energy even when they are turned off. One study of 10 homes in California found that consumption of "standby" power amounted to 5 to 26 percent of these homes' annual electricity use. Replacing existing appliances with those that minimize standby power use could reduce these losses by 68 percent.[120]

Energy efficiency in industry – Industry has been among the most aggressive adopters of energy-efficiency technologies, given the large amount of energy often used in manufacturing and its impact on the bottom line. Nonetheless, significant room for improvement exists in the efficiency with which industrial facilities make use of energy.[121]

Transformative Technologies

Making the appliances and heating, cooling and lighting systems we currently use more efficient is a significant step toward using less energy. To achieve maximum energy savings, however, American homes, businesses and factories will need to adopt new or improved technologies that transform the way we use energy.

Zero-energy and low-energy buildings – Zero-energy buildings are those that produce as much energy as they consume. Zero-energy buildings typically combine an array of energy-saving technologies with small-scale renewable energy production. For example, the U.S. Department of Energy worked with Habitat for Humanity to design and build several near-zero-energy homes in Tennessee. The buildings combined an airtight building envelope with energy-efficient windows, a geothermal heat pump, solar panels and energy-efficient appliances. Costs for building the homes were around $100,000 and daily expenditures for purchased energy were about $1 per day.[122] Near-zero-energy homes are becoming increasingly common in California and have the potential to dramatically reduce all forms of residential energy consumption.

Not all new buildings have the potential to use "zero" energy, but most residential and commercial buildings can be built in ways that use much less energy. The American Institute of Architects has set a target of reducing fossil fuel consumption in the construction and operation of new buildings by 50 percent by 2010 and to make all new buildings carbon-neutral by 2035.[123]

Solar water heating and passive solar – While most discussions of solar power focus on solar photovoltaics—which convert sunlight into electricity—solar thermal technologies may have as great a role to play in saving energy and reducing global warming pollution. Solar water heaters can reduce energy consumption for water heating by about two-thirds and pay for themselves within four to eight years.[124] New homes and businesses can be designed to make maximum use of the sun for lighting and heating.

Combined heat and power – Electric power plants that burn fossil fuels produce large amounts of waste heat. Many large apartment buildings, commercial developments and industrial facilities could make greater use of combined heat and power (CHP) in which electricity is generated onsite, with the remaining heat then used to provide space heating or other energy needs. CHP systems can reach 70 to 90 percent thermal efficiency, compared to the 33 percent efficiency of today's power plants.[125] Many industrial facilities already use CHP, but the potential for growth is enormous. Studies conducted for the U.S. Department of Energy found a market potential of 33 gigawatts for industrial CHP systems (compared to current deployment of 11 GW), and as much as 77 gigawatts in the commercial and institutional sector (compared to deployment of 5 gigawatts as of 1999).[126] Building out this existing CHP potential would equal about 1 percent of America's current generation capacity, and technological improvements could allow CHP technologies to spread even further in the years to come.[127]

Conclusion

Encouraging the installation of energy efficient technologies in homes, businesses and industry, while simultaneously opening the door for transformative technologies such as zero-energy buildings, solar water heating and combined heat and power, can reduce the amount of fossil fuels and centrally generated electricity consumed in the United States. Policies such as tax breaks for energy efficient equipment, stronger energy efficiency standards for appliances and homes, energy efficiency portfolio standards for utilities, the elimination of market barriers to technologies such as CHP, and others can move the United States toward a goal of reducing energy use in the residential, commercial and industrial sectors by 10 percent by 2020.

Step 5: Obtain 20 percent of electricity from new renewables by 2020

America has virtually unlimited technical potential for the generation of power from the wind, sun and other natural forces. Using new, zero-carbon renewable sources of energy such as solar and wind to produce 20 percent of America's power by 2020, while implementing a strong, mandatory cap on global warming emissions that reduces demand for power from inefficient existing coal-fired power plants, would reduce carbon dioxide emissions by approximately 511 million metric tons, or more than 8 percent of 2004 emission levels.[128]

Renewable Energy Growth Around the World

Countries around the world are demonstrating that renewable power sources can be ramped up quickly and play a significant role in their nations' electricity supplies.

