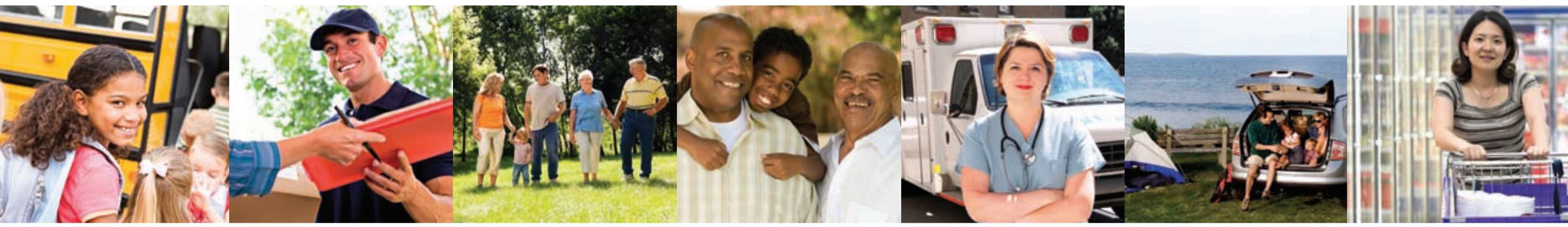
Primer on Transportation and Climate Change

April 2008



American Association of State Highway and Transportation Officials

AASHTO

The Voice of Transportation

Climate Change, VMT, and the Economy:
The AASHTO Perspective

In its July 2007 publication, ***A New Vision for the 21st Century***, AASHTO noted that "global climate change has become a political, environmental, and economic fact of life." That report identified bold but achievable goals for reducing Greenhouse gas (GHG) emissions from road transportation:

- Support the President's goal to reduce oil consumption 20 percent in 10 years. Double the fuel efficiency of passenger cars and light trucks.
- Double transit ridership by 2030, and significantly expand the market share of passengers and freight moved by rail.
- Reduce the growth in vehicle miles traveled (VMT)—from three trillion in 2006 to five trillion, rather than the projected seven trillion, by 2055.
- Increase the percentage of those who car pool, walk, bike, or work at home.

Achieving these goals will require major efforts to develop next-generation technologies in vehicles and fuels. Current government forecasts assume only incremental advances in vehicles and fuels between now and 2020, with few additional gains beyond that year. Much greater improvements will be needed in order to achieve major reductions in GHG emissions.

In addition to improving vehicles and fuels, it also will be important to reduce the growth in VMT as compared to recent trends. Between 1982 and 2007, VMT grew at approximate 2.5 percent annually—closely tracking growth in the economy and personal income, and exceeding the growth in population. Going forward, some growth in VMT will be needed to accommodate a growing population and a growing economy, including truck freight shipments. Therefore, rather than seeking to cut VMT in real terms, AASHTO has proposed a goal of reducing the *rate of growth* in VMT to approximately the rate of population growth—about 1 percent per year.

It was interesting to note how the United Kingdom addressed this issue in its October 2007 report *Toward a Sustainable Transport System*. The report found that for transport, supporting economic growth and tackling carbon emissions, "does not have to be an either/or choice." Likewise, AASHTO believes U.S. policies must be balanced in ways which help reduce transportation's impact on global climate change, but which also sustain VMT growth at the level needed to support a healthy National economy.

John Horsley
Executive Director

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Cover photo courtesy of FIGG, engineer of record for the Natchez Trace Parkway Arches.

Introduction


This primer is an introduction to the issue of climate change and its implications for transportation policy in the United States. The paper is organized in five parts:

Part I summarizes the current state of scientific knowledge concerning the causes and impacts of climate change. This section reviews the data that shows climate change is occurring; summarizes the impacts of climate change, including impacts on the transportation system; and explains how greenhouse gas emissions contribute to climate change.

Part II provides an introduction to climate change policy issues. This section briefly outlines the main goals of climate change policies, and provides an overview of the major strategies that are being considered and/or adopted to achieve those goals. This section includes a discussion of "cap and trade" proposals, a carbon tax, energy efficiency standards, and other economy-wide proposals that could be adopted to address climate change.

Part III discusses trends in GHG emissions from road transportation. This section reviews historical trends and current government projections for fuel economy, vehicle miles traveled (VMT), and greenhouse gas emissions from road transportation. It also presents four alternate scenarios showing that faster improvements in fuel economy and somewhat slower growth in VMT could result in steep reductions in greenhouse gas emissions by 2050.

Part IV reviews potential measures to reduce GHG emissions from road transportation. This section discusses potential improvements in vehicles and fuels; potential ways to reduce the growth of VMT; and potential operational strategies for reducing GHG emissions. This section then provides an overview of policy tools that could help promote these changes, including measures such as increasing fuel economy standards; requiring greater use of renewable fuels; expanding funding for research and development; and establishing a "carbon price" through a cap-and-trade system or other measures.

Part V identifies issues for further research. This section lists a series of issues that warrant additional research by AASHTO or others. For example, one important issue is the underlying growth trend in VMT. There is some evidence that growth in VMT is slowing due to economic and demographic factors. Additional research is needed to ensure that policymakers have a solid basis for setting policies on transportation and climate change.

The Reference Materials section, which follows Part V, includes a list of major studies and other published reports on climate change and transportation. A literature review summarizing these reports has been posted on the AASHTO web site along with this primer at bookstore.transportation.org.

This primer is based on the most recent research in the field. Its purpose is to outline the current thinking of governmental agencies, researchers, and advocacy groups on the issue of climate change and transportation. The conclusions stated in those reports do not necessarily reflect the views of AASHTO or its members. AASHTO will be sponsoring additional research and will be providing the results of that research in subsequent reports.




Executive Summary


Authoritative sources tell us the global climate is becoming warmer. Global warming is caused in large part by human activities. If allowed to continue unchecked, it will cause severe and lasting impacts. What is the role of transportation in mitigating global climate change and adjusting for its impacts?

Anticipated Impacts Affecting Transportation

Research studies have identified the serious impacts climate change poses for transportation. Increases in very hot days will increase the frequency of wildfires, compromise pavement integrity, and deform rail lines; increased flooding of coastal areas will inundate roads, bridges, and rail lines; increases in Arctic temperatures will cause subsidence of permafrost, disrupting roads, rail lines, and airports. Heavier rainfall in many parts of the country will require redesign and replacement of drainage structures; and more frequent and more severe hurricanes will disrupt service in affected areas and require devoting more resources to evacuations.

Recent Reports Say Climate Change Poses a Big Problem for Transportation

Recent authoritative reports have confirmed the challenges that global climate change will pose for the transportation sector. These studies include the *2007 Report of the Intergovernmental Panel on Climate Change* and TRB's Report 290: *Potential Impacts of Climate Change on U.S. Transportation*, 2008.

Emission of Greenhouse Gases Is Causing Temperatures to Rise

The strategy to stop the continuing rise in temperatures is to slow down the rate of greenhouse gas (GHG) emissions and ultimately stabilize GHG concentrations in the atmosphere.

The goals of climate change policy are to stabilize global average temperatures and prepare for the impacts of climate change.

U.S. Goals for Greenhouse Gas Emission Reduction

To date, the U.S. government has not adopted a specific GHG reduction goal. The U.S. Climate Action Partnership (U.S. CAP)—a broad coalition of industry and environmental groups—has set a goal to reduce U.S. GHG emissions below 2005 levels by 60–80 percent by 2050. Many states have adopted even more aggressive goals.

Cap-and-Trade or Carbon Tax

Many economists have agreed that the most cost-effective way to reduce GHG emissions is to establish a *carbon price*. Carbon pricing would give businesses and individuals an incentive to use less carbon. A carbon price could be set by establishing a cap-and-trade program or a carbon tax. Under a cap-and-trade program allowances for emissions would be allocated by the government, possibly through an auction. The price of emitting carbon and other greenhouse gases would be increased to the point a given industry would reduce them directly or by purchasing allowances from others. Imposing a carbon tax would have a similar effect. Cap-and-trade appears to be the solution which stands the best chance of near-term enactment in Congress.

Climate Change and Transportation

It is estimated that approximately 33 percent of GHG emissions in the United States come from transportation. Seventy-two percent of the transportation sector's emissions are generated by road use.

Factors Affecting Road-Related GHG Emissions

There are several factors that affect the GHG emissions from road transportation. These include: 1) fuel economy, 2) the type of fuel used, and 3) the number of vehicle miles traveled. A fourth is traffic operations, including traffic-flow management by transportation agencies and individual driving behavior.

Fuel Economy

In 2007, Congress enacted fuel economy standards that will require that the average of all new vehicles in the light-duty automotive fleet, which includes cars, light trucks, and sports utility vehicles, achieve a standard of 35 miles per gallon by 2020. The average today for both new and existing vehicles is approximately 20 mpg, so this will bring about a major change in the vehicles produced and sold by the auto industry.

Alternative Fuels and Hybrid Vehicles

It is hoped that alternative fuels, such as ethanol and biodiesel, will help reduce GHG emissions because they emit less CO_2 for each unit of energy produced. There is also interest in the contribution that hybrids, plug-in electric and hydrogen-fueled vehicles can make in the future. Alternative fuels represent less than two percent of the fuel supply in 2006, and DOE projects that they will rise to only eight percent by 2030.

- **Gas–Electric Hybrids.** A good example of the potential of hybrid vehicles is the Prius, which is rated at 46 mpg in average fuel efficiency, as compared to a standard Toyota vehicle, the Corolla, which is rated at 27 mpg city and 35 mpg highway.

- **Plug-In Electric Hybrids.** Plug-in electric hybrid vehicles are being developed. Many of them are expected to achieve fuel efficiency rates of 100 mpg. According to DOE, their commercial deployment is not expected to occur until around 2015.

- **Biofuels.** Federal and state laws have promoted increased use of ethanol and other biofuels as an energy supply for transportation vehicles. For example, in 2007 Congress enacted energy legislation mandating the production of 36 billion gallons of biofuels by 2020. While most current biofuels come from corn, there is great interest in the development of cellulosic ethanol, which is expected to represent a more clear-cut reduction in GHG emissions.

- **Zero-Emission Vehicles, Like Hydrogen.** Also under development are hydrogen fuel-cell powered vehicles which produce zero GHG emissions from the vehicle itself. (Energy is required to produce the hydrogen fuel supply for the vehicles; if fossil fuels are used to produce the hydrogen, then there will be some GHG emissions associated with the use of hydrogen-powered vehicles.) Hydrogen-powered vehicles are unlikely to become widespread by 2030, but they could become more widely used between 2030 and 2050.

Strategies to Reduce Growth in VMT. There is great interest in policies to reduce the growth of highway demand by shifting trips to other modes of travel. AASHTO, for example, supports a policy to double transit ridership by 2030. There is hope that making more trips by biking, walking, and telecommuting could help reduce GHG emissions as well.

Potential of Transit and Land Use. Many hope that increased transit usage can result in a net reduction in GHG emissions. What is not clear is to what extent. Research done for the Pew Center for Global Climate Change found that, "reducing emissions via increased use of transit would require momentous efforts as transit accounts for only one percent of passenger-miles traveled in the United States today." A recent report, published by several smart growth advocacy groups concluded that the combination of aggressive land-use strategies and increased transit ridership could bring about transportation-related CO_2 emission reductions in the range of 7 to 10 percent.

Reducing Congestion to Reduce GHG Emissions. Many transportation agencies believe that reducing traffic congestion can make a significant contribution to reducing GHG emissions. They point to the billions of gallons of fuel burned by vehicles stuck in traffic that would no longer take place if congestion could be reduced. Smoothing out traffic so vehicles can travel at speeds that burn fuel at more optimal rates has been documented as reducing emissions. Some researchers support congestion relief as a strategy that would result in net reductions in emissions. Others do not recommend congestion reduction as a desired strategy, because of the fear it could encourage more driving and thus increase VMT.

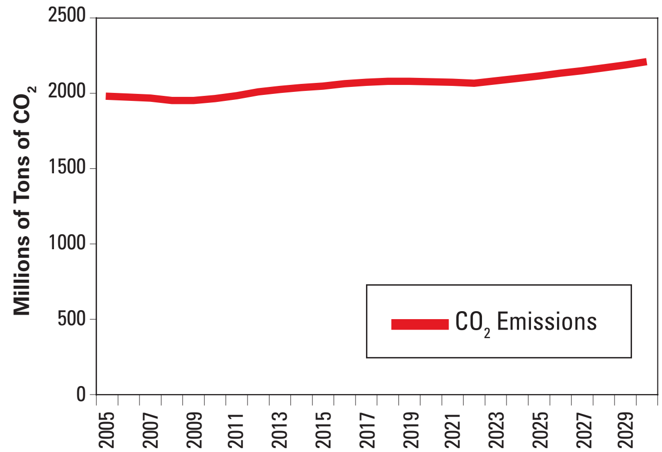
Department of Energy Projections Show Reduction of Road-Related GHG Emissions Will Be Difficult. With regard to increasing fuel economy, DOE projects that the average fuel economy for all light-duty vehicles, new and existing, will rise from 19.9 mpg in 2006 to 27.9 in 2030. DOE shows most of this increase occurring by 2021, with little additional improvement between 2021 and 2030. DOE makes similarly conservative assessments of the change expected to occur from alternative fuels. Finally, DOE forecasts that VMT will increase by 1.6 percent annually through 2030. (Figure 1)

More Potential for Transportation Sector GHG Emission Reductions May Exist Because High Petroleum Prices Are Expected to Stimulate Technological Innovation and Market Changes. While official forecasts are important to consider, they do not reflect the potential impact of major technological breakthroughs or policy changes.

Scenarios Illustrate GHG Emission Reductions Possible Through Changes in Technology and Policy

AASHTO-sponsored research tested four scenarios to see the GHG emission reductions that could be achieved through significant increases in fuel efficiency and reductions in VMT growth. The most aggressive scenario was for average fuel economy increasing to 100 mpg-ge*, and VMT increasing one percent annually through 2050. *This scenario achieved a decrease in CO_2 emissions from light-duty vehicles of 68 percent from 2005 levels by 2050.*

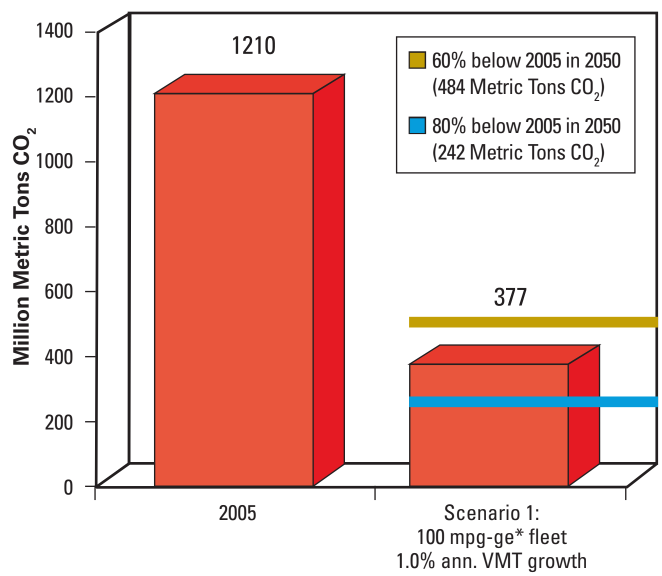
Figure 1a. DOE 2030 Forecast for CO_2 Emissions from All Transportation Sources



Source: U.S. DOE, Annual Energy Outlook 2008, Revised Early Release (March 2008). Based on 35 mpg CAFE standard.

Figure 1b. AASHTO Emissions Showing Major Reductions in CO_2 Emissions from Light-Duty Vehicles

CO_2 Reduction Scenario for 2050 100 mpg, 1% VMT Growth



* Miles per gallon-gasoline equivalent.

With average fuel economy equaling 100 mpg-ge and vehicle miles traveled increasing 1 percent annually CO_2 emissions from light-duty vehicles would be reduced to 377 million metric tons, a decrease of approximately 68 percent, by 2050.

Part I: The Causes and Impacts of Climate Change

The science of climate change is evolving and complex, but there is widespread agreement among leading scientists and governments around the world on three key points:

- ***The global climate is becoming warmer.*** Global average temperatures have increased measurably in the past century. The temperature increase is widespread across the globe.

- ***Global warming, if allowed to continue unchecked, will cause severe and lasting impacts.*** The impacts of global warming are now evident in rising sea levels, shrinking polar ice, warmer winters, and retreating glaciers. As global warming continues, these impacts will become more severe. While impacts will vary by region, all parts of the world will be affected by climate change.

- ***Global warming is caused in large part by human activities.*** Human activities contribute to climate change by releasing greenhouse gases, which accumulate in the atmosphere and trap the earth's heat. Human activities also contribute to climate change by reducing the earth's ability to *absorb* greenhouse gas emissions by converting forested lands to other uses.

There are many excellent sources of information on the causes and potential impacts of climate change. For a general introduction, refer to the *Climate Change 101* series published by the Pew Center for Global Climate Change, including "Climate Change 101: The Science and Impacts." See Reference Materials section.

The Evidence of Climate Change

There have been hundreds of scientific studies in recent years that have attempted to measure the pace of global climate change and determine the role of human activities in causing that change. To synthesize this vast body of research, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the U.N. Environment Programme and the World Meteorological Organization. The IPCC includes leading scientists from around the world. Its role is to synthesize the latest scientific research on climate change.[1]

The IPCC's *Fourth Assessment Report*, issued in November 2007, concludes that the evidence of global

[1] For more information, refer to the IPCC web site: http://www.ipcc.ch/index.htm.

warming is now "unequivocal." Some of the IPCC's most important findings include:

- ***Rising Temperatures.*** Eleven of the twelve years from 1995 to 2006 rank among the 12 warmest years for global surface temperature since 1850, when recordkeeping began. This temperature increase is widespread over the globe, and is greater at higher northern latitudes.[2]

- ***Rising Sea Levels.*** Since 1961, global average sea level has risen at an average rate of 1.8 millimeters (mm) per year. Since 1993, the average rate has increased to 3.1 mm/yr.[3]

- ***Retreating Arctic Ice.*** Since 1978, the annual average extent of Arctic Sea ice has shrunk by 2.7 percent per decade. The summer average extent of Arctic Sea ice—that is, the average during the warmest part of the year—has shrunk by 7.4 percent per decade. Similarly, glaciers and snow cover have been shrinking.[4]

The IPCC's conclusions have been widely accepted as representing the consensus of opinion in the scientific community. For example, while the United States government has been reluctant to adopt specific goals for reducing greenhouse gas emissions, the Environmental Protection Agency (EPA) accepted the main conclusions stated in the IPCC's Fourth Assessment Report.[5] Recent publications from the Transportation Research Board (TRB) and the Federal Highway Administration (FHWA) also accept the IPCC's conclusions as authoritative.[6]

Businesses—including many of the largest corporations in the United States—have also accepted the IPCC's conclusions and are acting to minimize risks and take advantage of opportunities presented by climate change. A recent report from McKinsey & Company, a consulting firm, noted that many U.S. businesses are establishing aggressive greenhouse gas abatement plans and are investing heavily to capture the business opportunities presented by climate change.[7] Lloyds of London, one of the world's largest and oldest insurers, issued a report in June 2006 concluding that the climate change presents substantial, immediate risks for insurers.[8]

The Impacts of Climate Change on the Transportation System

The Transportation Research Board (TRB) recently issued a comprehensive national report on the potential impacts of climate change on the U.S. transportation system.[9] Based on the IPCC's Fourth Assessment Report and numerous other sources, the TRB report identified five climate changes of particular importance for the transportation system in the United States:

- ***Increases in very hot days and heat waves.*** "It is highly likely (greater than 90 percent probability of occurrence) that heat extremes and heat waves will continue to become more intense, longer lasting, and more frequent in most regions during the 21st century. In 2007, for example, the probability of having five summer days at or above [110°F] in Dallas is about 2 percent. In 25 years, this probability increases to 5 percent; in 50 years, to 25 percent; and by 2099, to 90 percent." (p. 2)

- ***Increases in Arctic temperatures.*** "Arctic warming is virtually certain (greater than 99 percent probability of occurrence), as temperature increases are expected to be greatest over land and at most high northern latitudes. As much as 90 percent of the upper layer of permafrost could thaw under more pessimistic emission scenari-

[2] IPCC, *Fourth Assessment Report,* "Summary for Policymakers," p. 1.
[3] IPCC, *Fourth Assessment Report,* "Summary for Policymakers," p. 1.
[4] IPCC, *Fourth Assessment Report,* "Summary for Policymakers," p. 1.
[5] U.S. EPA, Notice of Decision Denying a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emissions Standards for New Motor Vehicles, 73 Fed. Reg. 156 (Feb. 29, 2008).
[6] TRB, *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation* (2008); Federal Highway Administration, *Information on Climate Change and Transportation* (March 2008).
[7] McKinsey & Co., *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost* (Dec. 2007).
[8] T. McAlister, "Lloyd's Tells Members Climate Change Could Destroy Insurers," *The Guardian* (June 6, 2006); see also Lloyds of London, "Climate Change Adapt or Bust" (June 2006), available at: http://www.lloyds.com/News_Centre/360_risk_project/Climate_change/.
[9] TRB, *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation* (2008).

os. The greatest temperature increases in North America are projected to occur in the winter in northern parts of Alaska and Canada as a result of feedback effects of shortened periods of snow cover….” (p. 2)

- ***Rising sea levels.*** “It is virtually certain (greater than 99 percent probability of occurrence) that sea levels will continue to rise in the 21st century as a result of thermal expansion and loss of mass from ice sheets. The projected global range in sea level rise is from [7.1 inches] to [23.2 inches] by 2099, but the rise will not be geographically uniform….These estimates do not include subsidence in the Gulf and uplift along the New England Coast. Nor do the global projections include the full effects of increased melting of the Greenland and Antarctic ice masses because current understanding of these effects is too limited to permit projection of an upper bound on sea level rise.” (p. 2)

- ***Increases in intense precipitation events.*** “It is highly likely (greater than 90 percent probability of occurrence) that intense precipitation events will continue to become more frequent in widespread areas of the United States.” (p. 2)

- ***Increases in hurricane intensity.*** “Increased tropical storm intensities, with larger peak wind speeds and more intense precipitation, are projected as likely (greater than 66 percent probability of occurrence).” (pp. 2–3)

These changes in climate will affect the transportation system in many ways. The TRB report noted several specific examples, including:

- ***Operational and maintenance impacts of excessive heat.*** “Periods of excessive summer heat are likely to increase wildfires, threatening communities and infrastructure directly and bringing about road and rail closures in affected areas. Longer periods of extreme heat may compromise pavement integrity (e.g., softening asphalt and increasing rutting from traffic); cause deformation of rail lines and derailments or, at a minimum, speed restrictions; and cause thermal expansion of bridge joints, adversely affecting bridge operation and increasing maintenance costs.” (p. 66)

- ***Increased flooding of coastal roads and rail lines.*** “The most immediate impact of more intense precipitation will be increased flooding of coastal roads and rail lines. Expected sea level rise will aggravate the flooding because storm surges will build on a higher base, reaching farther inland….[The IPCC] identifies coastal flooding from expected sea level rise and storm surge, especially along the Gulf and Atlantic coasts, as one of the most serious effects of climate change. Indeed, several studies of sea level rise project that transportation infrastructure in some coastal areas along the Gulf of Mexico and the Atlantic will be permanently inundated sometime in the next century.” (p. 68)

- ***Disruption of coastal waterway systems.*** “[A] combination of sea level rise and storm surge could eliminate waterway systems entirely. For example, the Gulf Coast portion of the intercoastal waterway will likely disappear with continued land subsidence and disappearance of barrier islands. This will bring an end to coastal barge traffic, which helps offset rail and highway congestion; all ships will have to navigate the open seas.” (p. 69)

- ***Impacts on Alaskan infrastructure.*** “The effects of temperature warming are already being experienced in Alaska in the form of continued retreat of permafrost regions (see the discussion of Alaska below), creating land subsidence issues for some sections of the road and rail systems and for some of the elevated supports for aboveground sections of the Trans-Alaska pipeline. Warming winter temperatures have also shortened the season for ice roads that provide vital access to communities and industrial activities in remote areas.” (p. 68)

Several other studies have also concluded that climate change is likely to have widespread and severe impacts on transportation infrastructure. These studies include:

- ***U.S. DOT Gulf Coast Study.*** This study examined the potential impacts of climate change on transportation infrastructure in the Gulf Coast region. The study recognized "four key climate drivers" in the Gulf Coast region: rising temperatures, changing precipitation patterns, rising sea levels, and increasing storm intensity. It suggested a range of possible responses, including raising transportation facilities in low-lying areas; hardening them to withstand storm events; relocating them to areas that are less vulnerable; and expanding redundant systems where needed.[10]

- ***ICF Studies of Sea-Level Rise.*** This two-part study focused specifically on the potential impacts of sea-level rise (not climate change in general) on transportation infrastructure. Phase 1 included maps showing impacts of sea-level rise under a range of scenarios on the District of Columbia, Maryland, Virginia, and North Carolina. Phase 2, which is still under way, will evaluate impacts of sea-level rise on seven additional states on the East Coast: New York, New Jersey, Pennsylvania, Delaware, South Carolina, Georgia, and the Atlantic Coast of Florida.[11]

As these studies reflect, there is a growing consensus that climate change has already begun to have impacts on the transportation system and that those impacts will become more severe over time as the global climate continues to warm.

The Causes of Climate Change

Greenhouse gases (GHGs) exist naturally in the earth's atmosphere. Indeed, their presence allows the earth to remain warm enough to support life. The problem of global warming is that GHG concentrations in the atmosphere are increasing above their natural levels, which in turn results in warming temperatures. According to the IPCC, global atmospheric concentrations of CO_2 and other GHGs "have increased markedly" since 1750 and now "far exceed pre-industrial values."[12] For example, the concentration of CO_2 rose from **280** parts per million (ppm) in 1750 to **380 ppm** in 2005.[13] The IPCC found that the current global atmospheric concentration of CO_2 far exceeds the natural range over the past 650,000 years.[14]

The IPCC has concluded, and the majority of scientists agree, that the increasing GHG concentrations in the atmosphere can only be explained by taking into account human activities. Specifically, scientists have identified two primary drivers of climate change: (1) the ***increase in GHG emissions*** that result from the combustion of fossil fuels and other human activities; and (2) the ***decrease in carbon absorption*** that results from deforestation and other land-clearing.

Increasing GHG Emissions

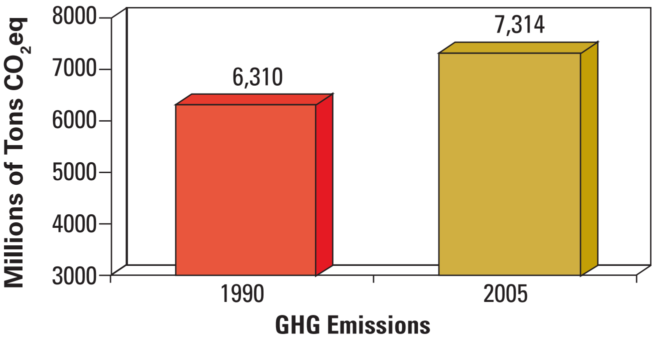
In recent years, GHG emissions have grown substantially, despite increases in energy efficiency. These increases are evident both in the United States and around the world. The rising trends in GHG emissions result from demographic, economic, and social changes that are, in many respects, accelerating. In particular, booming economic growth in developing countries such as China and India has greatly increased GHG emissions in those countries.

GHG Emissions Trends in the United States. In its most recent inventory of GHG emissions in the United States, the EPA found that:

- ***Total GHG emissions in the United States have been increasing.*** From 1990 to 2006, total GHG emissions in the United States rose **14.1 percent**.

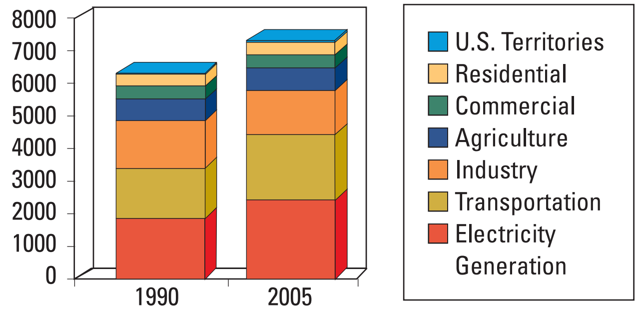
[10] U.S. DOT, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1—Final Report* (March 2008).
[11] *See* ICF International Inc., *The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure, Phase I Final Report* (Nov. 2007). 12 IPCC, *Fourth Assessment Report,* Topic 2, p. 37.
[13] ibid.
[14] IPCC, *Fourth Assessment Report,* Topic 2, p. 3.

Figure 2. Total U.S. GHG Emissions—1990 and 2005



Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (Feb. 2008).

Figure 3. GHG Emissions 1990 and 2005 by Economic Sector



Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (Feb. 2008).

Total GHG emissions in the United States in 2006 were approximately 7.2 billion metric tons. Emissions in 2006 actually decreased slightly from 2005, when the total was approximately 7.3 billion metric tons.[15] (Figure 2)

- ***CO_2 emissions make up the majority of GHG emissions in the United States.*** In 2006, CO_2 emissions represented approximately **83 percent** of GHG emissions in the United States. Total CO_2 emissions in the United States in 2006 were approximately 6 billion metric tons.[16] The vast majority (94 percent) of CO_2 emissions result from the combustion of fossil fuels.[17] (Figure 3)

- ***CO_2 emissions have been increasing at a faster rate than other GHGs.*** From 1990 to 2006, emissions of CO_2 increased **19.4 percent**, which is faster than the overall rate of increase for GHG emissions (14.1 percent).[18]

- ***The transportation sector contributes a large—and increasing—share of GHG emissions.*** Transportation sources—including roads, rail, air, and marine travel—accounted for approximately **27 percent** of all GHG emissions in the United States in 2005; the electricity sector was the only larger contributor, with 33 percent of all GHG emissions.[19] (Table 1)

Table 1. Percentage of Greenhouse Gas Emissions by Economic Sector

Sector	Percent of U.S. Greenhouse Gas Emissions in 2006
Electricity Generation	33%
Transportation	27%
Industry	19%
Agriculture	10%
Commercial	6%
Residential	5%
U.S. Territories	1%

Source: U.S. EPA Inventory of Greenhouse Gas Emissions and Sinks (Feb. 2008).