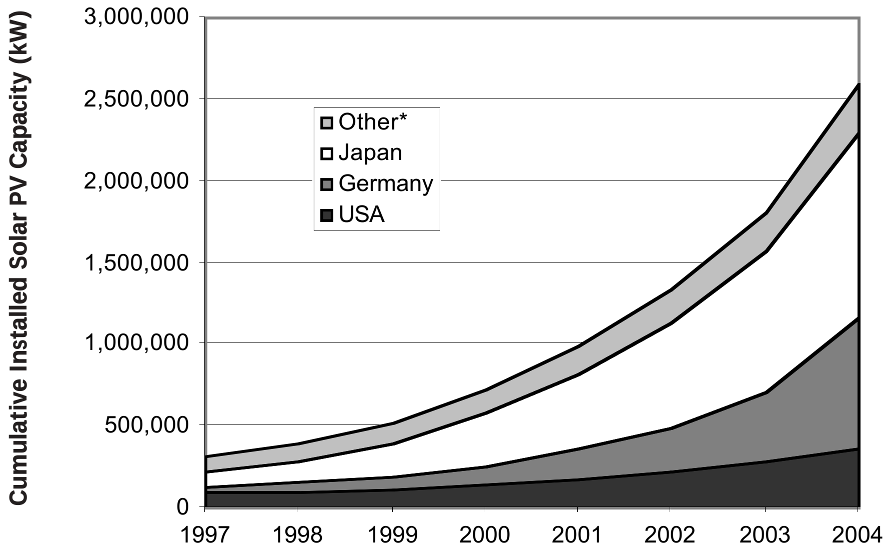
The United States has historically been a leader in the deployment of renewable energy technologies. As recently as 1996, the United States had more solar photovoltaic (PV) capacity than any other nation in the world. And as recently as 1997, the United States was number two in wind power capacity, trailing only Germany.[139]

In the years since, however, other nations—primarily European countries and Japan—have dramatically ramped up their production of renewable energy. By 2004, Japan had triple the solar PV capacity of the United States, while Germany had more than double the capacity. (See Fig. 10.) The United States now stands third in installed wind power capacity behind Germany (which now has twice the wind generation of the United States) and Spain, which has increased its wind power generation nearly 20-fold in just the last eight years. (See Fig. 11.)[140]

In several countries, renewable power now represents a sizeable share of overall electricity generation. Denmark now generates more than 16 percent of its electricity from wind power, with Spain generating 8 percent and Germany nearly 5 percent.[143]

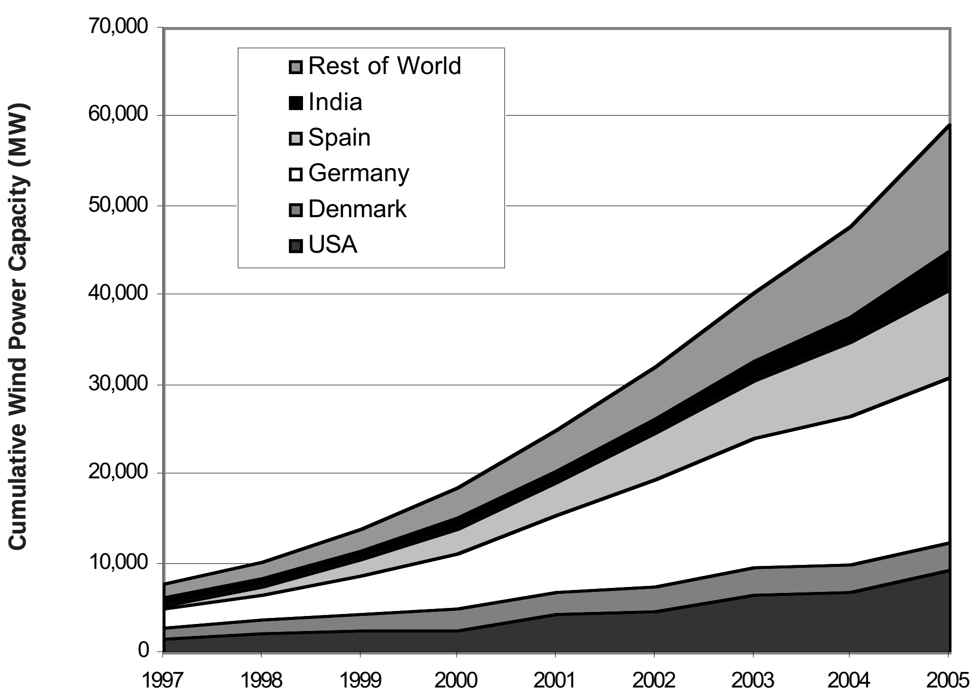
The growth of renewable energy in these nations is no accident—rather it is a direct result of aggressive public policies designed to prioritize renewable energy development.