Emissions from both the electricity generation and transportation sectors have been trending upward. By contrast, GHG emissions in other sectors—such as agriculture and industry—have been declining due to structural changes in the U.S. economy.

The following charts, which are based on data from the EPA emissions inventory, show these trends in GHG emissions. The first (Figure 2) shows the increase in GHG emissions from 1990 to the present; the second (Figure 3) shows the contribution from the energy, transportation, and other sectors of the economy; the third (Table 1) shows the percentage of GHG emissions by economic sector in 2006.[20]

[15] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2006—Public Review Draft* (Feb. 2008), p. ES-16.
[16] EPA, *GHG Inventory 1990–2006*, p. ES-7.
[17] ibid.
[18] EPA, *GHG Inventory 1990–2006*, p. ES-16.
[19] ibid.
[20] EPA, *GHG Inventory 1990–2006*, pp. ES-4 and ES-14.

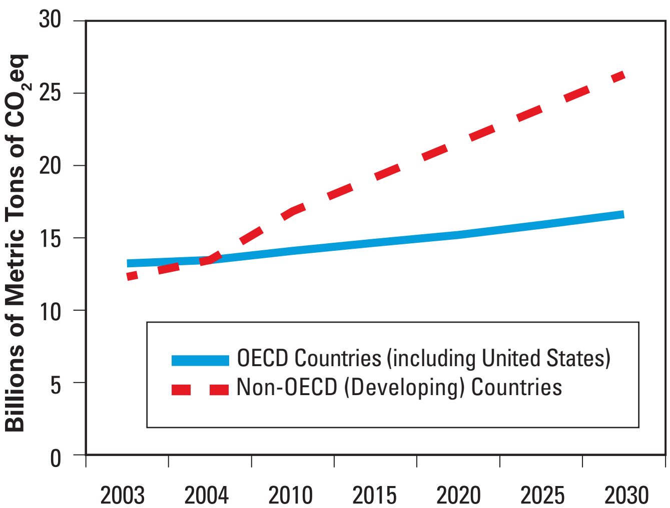
Based on official United States government forecasts, McKinsey & Company projects that GHG emissions will continue to increase, in the absence of major policy changes, at approximately 1.2 percent annually through 2030. McKinsey notes that, while this annual rate may appear small, it would result in a ***35 percent increase in total GHG emissions in the United States by 2030.*** Under this baseline scenario, GHG emissions would rise from 7.2 billion metric tons of CO_{2eq} in 2005 to 9.7 billion metric tons in 2030.[21]

Global Trends in GHG Emissions. GHG emissions are increasing faster in developing countries than in the United States. China is rapidly approaching—and may have even surpassed—the United States as the world's largest emitter of GHGs. Despite their rapid growth, per capita emissions in China and India are expected to remain a small fraction of the United States' level for the coming future: by 2025, China is expected to have a per capita rate that is only one-fourth, and India one-fourteenth, the level of America's per capita emissions.[22] But even with these lower per-capita levels, total GHG emissions from developing (non-OECD) countries are projected to exceed those of developed (OECD) countries by a substantial margin by 2030.[23] (Figure 4)

Reducing Carbon Absorption

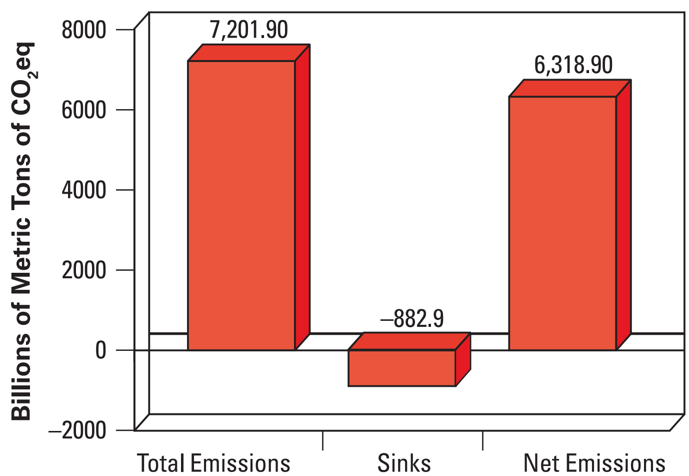
Human activities also affect the earth's ability to absorb CO_2 from the atmosphere. Forests and grasslands are considered "carbon sinks" because they naturally absorb large quantities of CO_2 through the process of photosynthesis. Clearing these lands, which occurs when they are converted to agricultural use or development, reduces the absorption

Figure 4. Total GHG Emissions Worldwide—2005 to 2030



Source: USDOE, International Energy Outlook 2007.

Figure 5. Net GHG Emissions in United States in 2006—Sources and Sinks



Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (Feb. 2008).

[21] McKinsey Report, p. 6.

[22] Pew Center on Global Climate Change, "Climate Change 101: International Actions."

[23] U.S. DOE, *International Energy Outlook 2008*, Fig. 77. The OECD is the Organization for Economic Cooperation and Development. Its members include the United States and other developed (higher-income) nations.

of CO_2 from the atmosphere. Thus, humans contribute to global warming both by emitting GHGs and by reducing the earth's natural ability to absorb CO_2 emissions.

According to the EPA's latest inventory, carbon sinks within the United States offset **12.3 percent** of all GHG emissions in this country in 2006.[24] The total GHG emissions, the amount offset by carbon sinks, and the net GHG emissions are shown in Figure 5.

Based on United States government forecasts, the McKinsey report estimates that carbon absorption in the United States will decline by nearly 7 percent between 2005 and 2030.[25] The report notes that this decline results from "fewer net additions to forested lands within the United States and slower rates of carbon absorption in maturing forests."[26] Concerns also have been expressed that increased reliance on biofuels will result in additional land-clearing, which would further reduce carbon absorption.[27]

Resources for the Future, a non-partisan think-tank, estimates that "the size of the global forest carbon stock appears to be declining, albeit less rapidly than previously," as deforestation trends in tropical areas are offset to some extent by expanding forests in the world's temperate and boreal (northern) areas.[28] The report concludes that while forest decline is a concern, it is not the major driver of climate change: "the primary cause of the build-up in atmospheric carbon is not attributable to land use changes, but is due largely to fossil fuel burning and its associated emissions."[29]

GHG Accounting: How GHG Emissions Are Measured

The most prevalent greenhouse gases (GHGs) in the atmosphere are ***carbon dioxide*** (CO_2) and water vapor. Other GHGs include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons, perflourocarbons, and sulfur hexafluoride.

GHGs vary in their effectiveness at trapping the earth's heat—also known as their ***global warming potential***. For example, one ton of methane affects the climate as much as 21 tons of carbon dioxide. To provide a standard unit measurement for global warming potential, GHG emissions are typically quantified in terms of their ***carbon dioxide equivalent*** (CO_2eq)—that is, the warming potential equivalent to one ton of carbon dioxide. Thus, a single ton of methane would have a **"CO_{2eq}"** of 21 tons.[30]

GHG emissions are typically measured in ***metric tons*** (sometimes called ***tonnes***) or other metric units. A metric ton is equal to approximately 2,205 pounds. The terms ***teragram*** and ***gigaton*** are also often used to express the quantity of GHG emissions. These can be translated into metric tons as follows: 1 teragram = 1 million metric tons; 1 gigaton = 1 billion metric tons. For example, the EPA gives the total GHG emissions for the U.S. in 2006 as 7,201.9 teragrams of CO_2eq. The same number could be expressed as 7.2 gigatons (or 7.2 billion tons) of CO_2eq.[31] It also could be expressed as 7,201 million tons of CO_2eq.

For further information on calculating GHG emissions, refer to the U.S. EPA publication, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2006* (Feb. 22, 2008).

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[24] EPA, *GHG Inventory 1990–2006*, p. ES-7.
[25] McKinsey Report, p. 8.
[26] ibid.
[27] E. Rosenthal, "Studies Call Biofuels a Greenhouse Threat," New York Times (Feb. 8, 2008).
[28] Resources for the Future, "Forest and Biological Carbon Sinks After Kyoto" (March 2006), pp. 5–6.
[29] Resources for the Future, "Forest and Biological Carbon Sinks After Kyoto" (March 2006), p. 6.
[30] EPA, *GHG Inventory 1990–2006,* p. ES-3. [check]
[31] ibid.

Part II: Climate Change and Public Policy

This section provides an introduction to climate change policy. It first reviews the basic goals of climate change policy: How much should global temperatures be allowed to rise? At what level should atmospheric concentrations of GHGs be stabilized? And how much do GHG emissions need to be reduced? It then surveys the principal policy tools that could be used to achieve these goals, including widely debated topics such as a cap-and-trade program for GHG emissions.

The Goals of Climate Change Policy

The two primary goals of climate change policy are to ***stabilize global average temperatures*** and ***prepare for the impacts of climate change.***

A Global Challenge, Not a Localized Problem

It is the *global total* of GHG emissions (minus carbon absorption) that will determine the rate of global warming. Therefore, reductions in GHG emissions from a specific sector of the economy, or in a specific country or region, are all equally valuable in reducing net emissions worldwide. As one expert recently testified in a U.S. Senate hearing, "greenhouse gases mix quickly throughout the atmosphere, which means that wherever you can reduce a ton of greenhouse gas emissions—whether from a car, a factory, or a power plant; whether in Los Angeles, London, or Lagos—the benefit to the climate is the same."[32]

From a practical and political standpoint, however, it *does* matter how the burdens of reducing GHG emissions are shared across countries and economic sectors. If the burdens are seen as falling disproportionately on one country, one region, or one economic sector, it will be far more difficult to gain support for significant climate change initiatives. These practical and political imperatives create strong pressure for policies to ensure that each region and sector contributes its "fair share" to reducing GHG emissions. Judgments about what constitutes a "fair share" are fundamentally policy judgments, not scientific facts.

Ultimately, any solution to the climate change problem must be global in scale. Reducing GHG emissions in the United States—or even eliminating them altogether—will not solve the problem if GHG emissions continue to rise robustly in developing nations. Reducing GHG emissions in developing countries such as China will be especially challenging, because their rapid economic growth and rising incomes will tend to push GHG emissions upward. ***Meeting this global challenge will require major technological innovations.*** Only through technological breakthroughs will it be possible for developing nations (as well as developed nations) to enjoy the benefits of economic growth while at the same time dramatically cutting GHG emissions.

[32] E. Claussen, President, Pew Center for Global Climate Change, Testimony to U.S. Senate Committee on Environment and Public Works, Nov. 15, 2007, available at: http://www.pewclimate.org/testimony/11.15.07/ec_epw.

Stabilizing Global Average Temperatures

It is now considered inevitable that temperatures will continue to increase for decades to come, both because of GHGs that have already been emitted and because global GHG emissions will continue growing for many years into the future.

The IPCC has defined a range of potential scenarios for stabilizing global average temperatures. At the low end, the IPCC examined a scenario under which global average temperatures increase between 1.1 and 2.9°C by 2099; at the high end, the IPCC identified a scenario under which average temperatures increase by 2.4 to 6.4°C.[33] Significant impacts would occur even at the low end, but the impacts would be far more severe at the high end of this range. As a frame of reference, the Earth is now approximately 5°C warmer than during the last ice age.[34]

The IPCC has not recommended a specific target for stabilizing the global average temperature, nor has the U.S. government adopted such a goal. However, there is general agreement that some additional warming is inevitable, so goals are defined in terms of minimizing additional warming, not preventing it altogether. One frequently cited goal is to stabilize global average temperatures at approximately **2 to 3°C** of warming over current conditions.[35]

Stabilizing GHG Concentrations in the Atmosphere

Stabilizing global average temperatures will require stabilizing GHG concentrations in the atmosphere, because elevated GHG concentrations are directly causing temperatures to rise.

As noted earlier, the average concentration of CO_2 in the atmosphere was **280** parts per million (ppm) in pre-industrial times. In 2005, the average concentration of CO_2 had risen to approximately **380** ppm. In the future, GHG concentrations will continue to increase as a result of population growth and economic growth worldwide. If no action is taken, the GHG concentration in the atmosphere will rise dramatically by 2100. According to one report, CO_2 concentrations could rise to between **710 and 880 ppm** by 2100 if action is not taken to curb GHG emissions.[36] This would be more than double today's levels, and more than triple pre-industrial levels.

Researchers have analyzed a range of potential targets for stabilizing GHG concentrations. It may be achievable to stabilize CO_2 concentrations at **550 ppm** and to stabilize the concentration of all GHGs (CO_2 and others) at 670 ppm of CO_{2eq}.[37] At this level, global average temperatures would still increase substantially—by roughly the 2 to 3°C as described above. Other targets are certainly possible. For example, one legislative proposal currently being considered in Congress would set a goal of stabilizing the atmospheric concentration of CO_2 at 450 ppm.[38]

The Stern Review—a major report by the British government on climate change—examined potential stabilization levels between 450 and 550 ppm. However, the *Stern Review* expressed strong skepticism about the feasibility of stabilizing GHGs at the lower end of that range: "Stabilisation at 450ppm CO_{2eq} is already almost out of reach, given that we are likely to reach this level within 10 years and that there are real difficulties of making the sharp reductions required with current and foreseeable technologies."[39]

Reducing GHG Emissions

To stabilize GHG concentrations, global emissions of GHGs will need to be reduced. Estimates vary about how much of a reduction is needed. But there is agreement that an **emission reduction pathway** will need to be established—both for GHG emissions worldwide and for GHG emissions in the United States.

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[33] IPCC, *Fourth Assessment Report,* "Summary for Policymakers," Table SPM.1, p. 7.

[34] Sir Nicholas Stern, "Stern Review on the Economics of Climate Change" (Oct. 2006), p. iv.

[35] R. Ewing, et al., *Growing Cooler: The Evidence on Urban Development and Climate Change*, Urban Land Institute (Oct. 2007), p. 11.

[36] R. Newell and D. Hall, "U.S. Climate Mitigation in the Context of Global Stabilization," *Assessing U.S. Climate Policy Options* (Resources for the Future) (Nov. 2007), pp. 44–50.

[37] Newell and Hall, p. 44. For an explanation of the term CO_2eq, refer to the text box on p. 15 above ("GHG Accounting: How GHG Emissions Are Measured").

[38] S. 309, Global Warming Pollution Emission Reduction Act, introduced Jan. 7, 2007 by Sens. Boxer and Sanders.

[39] *Stern Review*, p. xv.

To date, the U.S. government has not adopted a specific GHG emissions reductions goal. However, a number of recent reports recommend setting the goal of reducing GHG emissions in the United States by **60 to 80 percent below current levels by 2050**. For example, the U.S. Climate Action Partnership (U.S. CAP)—a broad coalition of industry and environmental groups—endorsed this target.[40] This goal also has been embraced by six Midwestern States as part of the Regional Greenhouse Gas Reduction Accord, which was signed in November 2007.[41]

The IPCC also has not set a specific emission reductions goal. Instead, the IPCC analyzed a range of potential GHG reduction goals, and estimated the potential global warming consequences of each goal. The IPCC projected that a global reduction of 50 to 85 percent below 2000 levels would stabilize GHG concentrations in the atmosphere at 445 to 490 ppm and would stabilize global temperatures at 2.0 to 2.4 degrees above pre-industrial temperatures.[42] The IPCC also developed a range of other scenarios, which showed less severe reductions in emissions and correspondingly greater increases in global temperatures.