Fig. 10. Cumulative Installed Solar Photovoltaic Generating Capacity[141]



* "Other" includes other members of the International Energy Agency's Photovoltaic Power System Program.

Fig. 11. Cumulative Installed Wind Power Generating Capacity[142]



Can it Be Done?

A 1993 U.S. Department of Energy study found that wind turbines on 0.6 percent of the nation's land area could produce 20 percent of the nation's electricity.[129] Preliminary data from the U.S. Department of Energy estimate that the potential wind generation capacity of America's offshore areas exceeds 1,000 gigawatts (GW), about as much as America's current generation capacity from all sources.[130] America's solar photovoltaic resource is similarly vast—the solar energy available in a 100 square-mile section of Nevada could provide electricity equivalent to America's annual consumption.[131]

Tapping this potential will require swift deployment of renewable energy technologies. To achieve the 20 percent goal, America will need to generate approximately 700 million MWh of electricity from new renewable sources by 2020.

Wind power installations have increased dramatically in the United States, with nearly 2.5 GW of wind power installed in the United States in 2005, representing an increase of 35 percent in the nation's wind power capacity over the year before. An additional 3 GW of wind capacity is expected to be installed in 2006.[132]

The U.S. wind industry has set a goal of having 100 GW of wind power installed in the United States by 2020, enough to generate about 289 million MWh of power.[133] But a more rapid ramp-up of wind power is certainly possible with vigorous public policy support. Spain, for example, now has more than 10 GW of installed wind capacity—more than the United States—and has seen its installed wind capacity triple within a four-year period. Applying Spain's 32 percent annual growth rate to the United States would result in America generating twice the amount of power required to meet the 20 percent new renewables goal.[134]

Solar photovoltaics can also play an important role in meeting the 20 percent target. The state of California, for example, recently launched an incentive program designed to bring 3 GW of distributed solar power on line within the next 11 years.[135] The U.S. solar industry has set a target of having 36 GW of solar PV capacity installed by 2020, increasing to 200 GW by 2030.[136] This would result in the generation of about 79 million MWh of power from solar photovoltaics by 2020.[137]

Another form of solar electricity—concentrating solar thermal energy—is also poised to make major strides. Unlike more familiar solar photovoltaic panels, which convert sunlight directly to electricity, concentrating solar power plants use mirrors to reflect and concentrate sunlight, which is then used to heat a liquid or gas that is then used to generate electricity. Within just the past year, California utilities have committed to concentrating solar thermal projects that could eventually add 1.7 GW of solar power generating capacity.[138]

Geothermal energy also has the potential to make an important contribution, particularly in the western United States. The U.S. Department of Energy is targeting the installation of another 15 GW of geothermal electricity generation capacity by the end of this decade, enough to generate approximately 118 million MWh of power.[144]

Achieving the goals mentioned above for wind, solar photovoltaics and geothermal energy would allow the United States to get more than two-thirds of the way to the goal of obtaining 20 percent of electricity from new renewable sources. Other renewable energy sources—including central-station solar power, small-scale wind, tidal power, biomass energy, landfill gas and others—have the potential to make significant contributions.

Significant hurdles remain in the way of a dramatic expansion of renewable energy. Concerns about the siting of wind turbines and long-distance transmission of wind power, utility interconnection problems and lack of equitable net metering for solar power in some parts of the country, as well as other roadblocks, must be addressed if renewable energy is to experience significant growth over the next two decades. But, given the enormity of America's renewable resource base—and the successful track record of other nations in bringing renewable energy on line quickly—there is little reason that a goal of generating 20 percent of America's power from new renewables cannot be achieved.

Step 6: Hold emissions from other parts of the economy to current levels

The five steps above address the vast majority of U.S. energy use and global warming emissions. However, achieving a goal of reducing U.S. global warming pollution by 15 to 20 percent by 2020 will require vigorous action in all sectors of the economy to ensure that energy use and global warming pollution at least remain stable. Mandatory limits on global warming pollution would help to achieve that goal.