In reaction to the IPCC's report and other research, many states have adopted GHG emission reduction targets, but the policies vary widely in the way the targets are defined. Some set the targets relative to 1990 levels, while others set them relative to current levels. Some are set in legislation, while others are set by executive order or simply by an announcement. While approaches differ, the common theme is the adoption of ambitious targets for reducing GHG emissions. In fact, as shown in the table below, many states have adopted goals that are more aggressive than the goal suggested by U.S. CAP.[43] For example, several states are aiming to reduce GHG emissions by 80 percent below *1990* levels by 2050. (Table 2)

Table 2. Overview of States' Long-Term GHG Emission Reduction Goals

State	Goal
Arizona	50% below 2000 by 2040
California	80% below 1990 by 2050
Florida	80% below 1990 levels by 2050
Illinois	60% below 1990 levels by 2050
Massachusetts	75–85% below 1990 long-term
Minnesota	80% below 2005 levels by 2050
New Hampshire	75–85% below 2001 long-term
New Jersey	80% below 2006 levels by 2050
New Mexico	75% below 2000 by 2050
Oregon	75% below 1990 by 2050
Vermont	75–85% below 2001 long-term
Washington	50% below 1990 levels by 2050

Source: Pew Center on Global Climate Change, "What's Being Done," available at: http://www.pewclimate.org/what_s_being_done/targets.

In short, there is not a single agreed-upon target for reducing GHG emissions, but there is emerging consensus that dramatic reductions in total GHG emissions are needed.

Increasing Carbon Absorption

As noted above, the earth naturally absorbs CO_2 from the atmosphere. Natural "carbon sinks" include oceans, forests, and vegetated areas (e.g., grasslands). One important goal of climate policy is to increase the earth's capacity to absorb carbon. Achieving this goal primarily involves reducing deforestation, while also promoting agricultural and land-management practices that increase carbon absorption.

Within the United States, there are many opportunities—on both privately and publicly owned lands—to increase carbon absorption. For example,

[40] U.S. CAP, "A Call to Action" (2007), p. 7.

[41] Midwestern Governors Association, *Midwestern Greenhouse Gas Reduction Accord* (Nov. 15, 2007), available at: http://www.midwesterngovernors.org/resolutions/GHGAccord.pdf.

[42] IPCC, *Fourth Assessment Report,* "Summary for Policymakers," p. 21.

[43] For ease of comparison to the goal suggested by U.S. CAP (60 to 80 percent reduction from current levels by 2050), this table lists only the States' long-term GHG emission reductions goals. Many States have established GHG reduction goals for earlier years, such as 2020 and 2030. For additional information, see the Pew Center on Global Climate Change web site at: http://www.pewclimate.org/what_s_being_done/targets.

publicly and privately owned lands can be managed in ways that promote *reforestation* (re-establishing forested areas that formerly existed) as well as *afforestation* (creating new forests).[44] In addition, incentives can be provided for agricultural practices that promote carbon absorption, such as planting trees or grasses along streams and croplands; using "conservation tillage" practices, which involve leaving 30 percent or more of crop residue on the soil after planting; and rotational grazing.[45]

Policies to promote GHG emissions reductions can have the unfortunate side-effect of reducing carbon absorption. For example, biofuels—such as ethanol—have been promoted as a way to reduce GHG emissions because they emit less carbon when burned than petroleum-based fuels such as gasoline. But producing biofuels on a large scale will require the clearing of additional land for agriculture. Conversion of forested lands to agricultural use will reduce carbon absorption, potentially offsetting the benefits of biofuels. One recent study predicted that "corn-based ethanol, instead of producing a 20 percent savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50 percent."[46] But the same study also highlighted the value of biofuels produced from waste products such as municipal waste, crop waste, and fall grass harvests from reserve lands because such biofuels can avoid land-use change and its associated GHG emission. The study also noted that "[a]lgae grown in the desert or feedstocks produced on lands that generate little carbon today might also keep land-use change emissions low…."

While carbon absorption is an important component of climate policy, it is not viewed as a complete solution in its own right. Total GHG emissions are simply too great to be entirely offset by increased carbon absorption.

Adaptation

Adapting to climate change will present challenges for all levels of government. Rather than a single national program or strategy, there will likely be many initiatives undertaken in response to the specific climate-related threats that exist in each region.

According to the Pew Center on Global Climate Change, five states have adopted adaptation strategies (as of January 2008) as part of their comprehensive climate action plans, while six others have started adaptation planning efforts.[47] In addition, cities and counties have begun to address adaptation as part of their climate plans. King County, Washington (which includes Seattle) has established an inter-departmental team to develop adaptation plans and has even produced a guidebook on this issue.[48] New York City has addressed adaptation as part of "PlaNYC," which calls for planning to protect critical infrastructure and high-risk communities from the effects of climate change.[49]

For the transportation system, the adaptation challenges will be substantial. These challenges were outlined in a major TRB report issued in March 2008, *Potential Impacts of Climate Change on U.S. Transportation*.[50] These challenges also were addressed in the U.S. DOT's Gulf Coast study, which also was released in March 2008.[51] Both of these studies underscore the need for adaptation planning at the state and local level, because of the im-

[44] EPA, "Forest Practices that Sequester or Preserve Carbon," available at: http://www.epa.gov/sequestration/forestry.html.

[45] EPA, "Agricultural Practices that Sequester and/or Preserve Carbon," available at: http://www.epa.gov/sequestration/ag.html.

[46] T. Searchinger et al., "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change" *Science*, Vol. 319 no. 5687 (Feb. 29, 2008), pp. 1238–1240; *see also* E. Rosenthal, "Studies Call Biofuels a Greenhouse Threat," New York Times (Feb. 8, 2008),

[47] Pew Center for Global Climate Change, "Climate Change 101: Adaptation" (Feb. 2008), p. 7.

[48] The guidebook, "Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments" is available at: http://www.iclei.org/documents/USA/download/0709climateGUIDEweb.pdf.

[49] Pew Center for Global Climate Change, "Climate Change 101: Adaptation" (Feb. 2008), p. 8.

[50] TRB, *Special Report 290*.

[51] U.S. DOT, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1—Final Report* (March 2008).

portant role of state and local governments in maintaining and operating the road system.

Potential Strategies for Reducing GHG Emissions in the United States

The following discussion provides a brief introduction to strategies for reducing net GHG emissions in the United States. A more detailed discussion is provided in Part III of this report as part of the discussion about how best to reduce GHG emissions from the transportation sector.

Establishing a "Carbon Price"

There is broad agreement among economists that the most cost-effective method for reducing GHG emissions is to establish a ***carbon price***—that is, an economic cost associated with the production and/or use of fuels that emit CO_2 or its equivalent into the atmosphere. Carbon pricing gives businesses and individuals an incentive to use less carbon, while giving them maximum flexibility to determine how best to minimize carbon use.[52] It also sends a signal to investors to undertake research and deployment of new, low-carbon technologies and fuels, which otherwise would not be economically competitive in the marketplace.

There are two basic approaches to establishing a carbon price—a cap-and-trade system and a carbon tax. These approaches also could be combined into a hybrid.

Cap-and-Trade Programs

Under a cap-and-trade program, the government establishes an overall limit ("cap") on the total amount of carbon (or other pollutants) that can be emitted within a given sector or in the economy as a whole, and then allocates emission "allowances" based on that overall cap. Generally, each allowance provides the right to emit one ton of carbon dioxide equivalent

[52] W. Pizer, "Scope and Point of Regulation for Pricing Policies to Reduce Fossil-Fuel CO_2 Emissions," in *Assessing U.S. Climate Policy Options* (Resources for the Future) (Nov. 2007), p. 71 ("A principal motivation for market-based policies—taxes or tradeable permits—is that they encourage the most reductions at the lowest cost compared to other policy architectures.").

(CO_{2eq}). The number of allowances decreases over time, in accordance with the goal of reducing GHG emissions. Companies have the option of purchasing allowances to cover increased emissions, but those allowances became much more expensive over time as the allowances become more scarce. This means that facilities within covered industries must find ways to consistently reduce their emissions. A company that has made sufficient gains in reducing emissions will possess excess allowances that it can sell on the open market. Under a cap-and-trade program, allowances can be distributed to emitting facilities for free (based on their current emissions), or can be distributed by auction, or through a combination of an auction and free distribution.

If a substantial number of the allowances are auctioned, a cap-and-trade program has the potential to generate enormous revenues. The magnitude of the revenue stream depends on the cost of the allowances, which would be determined in the auction. **However, it is reasonable to expect that a national cap-and-trade program could generate $ 100 billion or more in revenues annually.[53]** In creating such a program, one critically important decision will be the distribution of these revenues. They could be used to reduce existing taxes, support funding for existing or new programs, reimburse individuals or businesses that are disproportionately affected by higher energy prices, or a combination of these purposes. (The same would be true of a carbon tax.)

For additional information on cap-and-trade programs, refer to the Pew Center on Global Climate Change's paper, "Climate Change 101: Cap and Trade" (Feb. 2008).[54] The Pew Center's paper describes the European cap-and-trade program, regional cap-and-trade programs that have recently been established in the United States, and current legislative efforts to create a national cap-and-trade program in the United States. It also describes the mechanics of cap-and-trade programs.

Carbon Tax

The primary legislative alternative to a cap-and-trade program is the carbon tax. A carbon tax, rather than using the markets to price carbon, relies on the government to set the price charged for every ton of carbon dioxide emitted. Some carbon tax plans are revenue neutral, meaning that the government reduces other taxes as a way of redistributing revenue generated by the carbon tax. At this point, there is little broad political support for a carbon tax. Various bills have been introduced in the House and the Senate within the last two years, but none has garnered much attention. Many economists favor a carbon tax over a cap-and-trade program, seeing a carbon tax as more efficient and avoiding potential windfalls to polluting industries.

It also is possible to devise a system that combines some of the features of a carbon tax with those of a cap-and-trade system. For example, a cap-and-trade system could include a "safety valve," which would essentially be a ceiling on the price of carbon. This would provide some of the price certainty of a carbon tax, without actually imposing a tax. There continues to be debate about the relative merits of each approach, but there appears to be broad consensus on one fundamental point: it is necessary, in some manner, to establish an economy-wide price of carbon, in order to create permanent and powerful economic incentives for reducing GHG emissions and for private investment in low-carbon technologies and fuels that otherwise would not be economically viable.

For additional information on carbon pricing, refer to the Congressional Budget Office (CBO) study, "Policy Options for Reducing CO_2 Emissions" (Feb. 2008).[55] The CBO study compares the advantages and disadvantages of cap-and-trade programs and a carbon tax, and also explores potential hybrid concepts that combine the features of both approaches.[56]

Other Strategies to Promote GHG Emission Reductions

Even if a cap-and-trade program or a carbon tax is implemented, there is likely to be a role for other policy tools—mostly likely, a mix of mandates, voluntary initiatives, and research funding—to promote the development and widespread adoption of energy-efficient

[53] R. Kopp, "Allowance Allocation," in *Assessing U.S. Climate Policy Options*, Resources for the Future (Nov. 2007), p. 88.
[54] This paper is available at: http://www.pewclimate.org/docUploads/Cap&Trade.pdf.
[55] This paper is available at: http://www.cbo.gov/ftpdocs/89xx/doc8934/02-12-Carbon.pdf.
[56] See also I. Parry, "Should We Abandon Cap and Trade in Favor of a Carbon Tax?", available at: http://www.rff.org/rff/News/Features/AbandonCapandTrade.cfm.

technologies. These types of policies may be implemented at the federal, state, or local levels. The following discussion provides a brief introduction to these potential strategies.

Regulatory Strategies

Governments can adopt policies that directly regulate—i.e., limit—emissions of GHGs from certain types of facilities or activities. In general, regulatory strategies set a minimum level of performance that must be achieved by all regulated entities. In many cases, regulatory standards are "technology forcing" in the sense that they promote innovation by setting a standard that can only be achieved through the development of new, more energy-efficient technologies.

For example, the corporate average fuel economy (CAFE) standards, which were first established in 1975, established minimum requirements that must be met by new motor vehicles. The CAFE standards were increased in 2007, when Congress passed legislation requiring all manufacturers to achieve 35 mpg as the average fuel economy for new light-duty vehicles by 2020. The CAFE standards are widely credited with increasing fuel economy by giving auto manufacturers an incentive to develop more fuel-efficient vehicles.

Mandates also could be adopted in other economic sectors—for example, requiring electric utilities to generate a specific percentage of their power from renewable sources. In the longer term, more far-reaching regulatory policies also could be adopted. For example, new requirements could be adopted that would directly limit GHG emissions from certain types of facilities, vehicles, business processes, or consumer products.

Voluntary Initiatives

Governments also can promote voluntary emission reductions through programs that provide businesses and consumers with incentives and/or improved access to information. For example, the "EnergyStar" program, which is operated jointly by the U.S. Department of Energy and EPA, seeks to promote energy efficiency through a rating system for home and workplace products. The system is voluntary but has come into widespread use. The EPA estimates that the Energy Star program has dramatically increased the use of energy-efficient products by promoting awareness and giving consumers better information about energy usage when they make purchasing decisions.[57]

R&D Funding

Federal and State governments can use research funding to accelerate the development of more energy-efficient technologies. For example, the federal government has established the FreedomCar and Fuel Partnership Program to promote the development of hydrogen-powered vehicles.[58] In addition, the DOE has funded the FutureGen program, which provides funding to support the development of coal-fired power plants with near-zero-emissions, through the use of carbon capture and sequestration. Although DOE recently proposed to re-structure that program, it represents an example of federal funding for the development of next-generation technologies that can be used to dramatically lower GHG emissions.[59]

The range of potential strategies for reducing GHG emissions in the United States is extremely broad, and extends well beyond the few examples mentioned here. The important point to recognize is simply that reducing GHG emissions in the transportation sector is one part of a much larger challenge. Ultimately, any successful effort to reduce GHG emissions in the United States will almost certainly involve many separate initiatives, and will encompass every significant GHG-emitting sector of the economy.

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[57] EPA, "EnergyStar and Other Climate Protection Partnerships: 2006 Annual Report" available at: http://www.energystar.gov/ia/news/downloads/annual_report_2006.pdf.

[58] U.S. DOE, "FreedomCar and Fuel Partnership Program Plan" (March 2006), available at: http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/fc_fuel_partnership_plan.pdf.

[59] For additional information, see: http://www.fossil.energy.gov/programs/powersystems/futuregen/.




Part III: Trends in GHG Emissions from Road Travel

The transportation system is the second-largest contributor to GHG emissions in the United States, and the majority—approximately **72 percent**—of the transportation sector's emissions are generated by road transportation, including both passenger and freight travel. The large and increasing GHG emissions from road transportation present a major policy challenge.

The first step in addressing this challenge is to understand the facts. What is driving the trend toward rising GHG emissions? What are current government forecasts showing for the future? What types of changes would be needed in order to reverse the trends so that road transportation can become part of the solution, not part of the problem? This section begins to answer these questions by bringing together some basic facts about GHG emissions from the transportation system, specifically focusing on road transportation.

Data Sources

The facts presented in this section are based primarily on official government reports prepared by FHWA, EPA, and the U.S. Department of Energy (DOE).[60] These official reports underlie most of the forecasts developed by independent researchers and interest groups regarding GHG emissions of road transportation.

- **FHWA, Highway Statistics.** This report is prepared annually by the FHWA Office of Highway Policy Information. The report includes detailed break-downs of VMT as well as total fuel consumption, but does not include data on GHG emissions. The report includes only historical data (1945 through 2006); it does not include projections of future trends.
- **FHWA, *Conditions and Performance Report*.** This report is prepared by FHWA every two years. The most recent report, issued in 2006, is based on 2004 data. The report primarily includes historical data, along with some projections through 2024. Important information in this report includes vehicle miles of travel (VMT) growth rates from 1984 through 2004, as well as projected VMT growth trends through 2024. Notably, the FHWA forecast of VMT growth is somewhat

[60] See the Reference Materials section at the end of this Primer for links to these reports.

higher than the forecast in DOE's *Annual Energy Outlook*, as discussed below.

- **U.S. DOE, *Annual Energy Outlook.*** This report is prepared annually by the USDOE Energy Information Administration. The report provides a 25-year forecast of various measures of energy usage for all sectors of the economy. The report includes forecasts for VMT, fuel economy (miles per gallon), and energy usage (measured in BTUs), all of which are broken down by vehicle type. The report also provides CO_2 emissions for the transportation sector as a whole. The DOE's projections extend through 2030.

- **U.S. EPA, *Inventory of Greenhouse Gas Emissions and Sinks.*** This report is prepared annually by the U.S. EPA, pursuant to an international agreement under which the United States and other nations have committed to maintain an inventory of GHG emissions. The report includes historical data, not future projections. It includes data on VMT, fuel economy, and GHG emissions for various classifications of transportation vehicles. It also includes historical data on trends in use of ethanol and other biofuels. The latest version of this report includes data from 1990 through 2005; a draft report was recently issued with data through 2006.

- **U.S. DOE, *Transportation and Energy Data Book.*** This report is issued annually by the DOE's Oak Ridge National Laboratory. It is a compendium of primarily historical data regarding energy usage, transportation vehicle characteristics (e.g., fuel economy), alternative fuel usage, GHG emissions, economic conditions, and other factors. It includes some projections of future fuel usage, but does not include projections specifically for VMT growth or GHG emissions.

In addition to these sources, there are several secondary sources that provide excellent overviews of the transportation sector's contribution to GHG emissions. (See the Reference Materials section below.) One especially helpful source is **Appendix B to Special Report 290**, issued by the Transportation Research Board (TRB) in March 2008.[61] Appendix B provides an in-depth review and expla-

[61] TRB, *Special Report 290*, Appendix B, "Contribution of U.S. Transportation Sector to Greenhouse Gas Emissions and Assessment of Mitigation Strategies."

nation of the transportation sector's contribution to GHG emissions and a discussion of potential strategies for reducing those emissions.

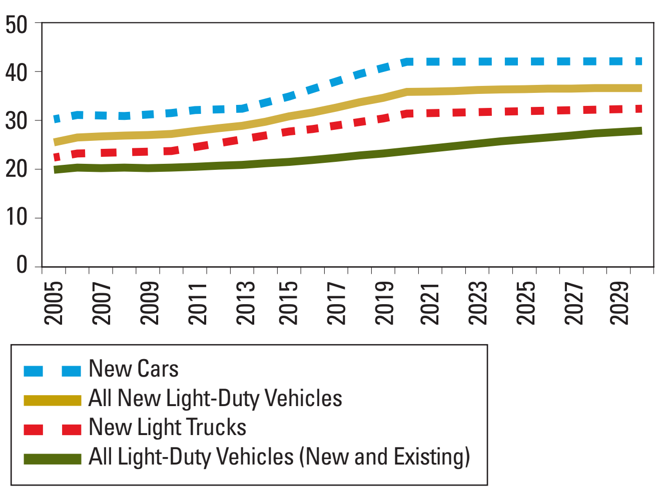
The studies listed here represent only a small fraction of the large and growing literature on climate change and transportation. For additional information, refer to the U.S. DOT's web site, which includes a list of publications on this topic: http://climate.dot.gov/ publications/index.html.

Current Government Forecasts

There are three main factors that affect the GHGs emitted from road transportation. These three factors—sometimes called the "three legged stool"—are (1) fuel economy, (2) the type of fuel used, and (3) the number vehicle miles traveled. A fourth important factor is traffic operations, including individual driving behavior and traffic-flow management by transportation agencies.

Current forecasts project gradual improvements in emissions based on fuel economy and greater use of biofuels, but also project that emissions from increased VMT will increase even faster through 2030. As a result, total GHG emissions from road transportation are expected to remain relatively flat or rise gradually through 2030. The following sections describe these trends in more detail, based on DOE and FHWA forecasts.

Figure 6. Average Fuel Economy—2006 to 2030



Source: U.S. DOE, Annual Energy Outlook 2006, Revised Early Release (March 2008).

Trends in Fuel Economy

From 2006 through 2030, the DOE projects gradual improvement in fuel economy. The DOE's latest projections, issued in March 2008, take into account the 2007 legislation that increased corporate average fuel economy requirements, which required manufacturers to achieve an average of 35 miles per gallon for new vehicles by 2020.[62] Based on that legislation, the forecasts show incremental improvement between now and 2020, but little additional improvement between 2020 and 2030.

Specifically, the DOE projects that average fuel economy for new light-duty vehicles will rise from 25.5 miles per gallon in 2005 to 36.6 in 2030—an average annual increase of 1.4 percent. The DOE projects that average fuel economy for all light-duty vehicles, including both new and existing will rise from 19.9 miles per gallon to 27.9 in 2030—an average annual increase of 1.3 percent. The total increase in fuel economy is substantial—more than a **30 percent** increase by 2030. However, most of this increase occurs by 2021. From that point onward, DOE assumes that fuel economy will remain relatively unchanged through 2030.

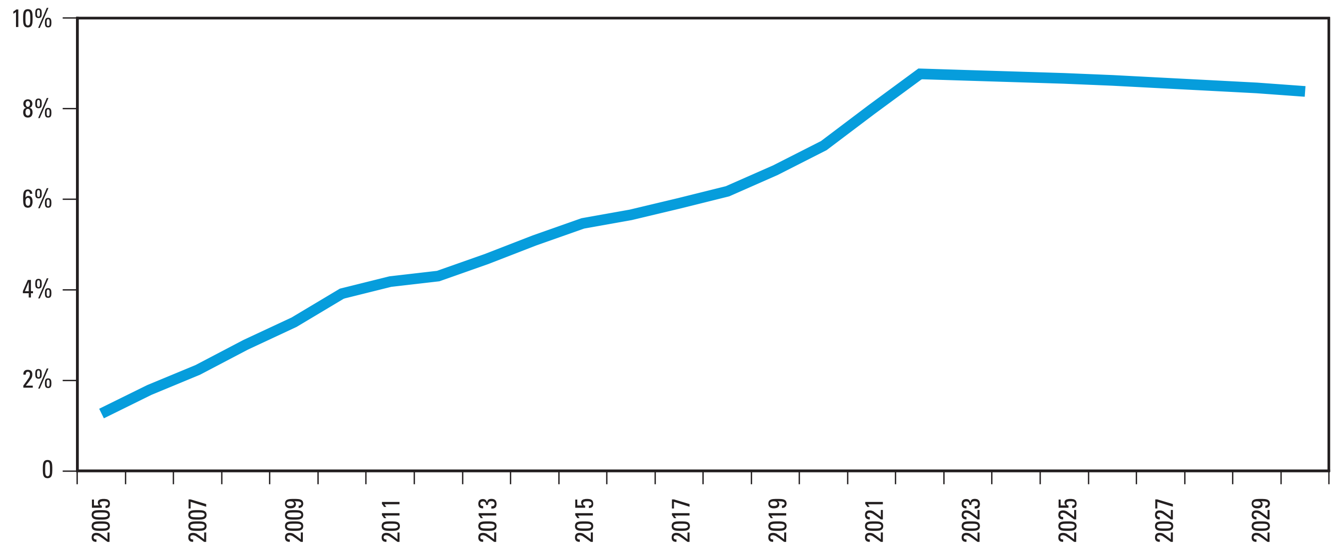
Trends in Use of Alternative Fuels

The vast majority of the fuel used for road transportation has been, and remains, traditional fossil fuels—gasoline and diesel. Alternative fuels, such as ethanol and biodiesel, could help to reduce GHG emissions because they have a lower "carbon intensity"—in other words, they emit less CO_2 for each unit of energy produced.[63] Alternative fuels made from renewable sources also help to reduce the need for imported oil, which has potential economic and other benefits that extend beyond the issue of climate change. For all of these reasons, governments at all levels have adopted

[62] DOE, *Annual Energy Outlook 2008, Revised Early Release*, Tab 7, "Transportation Sector Key Indicators and Delivered Energy Consumption."

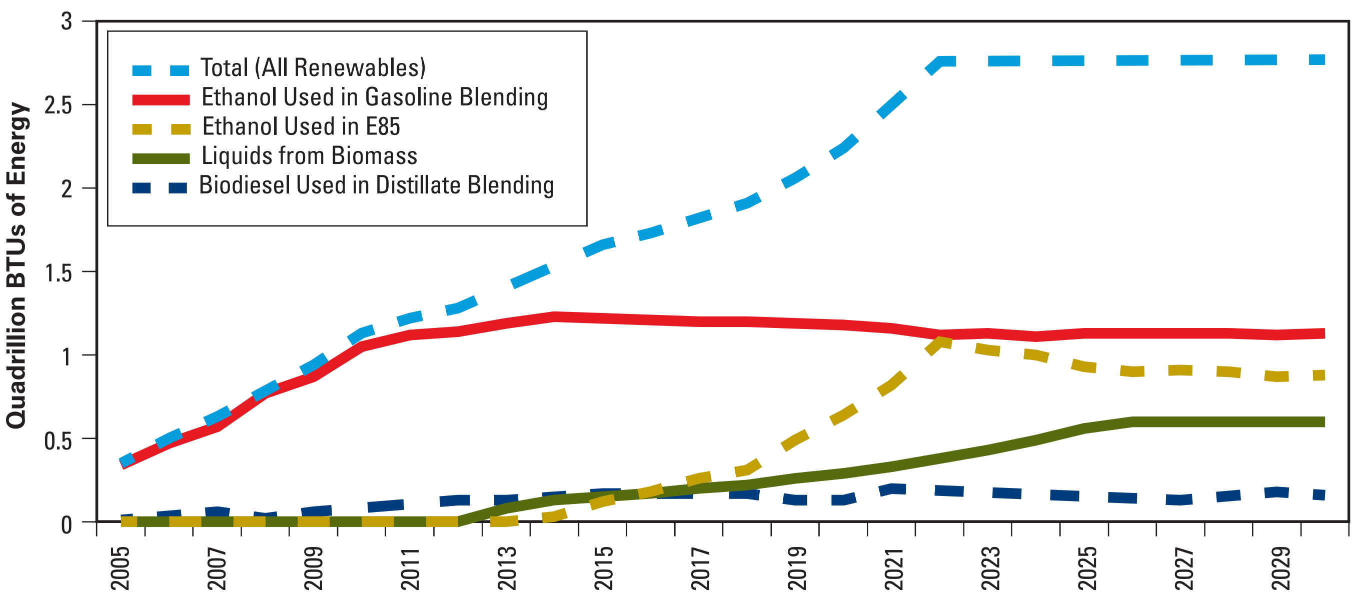
[63] The production of biofuels consumes carbon, potentially offsetting the lower carbon-intensity of the fuel itself. In addition, the production of some biofuels may involve the clearing of forested land, which in turn reduces the natural absorption of carbon (by eliminating a "carbon sink"). Therefore, a key factor in evaluating the carbon intensity of fuels is the carbon consumed in the production as well as the use of those fuels. See TRB, *Special Report 290*, Appendix B, pp. 195–198.

Figure 7. Renewables as Percent of All Transportation Energy Use 2005 to 2030



Source: U.S. DOE, Annual Energy Outlook 2008, Revised Early Release (March 2008).

Figure 8. Use of Renewable Fuels in Transportation Sector—2005 to 2030



Source: U.S. DOE, Annual Energy Outlook 2008, Revised Early Release (March 2008).

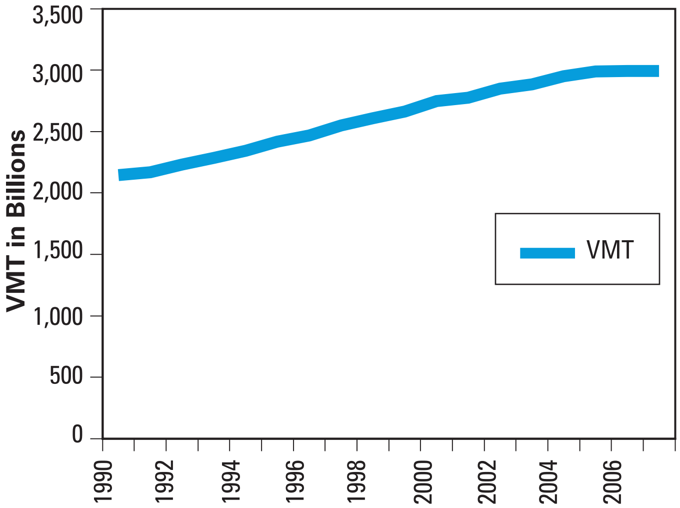
policies in recent years to promote broader use of alternative fuels. The 2007 Energy Independence and Security Act requires increased amounts of renewable fuels in the nation's fuel supply. (Figure 7).

In the long run, alternative fuels have the potential to reduce GHG emissions from the transportation sector. However, they remain a small percentage of total fuel usage. Measured as a percentage of energy usage for the entire transportation sector (all modes), renewable fuels constituted less than 2 percent of the fuel supply in 2006 (measured by energy content).[64] Going forward, DOE projects that renewable fuels will increase to more than 8 percent of the transportation fuel supply by 2030.[65] As with fuel economy, DOE projects that most of the increase will occur by

[64] Total energy usage for the transportation sector in 2006 was 28.2 quadrillion BTUs. Renewable fuels in the transportation sector constituted 0.5 quadrillion BTUs, which is 1.78 percent of the total. DOE, *Annual Energy Outlook*, March 2008 Release, Tables 7 and 17.

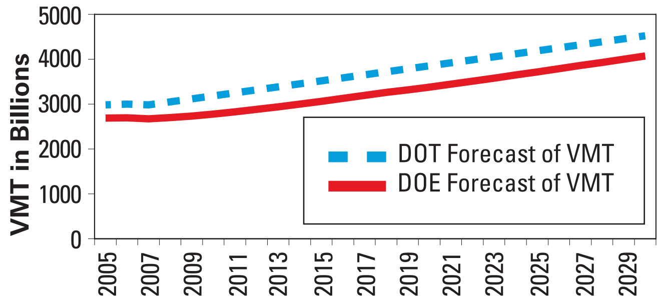
[65] Total energy usage for the transportation sector in 2030 is forecasted to be 32.98 quadrillion BTUs. Renewable fuels in the transportation sector are projected to be 2.77 quadrillion BTUs, which is 8.93 percent of the total. DOE, *Annual Energy Outlook*, March 2008 Release, Tables 7 and 17.

Figure 9. VMT Growth in the United States 1990—2007



Source: FHWA, Highway Statistics, 1990–2007.

Figure 10. VMT Forecast 2005 to 2030



Sources: U.S. DOE, *Annual Energy Outlook* 2006, Revised Early Release (March 2008) FHWA, *2006 Conditions and Performance Report*.