Several areas in which global warming pollution could increase significantly in the years ahead are the following:

Air travel – The Energy Information Administration projects that jet fuel consumption will increase by 35 percent between 2004 and 2020, due to a projected increase in air travel.[145] This increase in jet fuel use would amount to an increase in carbon dioxide emissions of approximately 83 million metric tons. Air travel is among the least energy efficient modes of travel, consuming more than 50 percent more energy per passenger mile than rail travel.[146] While some improvements in aircraft fuel efficiency are possible, greater gains are possible by shifting some air trips to lower-emission modes.

More than half of all flights in the United States are less than 500 miles in length—a distance at which rail travel, particularly high-speed rail, can be competitive in terms of time and convenience.[147] Shifting even a portion of short- to medium-distance air travel to rail can reduce global warming emissions. Bolstering the nation's rail network to accommodate such a shift could also allow some trips to be shifted from automobile and other high-emitting modes as well.

Freight transportation – The energy efficiency of freight transport in the United States has been declining for more than a decade, due in part to a decline in the energy efficiency of moving freight by air, water and pipeline.[148] While improving fuel economy and increasing the use of renewable fuels in heavy-duty trucks will reduce the global warming impacts of increased freight transport, the United States should also seek out ways to increase the amount of freight that travels by low-emission modes such as rail.

Other global warming pollutants – In addition to carbon dioxide, the United States emits a variety of other pollutants that contribute to global warming. In 2000, these emissions represented about 16 percent of the United States contribution to global warming.[149] Emissions of global warming pollutants like methane and nitrous oxide are projected to increase modestly or decrease over the next two decades, but emissions of several "high global warming potential" pollutants could skyrocket—more than tripling between 2000 and 2020.[150] Currently, the federal government is involved in voluntary partnerships with industry to reduce emissions of high global warming potential pollutants. To stem increases in these pollutants, all global warming pollutants should be included in a comprehensive program to limit global warming emissions.

A mandatory, economy-wide cap on global warming pollution would ensure that increases in emissions from other sectors of the economy do not offset or overwhelm the emission reductions achieved through clean energy strategies.

Conclusion & Recommendations

Benefits of the Six Steps

The six strategies listed above, if implemented and augmented by strong, mandatory limits on global warming pollution, would reduce U.S. global warming emissions by about 19 percent below 2004 levels by 2020. Carbon dioxide emissions would be reduced by about 23 percent below 2004 levels.

Achieving significant reductions in global warming pollution over the next decade and a half will help reduce the impact of global warming in the next century and position the United States as a leader in the worldwide effort to forestall dangerous climate change.

But pursuing the six strategies listed above will also have other benefits for America's economy and environment.

Table 2. Global Warming Emission Impact of the Six Steps (Relative to 2004 Emissions)

Strategy	Savings MMTCO$_2$E
Stabilize Vehicle Travel	0*
40 MPG Fuel Economy and Heavy-Duty Truck Fuel Economy Standards	383
10% of Transportation Fuel from Renewables	61
10% Reduction in Energy Consumption	400
20% of Electricity from New Renewables	511
Total Savings	**1355**
2004 U.S. Global Warming Emissions	7122
Reduction Relative to 2004	**19%**

* Avoids increase in emissions resulting from projected increases in vehicle travel between now and 2020.

- **Reduced fossil fuel dependence** – Holding vehicle travel stable while improving fuel economy and increasing our use of biofuels will dramatically reduce America's addiction to oil—slashing light-duty vehicle gasoline use by more than one-quarter. At the same time, the United States can reduce its dependence on other scarce fossil fuels, such as natural gas, ensuring America's long-term energy security.
- **Create jobs** – A variety of studies have shown that investing in energy efficiency and renewable energy creates more jobs than investing in fossil fuels. One 2005 study estimated that a clean energy strategy, coupled with a shifting of federal energy subsidies to renewables and efficiency, could create as many as 154,000 new jobs in the United States and increase net wages by $6.8 billion.[151] The Union of Concerned Scientists estimates that a 20 percent national renewable energy standard for electricity would create twice as many new jobs as meeting demand with fossil fuels, while adding $10.2 billion to the nation's gross domestic product.[152]
- **Save money** – Many of the steps mentioned above—including major improvements in vehicle fuel economy, improvements in energy efficiency, and some investments in renewable power—are cost-effective today. That is, they save money for American consumers over the lifetime of the investment. At a time when many Americans face rising energy costs at the pump and in their homes, investing in efficient, clean energy sources today is likely to reap a substantial long-term savings, helping to ensure America's economic stability long into the future.
- **Reduce other environmental and public health threats** – America's dependence on fossil fuels causes a litany of environmental and public health problems from urban smog caused by motor vehicle exhaust to mercury pollution from coal-fired power plants. Reducing our consumption of fossil fuels can alleviate many of these threats.

Recommendations

The United States should pursue the following strategy for achieving the necessary reductions in global warming emissions:

Cap Global Warming Emissions – Establish mandatory, science-based limits on carbon dioxide and other global warming gases that reduce emissions from today's levels within 10 years, by 15-20 percent by 2020, and by 80 percent by 2050.

Adopt Complementary Policies to Reduce Global Warming Emissions – Adopt public policies that would achieve the specific targets laid out in this report, including:

- Transportation policies designed to reduce growth in vehicle travel and promote alternatives to automobile travel.
- An increase in federal fuel economy standards for cars and light trucks.
- Creation of federal fuel economy standards for heavy trucks.
- A renewable fuel standard requiring a significant share of transportation fuel to come from renewables by 2020.
- Policy support for the development and introduction of plug-in hybrid, electric and fuel-cell vehicles.
- Stronger appliance efficiency standards, energy efficiency programs and other policies designed to improve energy efficiency.

- A federal renewable energy standard requiring a large and increasing share of the nation's electricity to come from renewable energy.

Encourage Action at the State Level – Many states have taken action to reduce global warming pollution, either by adopting specific goals or targets for emission reductions or by adopting clean energy policies designed to improve energy efficiency or promote renewable energy. Federal action to reduce global warming pollution should in no way impede individual states or groups of states from pursuing policies that go above and beyond the commitment made by the federal government.

Methodology

The estimated global warming emission reductions presented in this report are based on a comparison with 2004 U.S. global warming emissions as presented in U.S. Department of Energy, Energy Information Administration (EIA), *Emissions of Greenhouse Gases in the United States 2004*, December 2005.

To estimate the reductions that would result from each of the strategies, we began with estimates of energy use in vehicles, homes, businesses, industry and electric power plants in 2004 from the EIA's *Annual Energy Outlook 2006* (*AEO 2006*). Except where otherwise noted, the amount of carbon dioxide released from the consumption of various fossil fuels is based on carbon coefficients from the EIA's *Documentation for Emissions of Greenhouse Gases in the United States 2003*, May 2005.

Specific assumptions and quantification methods for the various strategies follow:

1. Stabilization of Vehicle Travel

Emissions from light-duty vehicles were assumed to be held constant at 2004 levels in 2020.

2. Increase Fuel Economy Standards to 40 MPG and Set Fuel Economy Standards for Heavy-Duty Trucks

To estimate the benefits of increased fuel economy standards for light-duty vehicles, we first assumed that vehicle fuel economy would remain constant at 2005 levels in the absence of policy action to the contrary. Estimated 2005 laboratory fuel economy for cars of 28.9 MPG and for light trucks of 21.3 MPG were obtained from U.S. Environmental Protection Agency, *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, July 2005. These laboratory fuel economy values were reduced by approximately 20 percent to approximate "real world" conditions, based on on-road fuel economy degradation factors for 2020 from EIA, *Assumptions to AEO 2006*.

The on-road fuel economy for new vehicles under a 40 MPG fuel economy scenario was assumed to be 32 MPG for both cars and light trucks, taking into account the 20 percent difference between laboratory and on-road values described above. The 40 MPG standard was assumed to be phased in linearly, with gradual increases in new vehicle fuel economy beginning in 2009 and ending with the 40 MPG standard in 2018.

To estimate how increasing fuel economy standards would affect vehicle emissions in 2020 among all vehicles (not just new vehicles), we made assumptions about the proportion of miles that will be driven by vehicles of various ages in 2020 and about the split in vehicle-miles traveled between passenger cars and light trucks, such as SUVs. To make the former estimate, we relied on data on VMT accumulation by vehicle age from the U.S. Department of Transportation's 2001 National Household Transportation Survey (NHTS, downloaded from nhts.ornl.gov/2001/index.shtml, 21 June 2006). We used the estimates of the number of miles driven per vehicle by vehicles of various ages from NHTS to estimate the percentage of total VMT in 2020 that could be allocated to vehicles of various model years. (To eliminate year-to-year anomalies in the NHTS data, we smoothed the VMT accumulation curves for cars and light trucks using several sixth-degree polynomial curve fits.) These percentages were then applied to the on-road fuel economy standard for new vehicles of each model year to create a weighted average fleetwide fuel economy estimate for both cars and light trucks in 2020, which we then compared with the baseline estimate of what fleetwide fuel economy would be without stronger fuel economy standards. Finally, we assumed that 40 percent of VMT in 2020 would take place in cars and 60 percent in light trucks, per a methodology described in Environment Maine Research and Policy Center, Natural Resources Council of Maine, *Cars and Global Warming*, Fall 2004. The weighted average fleetwide fuel economy for cars and light trucks was then multiplied by their share of total VMT to arrive at a percentage reduction in fuel consumption that would result from the higher fuel economy standards in 2020.