2020, with relatively little further improvement between 2020 and 2030. DOE's Annual Energy Outlook does not include forecasts for renewable fuel usage beyond 2030. (Figure 8)

Trends in VMT

While fuel economy and renewable fuel usage have both remained relatively constant in recent years, the amount of road travel has increased dramatically. According to FHWA's statistics, VMT increased from approximately **2.1 trillion** to nearly **3 trillion** between 1990 and 2005. The average annual increase during this 15-year period has been approximately **2.2 percent**. By contrast, population has increased only about **0.8 percent** per year during this period.[66]

Between 2005 and 2007, VMT growth occurred at a much slower rate—approximately **0.5 percent** annually—potentially because of rising fuel prices during this period. When these years are taken into account, the growth rate since 1990 is approximately **2.0 percent**. The VMT trend line from 1990 through 2007 is shown in Figure 9.

This recent data suggests that the VMT growth rates may be moderating. It is unclear at this point whether the lower growth rates are merely a temporary departure from historical trends or a sign that future VMT growth will be much lower than in the past. Certainly, it is plausible that continued record high oil prices will cause motor fuel prices to remain high or increase, which could continue to dampen growth in VMT. In addition, changing demographics (an increase in retirees as the baby boomer generation reaches 65 years of age) could also help to reduce the rate of VMT growth, since people over the age of 65 generally drive less than the rest of the population. Based on these factors, some researchers have suggested we may be entering a new era in which VMT naturally will increase at a lower rate.[67]

The latest U.S. DOT and DOE forecasts reflect a slight reduction in VMT growth rates, as compared to historical trends. In its 2006 Conditions and Performance report, the U.S. DOT predicts that VMT will grow at **1.92 percent** annually for the next 20 years. In its 2008 Annual Energy Outlook, the DOE projects that VMT will grow at approximately **1.6 percent** annually through 2030. Both of these growth projections are somewhat lower than the 2.2 percent annual increase that occurred between 1990 and 2005, but still well above the 0.5 percent growth rate from 2005 to 2007.

While a 1.6 percent growth rate may seem modest, it would lead to substantial growth in VMT over the next 25 years. If VMT grows at this rate, total VMT would rise from approximately 3 trillion in 2006 to approximately **4.5 trillion in 2030**. And

[66] See FHWA, Office of Highway Policy Information, "Highway Statistics", available at: http://www.fhwa.dot.gov/policy/ohpi/index.htm.
[67] For example, see Steven E. Polzin, "The Case for Moderate Growth in VMT" (April 2006).

a 1.92 percent growth rate would cause VMT to reach 4.3 trillion by 2024 (the horizon year of the U.S. DOT forecast); at that rate, VMT would be approximately **4.9 trillion** by 2030. (Figure 10)

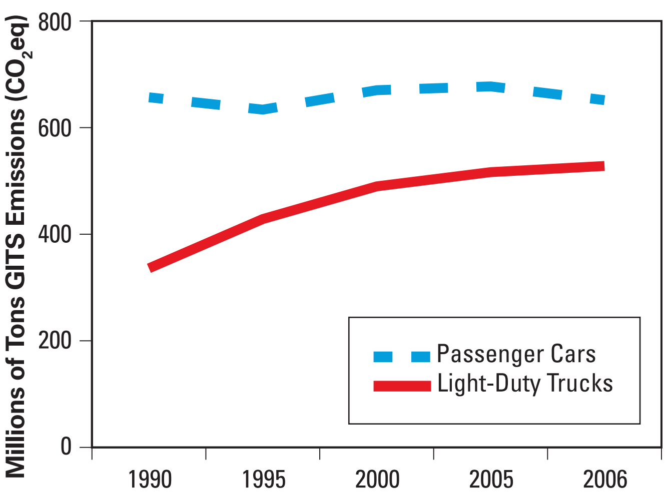
The vast majority of this growth in VMT reflects an increase in personal travel, not freight shipments. The VMT for light-duty vehicles (passenger cars and light trucks) is projected by DOE to rise from approximately 2.7 million in 2006 to approximately 4 trillion by 2030.

Trends in GHG Emissions

According to EPA's emissions inventory, total GHG emissions from all transportation sources rose from **1.53 billion** metric tons of CO_2eq in 1990 to **1.96 billion** metric tons in 2006. EPA reports that in the same period, total GHG emissions from all on-road vehicles rose from 1.22 billion to 1.59 billion metric tons of CO_{2eq}—an increase of approximately 30 percent in 15 years. [68]

As shown in Figure 11, GHG emissions from passenger cars actually **declined by 1 percent** between 1990 and 2006. But during that same period, GHG emissions from light-duty trucks (which include pick-up trucks and SUVs) **increased by 57 percent**, GHG emissions from medium and heavy-duty trucks increased by 80 percent, and GHG emissions from buses increased by 47 percent.[69]

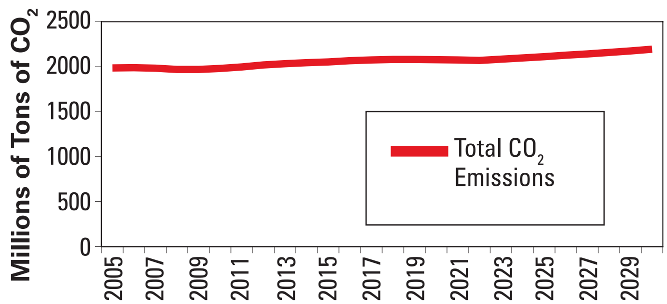
Figure 11. GHG Emissions from Passanger Cars and Light Duty Trucks



Going forward, the DOE forecasts that total CO_2 emissions from all transportation sources will rise from 1.98 billion metric tons in 2006 to 2.19 billion tons in 2030.[70] (Figure 12) The vast majority of these CO_2 emissions will continue to be produced by combustion of petroleum products, according to DOE's projections.[71] The largest contributor to these emissions in the transportation sector will be on-road vehicles.

In sum, DOE projects that fuel efficiency will improve and renewable fuels will gain market share, but also projects that VMT will continue to grow robustly, outpacing these gains in efficiency. The result is that GHG emissions from the transportation sector are projected to increase gradually between now and 2030.

Figure 12. CO_2 Emissions from All Transportation Sources—2005 to 2030



Source: U.S. DOE, Annual Energy Outlook 2008, Revised Early Release (March 2008).
Based on 35 mpg CAFE standard.

Alternative Forecasts: The Potential for Faster Reductions

The preceding section described GHG emission trends based on the official U.S. DOT and DOE forecasts for vehicle fuel economy, renewable fuel usage, and VMT growth. Those forecasts suggest that VMT growth will outpace improvements in vehicles and fuels between now and 2030, resulting in a gradual increase in GHG emissions. If that were to happen, the transportation sector would not contribute to achieving the goal of reducing global emissions of GHGs by 60 to 80 percent by 2050.

[68] EPA, *GHG Inventory 1990–2006*, Table A-97, p. A-121.
[69] EPA, *GHG Inventory 1990–2006*, Table A-97, p. A-121.
[70] DOE, *Annual Energy Outlook* (March 2008), Table 18.
[71] DOE, *Annual Energy Outlook* (March 2008), Table 18.

While the official forecasts are important to consider as a baseline, they do not reflect the potential impact of major technological breakthroughs or policy changes. If high oil prices continue and concerns about climate change result in major legislation limiting GHG emissions, the future trends in GHG emissions could be dramatically lower than current forecasts.

To illustrate the range of possible trends in GHG emissions from the transportation system, this report presents four possible scenarios. All of these scenarios are presented in terms of trends through 2050, instead of the 2030 horizon year used by DOE.

mpg-ge

The term "miles per gallon—gasoline equivalent" (mpg-ge) provides a single unit of measurement that reflects the overall gain in the fuel-efficiency of the vehicle fleet, regardless of what kinds of fuel are actually used to power the vehicles. For example, a vehicle powered by hydrogen does not produce any GHG emissions from the tailpipe, but the production of hydrogen (the fuel for the vehicle) requires energy, and today, the fuel most commonly used to produce hydrogen is natural gas, which results in GHG emissions. Similarly, a plug-in hybrid emits lower GHGs from the tailpipe than a conventional gasoline-powered engine, but electricity typically is generated primarily from coal and natural gas, which produces GHG emissions. **"Mpg-ge" is one way to account for GHG emissions at all stages of fuel production and consumption, not just the GHG emissions that come directly from the vehicle itself.**

Four Alternate Scenarios

The four scenarios presented below represent variations in two key variables (Figure 13): (1) improvements in vehicles and fuels, which are represented in a single variable known as 'miles per gallon-gasoline equivalent" (mpg-ge); and (2) reductions in the growth of VMT. The four scenarios include:

- **Scenario 1:** Average fuel economy increases to **100 mpg-ge** in 2050; VMT increases **1 percent** annually through 2050
- **Scenario 2:** Average fuel economy increases to **100 mpg-ge** in 2050; VMT increases **1.5 percent** annually through 2050
- **Scenario 3:** Average fuel economy increases to **50 mpg-ge** in 2050; VMT increases **1 percent** annually through 2050
- **Scenario 4:** Average fuel economy increases to 50 mpg-ge in 2050; VMT increases 1.5 percent annually through 2050

For the sake of simplicity, these four scenarios depict gradual improvement at a steady pace through 2050. In actuality, the improvements would probably occur more slowly in some years and more quickly in others. Also, there are other factors, such as congestion relief and changes in driver behavior, that could affect total GHG emissions from road transportation, but are not reflected in these scenarios. These scenarios simply provide a broad, conceptual illustration of trend lines that could result in greater improvements than are currently predicted by official government forecasts.

Results

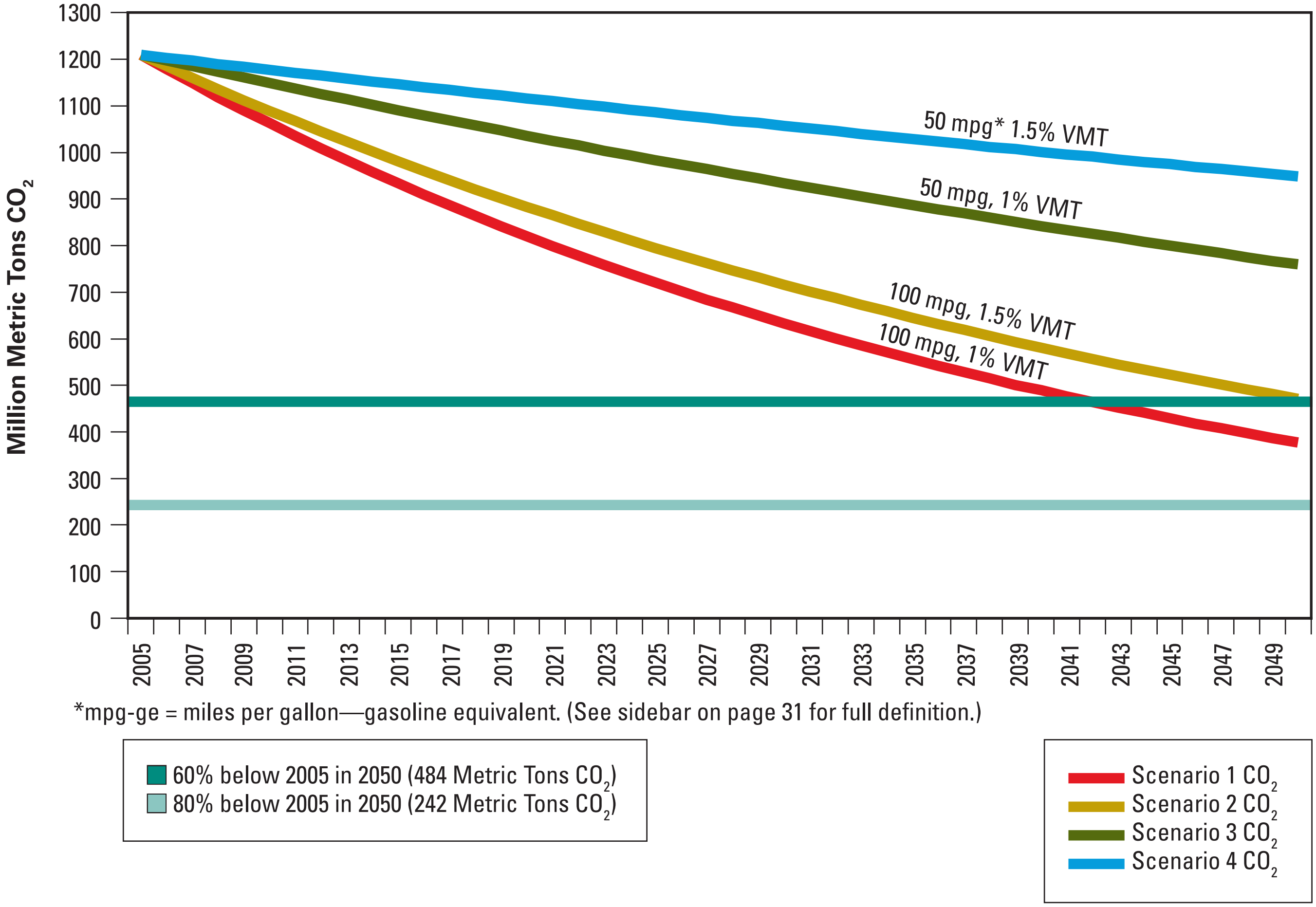
As shown in Figures 13 and 14, substantial reductions in CO_2 emissions from the transportation sector could be achieved even as VMT increases. (CO_2 emissions are used in this analysis, since they are the largest component of GHG emissions from road vehicles). For example, if VMT grows on average at 1 percent annually between now and 2050, and average fuel economy gradually rises to 100 mpg by 2050, CO_2 emissions from the U.S. light-duty vehicle fleet would drop from **1,210** million metric tons in 2005 to **377** million metric tons in 2050—a decrease of approximately **68 percent** from 2005 levels.

The scenarios shown here could all be considered optimistic, because they assume slower growth in VMT and faster growth in fuel economy than we have experienced in the recent past. But the scenarios are plausible depictions of the improvements that *could* occur if significant investments

are made in improving technology, separately or in combination with slower growth in VMT. These scenarios show that, in principle, it is possible to cut GHG emissions sharply even while VMT continues to increase at 1 percent annually or more.