The percentage reduction in per-mile fuel consumption was then applied to the estimated gasoline consumption of light-duty vehicles in 2004 (from *AEO 2006*) to estimate the amount of gasoline that would be saved. Global warming emission reductions from those fuel savings were calculated using carbon dioxide coefficients for tailpipe emissions (approximately 19.3 pounds of carbon dioxide per gallon, based on EIA, *Documentation for Emissions of Greenhouse Gases in the United States 2003*) and for "upstream" emissions resulting from the production and distribution of gasoline (approximately 5.7 pounds of carbon dioxide per gallon, based on well-to-tank results from General Motors Corporation, Argonne National Laboratory, et al., *Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – North American Analysis*, *Volume I*, June 2001).

For heavy-duty truck fuel economy standards, we used 2004 fuel economy estimates for heavy-duty diesel and gasoline-powered trucks from *AEO 2006* to establish a baseline. We then assumed that fuel economy standards equivalent to a 50 percent increase in miles-per-gallon fuel economy would be phased in linearly beginning in 2009 and ending in 2020. Fuel economy improvements were assumed to penetrate the vehicle fleet according to VMT accumulation by vehicle age estimates from U.S. Census Bureau, *2002 Economic Census: Vehicle Inventory and Use Survey*, December 2004. Fuel consumption per mile for vehicles of each model year was then multiplied by the percentage of VMT traveled in vehicles of each model year, and then summed across model years to arrive at an estimate of fleetwide fuel economy after imposition of fuel economy standards. The fleet fuel economy estimate for heavy-duty trucks was then divided by current average fleet fuel economy to arrive at a percentage reduction in fuel consumption per mile driven. This percentage reduction was then applied to estimates of diesel and gasoline use by heavy-duty trucks in *AEO 2006* to arrive at an estimate of total fuel savings. The fuel savings estimate was then converted to carbon dioxide emission savings using tailpipe and upstream emission factors from the same sources used for light-duty vehicle gasoline use, described above.

Increases in fuel economy may have other impacts on consumers' driving and vehicle purchasing habits. Many studies have identified a "rebound effect" in which purchasers of more efficient vehicles increase their vehicle travel. In addition, changes in fuel economy standards can cause consumers to shift from one class of vehicles to another (for example, from cars to SUVs). We do not include the rebound effect in these calculations, on the assumption that strategies to eliminate growth in vehicle travel (See Step 1) will achieve their goal. We also do not include "mix shifting" among vehicle types.

3. Replace 10 Percent of Vehicle Fuel with Biofuels

The energy value of gasoline and diesel fuel that would be replaced with biofuels was determined by multiplying the amount of light-duty vehicle gasoline use (or, in the case of biodiesel, transportation sector diesel use) remaining after the imposition of stronger fuel economy standards, in BTU, by 10 percent.

Avoided global warming pollutant emissions from biofuels were estimated by multiplying the life-cycle (tailpipe plus upstream) emissions from the avoided gasoline and diesel use by the percentage life-cycle reductions in global warming emissions from the various biofuels compared to their petroleum equivalents. For ethanol, separate emission reduction factors were estimated for corn-based and cellulosic ethanol. Per-mile global warming emission reductions from corn-based ethanol were assumed to be 13 percent compared with conventional gasoline based on Alexander E. Farrell, et al., "Ethanol Can Contribute to Energy and Environmental Goals," *Science*, 311: 506-508, 27 January 2006. Per-mile global warming emission reductions from cellulosic ethanol were assumed to be 85 percent, based on Michael Wang, Argonne National Laboratory, *Updated Energy and Greenhouse Gas Emissions Results of Fuel Ethanol*, PowerPoint presentation to the 15th International Symposium on Alcohol Fuels, 26-28 September 2005.