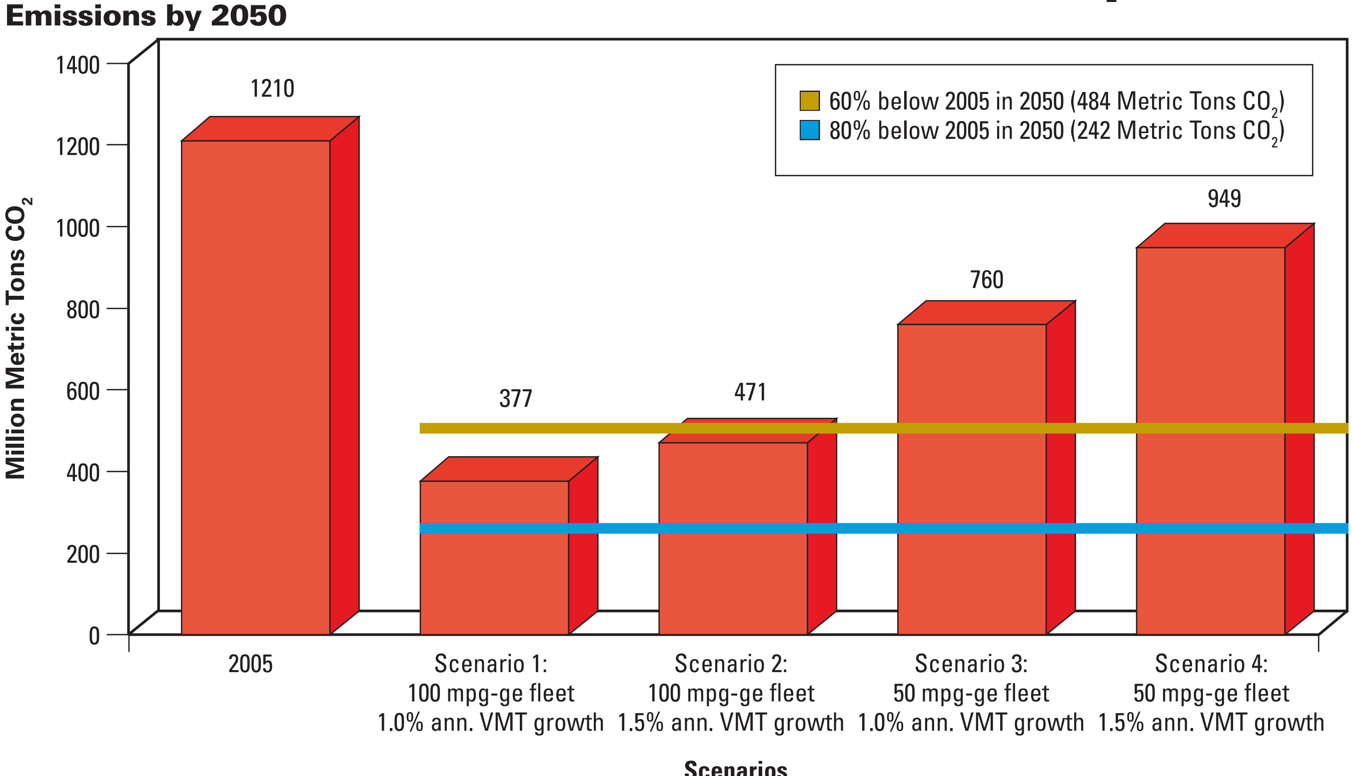
As a frame of reference for these scenarios, note that VMT has increased at a rate of approximately 0.5 annually between 2005 and 2007, so a 1 percent annual growth rate in VMT would actually be much greater than the pace of VMT growth in the last few years. Also, population growth between 2005 and 2030 is projected at approximately 0.9 percent. So a growth rate of 1 percent in VMT would allow per-capita VMT to increase slightly.

Figure 13. U.S. Light Duty Fleet CO_2 Emission for Various Scenarios (2005 to 2050) From Higher Fuel Economy and Reductions in Travel Growth (VMT)



*mpg-ge = miles per gallon—gasoline equivalent. (See sidebar on page 31 for full definition.)

Figure 14. Alternative Scenarios for Reducing U.S. Light Duty Vehicle CO_2 Emissions by 2050



Part IV. How Do We Get There from Here?

The scenarios outlined in Part III show that substantial reductions in GHG emissions from road travel could be achieved, *if* there are major advances in vehicle and fuel technologies, along with some reduction in the rate of growth in VMT. This section turns to the practical question of how these improvements can be achieved. Technologies already in existence can help reduce GHG emissions significantly, and emerging technologies hold the key to even greater reductions. Transit and land-use changes can also play an important role, along with operational strategies and driver education.

Technological Innovations in Vehicles and Fuels

In recent decades, the volume of road travel has greatly increased, while the emissions of many harmful air pollutants have been cut. Technological innovation has made this progress possible: today's vehicles are more fuel-efficient and employ far more sophisticated emissions-control technologies than those on the roads in the 1970s. Reducing GHG emissions presents a new challenge, and in some ways a greater one. But technological advances will be just as important to meeting this challenge as they have been to achieving environmental goals in the past. The following discussion provides a brief introduction to some of the existing and emerging technologies that may help reduce GHG emissions from road travel.

Gas/Electric Hybrids

Today, gas-electric hybrid vehicles are widely available on the market. Hybrid vehicles, which combine an internal combustion engine with a battery-powered motor, are significantly more fuel efficient than regular gasoline powered vehicles. For example, the 2008 Toyota Prius hybrid has a combined city/highway fuel economy of 46 miles per gallon, while the non-hybrid Toyota Corolla—which is comparable in size—is rated at 27 mpg city and 35 highway.

Sales of hybrid vehicles have increased in recent years, but they remain a very small percentage of vehicles on the road and therefore do not have a major impact on total GHG emissions today. Changes in federal policy, technological innovations, and rising fuel prices could all result in more rapid penetration of hybrid vehicles into the market.

Plug-In Hybrids

In addition to traditional hybrid vehicles, which still require the substantial use of gasoline, there has been a renewed push to develop electric cars that recharge by plugging the vehicle in. These "plug-in hybrids" are designed to operate mainly as limited range electric vehicles, with a small gasoline engine to extend range and recharge the batteries, if needed. They are expected to reach roughly 100 miles per gallon of onboard fuel consumed. (The electricity consumed from the grid is not included in this measure.) This technology is still several years from widespread deployment, as the battery systems that operate the vehicles are extremely expensive and not yet sufficiently reliable for commercial use. The hope is to have more advanced technology ready for commercial deployment by 2015. This means having a battery system that can operate for 15 years without failure.

The potential climate benefits of a plug-in hybrid depend, to a great extent, on the source of the electricity supply that is used to power the vehicle. If the electricity source is a power plant that produces a high level of GHG emissions (e.g., coal power without carbon capture and sequestration), then there may be little or no net reduction in GHG emissions, or possibly even increased GHG emissions, from the use of electrical power. On the other hand, if the electricity comes from an energy source that produces low GHG emissions (e.g., wind, solar, biomass, natural gas, nuclear, or hydropower), the plug-in hybrid would produce a net reduction in GHG emissions. A report prepared by McKinsey & Company on potential GHG reductions in the transportation sector describes plug-in hybrids as a "high-potential emerging technology" and states that there is a consensus among experts that plug-in hybrids "would likely be commercially available by 2030."[72]

Biofuels

Through a variety of financial incentives and renewable-fuel mandates, federal and state laws and policies have promoted increased use of biofuels—that is, agriculturally based fuels—as an energy supply. The Energy Independence and Security Act of 2007, which was enacted in December 2007, mandates that fuel producers use at least 36 billion gallons of biofuels by 2022.[73] It also provides a range of incentives and other support to encourage wider availability of biofuels, particularly next-generation biofuels that produce lower GHG emissions.

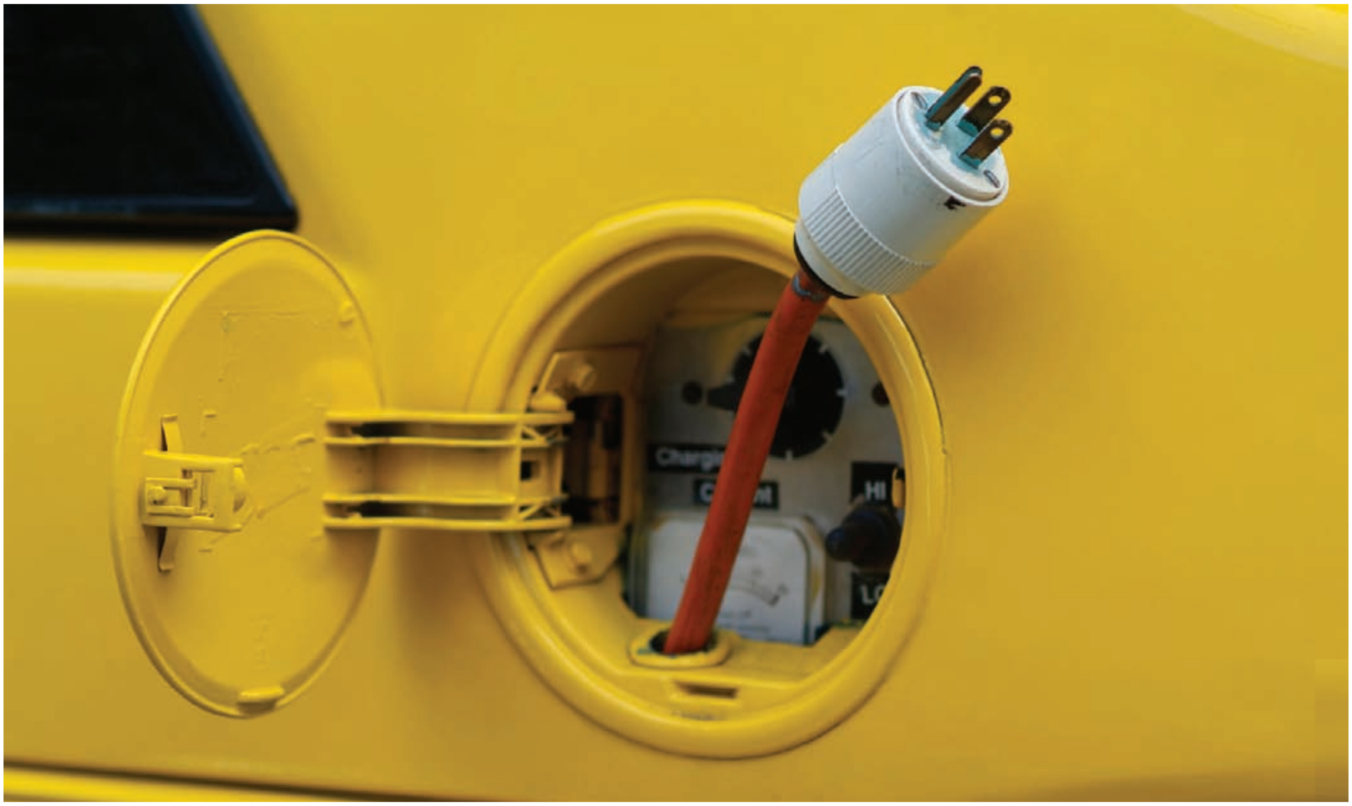
The dominant biofuel in the market today is ethanol, which can be used as a blended fuel (up to 10 percent in all cases, and up to 85 percent in some cases) in existing automobile engines and can be distributed through the existing gasoline supply chain. Ethanol is a **starch-based biofuel**, because the energy in ethanol is derived from corn. It is commercially available today, but still makes up only a small fraction of the fuel supply for transportation; according to DOE, all renewable fuels comprise less than 2 percent of the fuel supply. In addition, there remains significant debate about how much (if at all) ethanol helps to reduce GHG emissions.

Efforts are under way to develop **cellulosic biofuels**, which are developed from cellulosic (woody) plants, such as switchgrass. Cellulosic biofuels are less carbon-intensive than ethanol—that is, they emit fewer GHGs for each unit of energy generated—but they are not yet commercially available. The main challenge facing cellulosic biofuel is the difficulty of breaking down woody plant material into fuel; this process requires the use of enzymes, and enzymes are not yet available that can break down cellulosic material into fuel on a commercially viable scale. Despite these difficulties, many of the major oil and chemical companies (and others) are working on advanced methods for converting cellulosic feedstocks to fuel at a commercially viable scale. The McKinsey study describes cellulosic biofuels as a "high-potential emerging technology" that could play a key role in reducing GHG emissions.

While biofuels have significant potential to help reduce GHG emissions, there are some important caveats. First, there is an issue of scale. Biofuels remain a small fraction of the total fuel supply for motor vehicles. According to the McKinsey study, the federal government's reference-case estimate is that that biofuels will make up 8 percent (15 billion gallons) of

[72] McKinsey Report, p. 3.

[73] H.R.6, Energy Independence and Security Act of 2007, § 202(a).



the fuel supply by 2030. Of this amount, the majority (10.8 billion gallons) would be starch-based biofuels, primarily ethanol, and the minority (less than 4 billion gallons) would be cellulosic biofuels.[74] According to the McKinsey study, biofuels under these projections would result in only a “slight reduction” of the carbon intensity of the fuel supply by 2030.[75]

Hydrogen Fuel-Cell Vehicles

Research is under way to develop zero-emission vehicles, which would be powered by hydrogen fuel cells. The fuel cells operate on a mixture of hydrogen and oxygen. They produce zero emissions on the road, as the energy is produced by a chemical reaction that yields only water and electricity. The basic fuel cell technology exists today, and several hydrogen prototype vehicles are already on the roads. Many commentators consider hydrogen-based fuels to be a solution that, at least in the long term, could completely eliminate GHG emissions (as well as other harmful pollutants) from motor vehicles.

While hydrogen fuel cells are extremely promising, they are not yet commercially available. The basic problems that need to be addressed with fuel cell technology include reducing the size and weight of the fuel cells, making them durable enough to survive long-term road use, and reducing the costs of producing the fuel cells. Other obstacles to commercialization revolve around the hydrogen fuel source itself. In order to support a large fleet of hydrogen vehicles, sources of hydrogen fuel would need to be widely available—just as gasoline filling stations are widely available today. In essence, an entirely new infrastructure of hydrogen distribution and sale would need to be created on a national scale. Given all of these hurdles, hydrogen fuel-cell vehicles are unlikely to become widespread by 2030, but could become a more widely used in the 2030 to 2050 timeframe.

Finally, as with biofuels, it is necessary to consider the full life-cycle emissions of GHGs that result from the production of hydrogen for use in vehicles.[76] Energy is required to produce hydrogen in a form that can be used as a fuel source in vehicles. Today, most hydrogen

[74] McKinsey Report, p. 11.
[75] ibid.
[76] See TRB, Special Report 290, Appendix B, pp. 195–198.

is produced with fossil fuels, which results in GHG emissions. Hydrogen can also be produced from carbon-free or renewable sources, such as nuclear power, wind, solar, and geothermal power, and research efforts are underway to produce hydrogen at costs that are comparable to the costs of gasoline. To gain the full benefits of hydrogen as a power source, it will be necessary to come up with ways to produce hydrogen in ways that avoid or minimize emissions of GHGs.

Reducing the Growth in VMT

While technological change is essential to reducing GHG emissions, there is also a role for strategies that help to limit the growth in travel demand. As discussed earlier in this report, the total VMT has grown much faster than population growth for the past several decades, but appears to have slowed considerably in the past few years, perhaps in response to sharply rising fuel prices. Going forward, even a seemingly small difference in VMT growth rates—e.g., the difference between 1.5 percent and 2.0 percent annual growth—can make an enormous difference in the total amount of VMT on the roads in 2030 or 2050.

There are many factors that can affect the future growth rate of VMT. Among the most important factors are economic trends and demographic forces, which are largely beyond the influence of government policies. For example, a strong economy and rising average incomes tend to produce increases in VMT; conversely, large and sustained increases in fuel prices will tend to dampen the growth in VMT.

Against the backdrop of these larger trends, government policies also can play a role—albeit a limited one—in influencing VMT growth. Two strategies that can be used include (1) expanding transit service and other alternatives to single-occupant vehicle travel; and (2) encouraging land uses that minimize the number and length of auto trips. Operational strategies, such as "traffic smoothing," also can help reduce GHG emissions.

Expanding Transit Service

Transit service provides an alternative to automobile travel and, under certain conditions, can help reduce GHG emissions. The challenge is how to make the most of transit's potential, given that it serves a relatively small share of travel in the United States and major transit system expansions require significant public-sector funding.