We assumed that 80 percent of ethanol used in 2020 would come from corn, with 20 percent (approximately 3.4 billion gallons per year) coming from cellulosic sources. The amount of cellulosic ethanol is consistent with a pathway for the development of cellulosic ethanol described in Nathanael Greene, et al., *Growing Energy: How Biofuels Can Help End America's Oil Dependence*, December 2004. That pathway calls for production of 1 billion gallons of cellulosic ethanol in 2015, with a 30 percent annual growth rate thereafter.

Per-mile global warming emission reductions from biodiesel were assumed to be 65 percent per two life-cycle studies: $(S\&T)^2$ Consultants Inc., *Biodiesel GHG Emissions Using GHGenius: An Update*, prepared for Natural Resources Canada, 31 January 2005 and Tom Beer, et al., *Comparison of Transport Fuels: Final Report to the Australian Greenhouse Office on the Stage 2 Study of Life-Cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*.

4. Reduce Energy Consumption in Homes, Business and Industry by 10 Percent

Reductions in energy consumption were assumed to be 10 percent versus 2004 energy consumption as estimated in *AEO 2006*. The 10 percent reduction was applied to all electricity, natural gas and petroleum consumed in the residential and commercial sectors. For the industrial sector, the 10 percent reduction was applied to all electricity and natural gas consumption, and to all petroleum consumption except consumption of "other petroleum" and "petroleum feedstocks" as defined by the EIA, which were excluded completely, and industrial consumption of liquefied petroleum gas, 75 percent of which were excluded. These petroleum products are frequently consumed for non-energy purposes, and therefore were not assumed to be affected by energy efficiency programs.

For natural gas and petroleum, global warming emission reductions were calculated by multiplying the amount of energy saved by the carbon coefficients in EIA, *Documentation for Emissions of Greenhouse Gases in the United States 2003*. For electricity, the 10 percent reduction in residential, commercial and industrial electricity consumption was assumed to result in a 10 percent reduction in net electricity generation from 2004 levels. We assumed that 25 percent of the reduction in generation would offset generation from existing nuclear power plants. For the main scenario in this report, we assumed that the remaining 75 percent of reduced electricity consumption would be used to offset generation at existing coal-fired power plants. To determine the amount of coal consumption that would be eliminated, we multiplied the amount of electricity saved through efficiency improvements by 0.75 and then by the average heat rate of U.S. coal-fired power plants in 2004 (10,476 BTU/kWh) per *AEO 2006*. We then multiplied this reduction in coal consumption by the carbon coefficient for coal from EIA, *Documentation for Emissions of Greenhouse Gases in the United States 2003*, to arrive at the estimated reduction in global warming emissions.

To illustrate the centrality of strong, mandatory limits on global warming pollution to successful efforts to curb global warming emissions, we also constructed an alternative case, in which energy efficiency savings were used to reduce generation from new, efficient natural gas combined cycle power plants instead of existing coal-fired power plants. We multiplied the amount of electricity saved through efficiency improvements by 0.75 and then by the estimated heat rate of a natural gas combined cycle power plant (7,844 BTU/kWh, based on Pamela L. Spath and Margaret K. Mann, National Renewable Energy Laboratory, *Life Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System*, September 2000). We then multiplied this reduction in natural gas consumption by the carbon coefficient for natural gas from EIA, *Documentation for Emissions of Greenhouse Gases in the United States 2003*, to arrive at the estimated reduction in global warming emissions for the alternative case.

"Upstream" global warming emission reductions resulting from reduced production of coal, oil and natural gas were not included in the estimated emission reductions from this scenario. Including upstream emissions would lead to greater global warming emission reductions from this strategy than are estimated here.

5. Obtain 20 Percent of Electricity from New Renewables by 2020

The amount of fossil fuel power generation that would be displaced by 20 percent new renewables was calculated by taking the amount of electricity generation needed to supply demand after the 10 percent reduction in consumption in Step 4, and multiplying it by 20 percent. Global warming emission reductions were calculated as described in the scenario above. New renewables were assumed to have zero carbon dioxide emissions. In reality, some renewable energy sources (such as geothermal energy) do result in some global warming emissions, while all renewable technologies create some "upstream" emissions. As a result, the emission reductions estimated here may slightly overestimate the reductions that would result from receiving 20 percent of U.S. electricity from new renewable sources.

6. Hold Other Emissions to 2004 Levels

No increase was assumed in energy use or global warming emissions from other sectors of the economy.

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