In a report for the Pew Center for Global Climate Change, the researchers David Greene and Andreas Schafer stated that: "[s]ignificantly reducing national GHG emissions via increased use of transit would require momentous efforts. All modes of transit (bus and rail) account for only 1 percent of passenger-miles traveled in the United States today."[77] Thus, even a doubling of transit ridership would have a modest impact on reducing total GHG emissions in the United States. Additional research will be required to determine how much of a reduction in total GHG emissions could be achieved through increased transit ridership and which types of transit investments would yield the greatest (and most cost-effective) reductions in GHG emissions.

While expanding transit service may not yield major reductions in GHG emissions, there are still good policy justifications for increasing investments in transit service. For example, transit service continues to play a key role in maintaining mobility within large and densely populated metropolitan areas, especially for populations that lack access to an automobile. In addition, expanding transit service can facilitate higher-density land-use patterns that help to reduce the need for auto trips. These considerations, in combination with the potential GHG emission reduction benefits, provide support for continuing to expand transit service as an integral part of the transportation system.

In Europe, where transit is more prevalent and receives significant policy support, the European Conference of Ministers of Transport expressed support for transit and other mode shifts, but cautioned against expecting significant impacts on GHG emissions:

> Modal shift policies are usually weak in terms of the quantity of CO_2 abated and have generally been inadequately assessed in national

[77] Greene, D. and A. Schafer, "Reducing Greenhouse Gas Emissions from U.S. Transportation" (May 2003), pp. 38–39.

communications on CO_2 emissions policy. Modal shift measures can be effective when well targeted, particularly when integrated with demand management measures. They can not, however, form the corner-stone of effective CO_2 abatement policy and the prominence given to modal shift policies is at odds with indications that most modal shift policies achieve much lower abatement levels than measures focussing on fuel efficiency.[78]

Other Alternatives to Single-Occupant Auto Travel

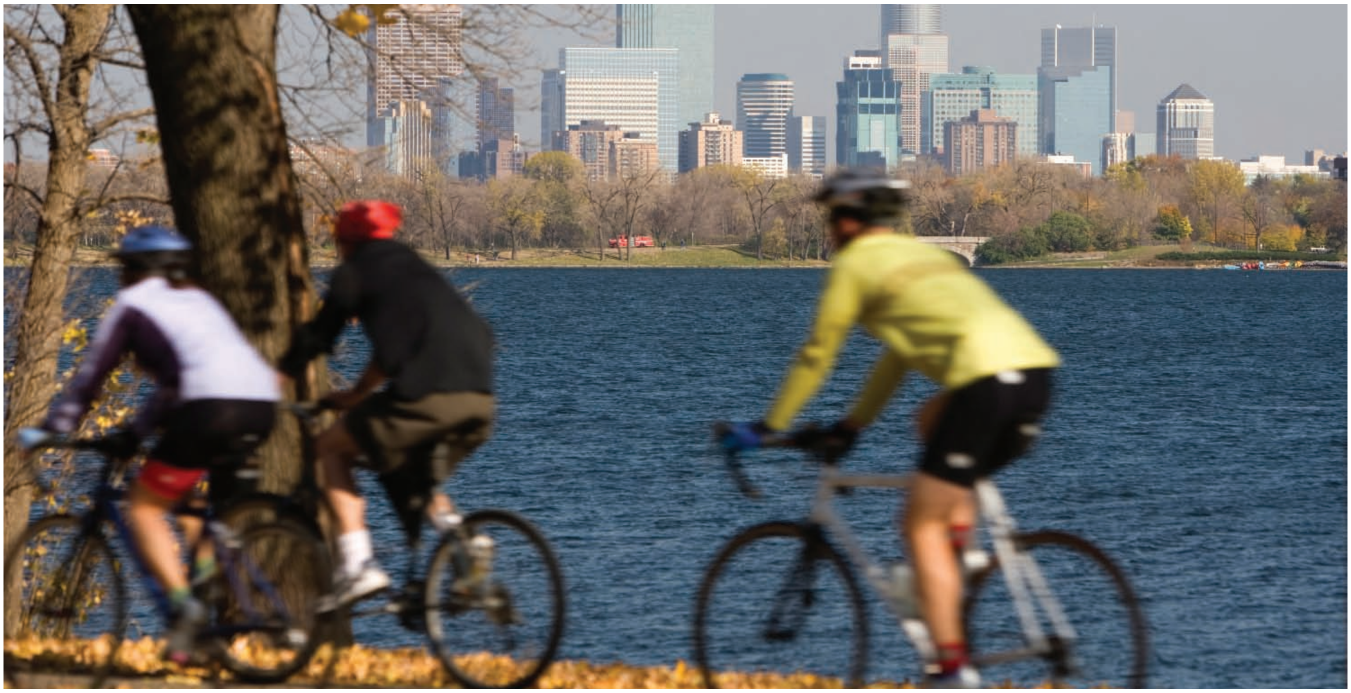
In addition to transit, passenger travel also occurs by walking, biking, carpooling, vanpooling, and telecommuting. To the extent that auto driving in single-occupant vehicles can be shifted to these alternatives, GHG reductions can be achieved. According to the recent "Commuting in America" study, one important trend in recent years has been an increase in telecommuting. Between 1980 and 2000, the number of commuters driving alone increased, the number taking transit remained roughly constant, and the number carpooling and walking to work declined; however, the number of people telecommuting almost doubled—from approximately 2.1 million in 1980 to 4.1 million in 2000.[79] This change suggests a possible opportunity to reduce growth in VMT by providing incentives and logistical support for telecommuting. Telecommuting is likely to be a highly cost-effective strategy for reducing GHG emissions, as telecommuting costs are quite low, with potentially a net savings per ton of GHG reduction, after factoring in reduced auto operating costs.

Changes in Land-Use Patterns

Land-use decisions play an important role in determining the demand for automobile travel. Existing land-use patterns in many areas make automobile travel a necessity for most trips. Higher-density land-use patterns, combined with increased availability of transit service, could help to reduce the

[78] European Conference of Ministers of Transport, "Transport and Environment: Review of CO2 Abatement Policies for the Transport Sector" (2006), p. 7.

[79] A. Pisarski, *Commuting in America III: The Third National Report on Commuting Patterns and Trends*" (2006), p. xvi, available at: http://onlinepubs.trb.org/onlinepubs/nchrp/CIAIII.pdf.



demand for automobile travel without reducing mobility. In other words, there may be an important role for land-use policy in reducing GHG emissions from transportation.

As with transit, a key question to consider is how much GHG emissions reduction can be achieved by shifting to higher-density and less auto-dependent land-use patterns. A related question is how to bring about those types of changes in land use, which can be difficult because land-use decisions are primarily made by local governments.

The first issue—the magnitude of the effect on VMT—has been addressed in several reports. In a May 2003 report on reducing GHG emissions from transportation, David Greene and Andrea Schafer of the Oak Ridge National Laboratories expressed skepticism about the potential for land-use changes to reduce GHG emissions, but acknowledged that over a long time period, they could have a meaningful impact:

> Studies of large-scale metropolitan planning strategies for reducing travel while maintaining accessibility suggest that a combination of land-use and transit policies might succeed in reducing vehicle miles traveled in urban areas by about 5 to 7 percent over a period of 30 years, and perhaps 9 to 10 percent if combined with policies to charge for parking and for use of congested roads. Modeling and simulation analyses of travel at the neighborhood level suggest that vehicle travel might be reduced 10 to 25 percent by changing the design of subdivision development to more closely resemble the grid street layouts and mixed land uses of pre-WWII communities.[80]

This issue also was addressed in *Growing Cooler: Evidence on Urban Development and Climate Change*, which was issued in November 2007 by the Urban Land Institute, Smart Growth America, the Center for Clean Air Policy, and the National Center for Smart Growth Research and Education. The *Growing Cooler* report concluded that changes in land-use policy can significantly reduce VMT and thus can play an important role in reducing GHG emissions. Key findings included:

- A new development that conforms to Smart Growth principles can reduce VMT by 30 percent, as com-

[80] D. Greene and A. Schafer, p.40.

pared with a new development that follows more traditional, auto-dependent land-use patterns.[81]

- Shifting 60 percent of new growth to compact development would save 85 million metric tons of GHG emissions annually by 2030 and would reduce transportation GHG emissions by 7 to 10 percent by 2050, as compared to emissions that would have occurred if all development continued to follow traditional auto-dependent patterns.[82] The 7 to 10 percent reduction is an "end year" estimate—meaning that GHG emissions would be 7 to 10 percent lower in 2050. The cumulative reactions between now and 2050 would be about half that amount—i.e., 3 to 5 percent.

The findings in both reports are generally consistent. While one takes a more skeptical view and the other strongly advocates land-use changes, both conclude that changes in land-use can reduce VMT growth—and thus can reduce emissions—but the reactions would accrue gradually as land uses change, so large benefits may not occur until the 2030 to 2050 time period.

Operational Strategies

Finally, GHG emissions are influenced not only by the number of miles traveled, but also by the operating conditions that exist during each mile of travel. A vehicle sitting in traffic consumes more energy, and emits more GHGs per mile, than a vehicle operating at a moderate but consistent speed. Similarly, a vehicle that is poorly maintained, or has low tire pressure, will emit more GHGs per mile than one maintained in peak condition. These factors suggestion that congestion relief and driver education can also help reduce GHG emissions.

Congestion Relief

Traffic congestion contributes to GHG emissions because vehicle engines operate less efficiently—and therefore produce higher emissions per mile—when they are driven at low speeds in stop-and-go traffic. The optimal speed for motor vehicles with internal combustion engines is about **45 mph**. At lower speeds, CO_2 emissions per-mile are several times higher than at 45 mph. At higher speeds, CO_2 emissions per mile increase as well, but somewhat less sharply.[83]

Based on this data, some researchers have concluded that congestion relief can play a role in reducing GHG emissions. In a paper presented at the TRB annual meeting in 2008, researchers from the University of California at Riverside concluded that:

> While progress in vehicle efficiency improvements and carbon-neutral fuels are underway, innovative traffic operations improvements (i.e., mitigating congestion, reducing excessive speeds, and smoothing traffic flow) can have a significant impact on vehicle CO_2 emissions and this impact can be realized in the near-term. In addition to improving traffic operations as a means of reducing vehicle CO_2 emissions, other transportation measures can also be simultaneously promoted to reduce VMT, and thus vehicle CO_2 emissions. These measures include alternative modes of transportation, innovative land-use patterns, and travel demand-management strategies.[84]

In short, the University of California researchers concluded that congestion relief has the potential to reduce CO_2 emissions, in combination with other strategies that can help offset any induced growth in VMT. Others, however, are more skeptical. The "Growing Cooler" report—recognizes that vehicles operate more efficiently at speeds around 45 mph, but does not recommend congestion-relief as a method for reducing GHG emissions. The authors' concern is that reducing congestion will result in increased vehicle miles traveled, so that the net effect of reducing congestion will be to increase GHG emissions overall.[85] The authors also point out that the GHG emission curves for hybrid vehicles may be different, because hybrids operate more efficiently than traditional interal combustion engines at low speeds.

[81] R. Ewing, et al., "Growing Cooler," p. 11.
[82] ibid.
[83] M. Barth and K. Boriboonsomsin, "Real-World CO2 Impacts of Traffic Congestion," (Nov. 15, 2007) (presented to January 2008 annual meeting of Transportation Research Board. 84 M. Barth and K. Boriboonsomsin, "Real-World CO2 Impacts of Traffic Congestion," p. 16.
[85] R. Ewing, et al., *Growing Cooler: The Evidence on Urban Development and Climate Change,* Urban Land Institute (Oct. 2007), pp. 58–59.

Driver Behavior

In addition to vehicles, fuels, and VMT, the way motorists actually operate their vehicles affects GHG. The March 2007 TRB Special Report 290 notes that: "The way vehicles are operated has a significant influence on fuel consumption….EPA currently adjusts 'as tested' mpg downward by 15 percent to make it more comparable to the fuel economy vehicle users are likely to experience in practice. However, the agency believes that this adjustment factor, which is about two decades old, is outdated, and proposes increasing it to approximately 22 percent." This suggests that a significant component of GHG emissions—as much as 22 percent—results from inefficient operation of motor vehicles. These inefficiencies could result from factors beyond the driver's control, such as traffic congestion, and also could reflect a driver's own behavior, such as high-speed driving, vehicle maintenance, and tire pressures. Driver education and other policies could help to promote more efficient vehicle operations, which would help reduce GHG emissions.

The Policy Toolbox

Governments have many policy tools that can help encourage GHG emission reductions from road travel. This primer does not advocate a specific set of policies, but instead briefly reviews the tools in the policy toolbox. This discussion focuses mainly on policies that could be implemented at the national level in the United States, but many of the same options would apply at the State and even local levels.

R&D Funding

Major reductions in GHG emissions from the transportation sector will depend, to a large extent, on achieving technological breakthroughs that dramatically reduce the GHGs emitted per mile traveled. Private industry is investing billions in a wide range of R&D efforts, involving both vehicles and fuels. In addition, the federal government has published a long-term plan[86] for guiding such a transformation, across all sectors, not just transportation. Research in support of this plan has increased from \$2.1 billion to \$4.4

[86] DOE, "Strategic Plan, U.S. Climate Change Technology Program" (Sep. 2006), available at: http://www.climatetechnology.gov.

billion annually since 2003. One part of this effort is seen in the significant funding of research on innovative vehicle propulsion systems. For example, the FreedomCar program, which is funded by the U.S. Department of Energy, supports research into the development of hydrogen fuel-cell vehicles and the infrastructure needed to support them. Continued funding of this effort may play a key role in accelerating commercial development of zero-emission vehicles, which could ultimately play a critical role in enabling continued growth in travel while still dramatically cutting GHG emissions.

Vehicle Emission Standards

In 2007, Congress increased the CAFE standard for passenger vehicles and light trucks to 35 mpg, which must be achieved by 2020. The law also creates a framework under which CAFE standards may further increase between 2021 and 2030 for passenger cars and light trucks, and also establishes a program under which fuel-economy standards will be set for medium-duty and heavy-duty trucks. There could also be separate legislative or regulatory initiatives to continue raising fuel-economy standards, as a way of making continued progress toward reducing GHG emissions despite increasing travel demand.

In addition, California and several other states have adopted stricter vehicle emission standards than those established by the federal government. However, these standards cannot take effect unless a waiver is granted by EPA, and in December 2007, EPA denied the waiver.[87] California and other states have filed a lawsuit to overturn the waiver, and that case is now pending. If the California standards are eventually allowed to proceed, or are adopted in some form at the federal level, they will contribute to further reductions in GHG emissions.

Researchers have suggested another regulatory option, which focuses specifically on GHG emissions. This concept involves setting GHG emission standards for vehicles—that is, a standard for the grams of GHGs emitted per mile of travel. This type of standard would more precisely reflect the underlying goal of reducing GHG emissions, not just reducing the amount of fuel consumed. This standard could be defined so that it covers all GHGs emitted by vehicles, including methane and nitrous dioxide, not just CO_2.[88]

Low-Carbon Fuel Standards

Federal legislation has set goals for the total amount of biofuels to be produced in 2022 (36 billion gallons), but has not set any overall goal or requirement for reducing the carbon content of transportation fuels. However, California has adopted a low-carbon fuel standard, which calls for a 10 percent reduction in the carbon intensity of transportation fuels by 2020.[89] Additional states, and possibly the federal government, could adopt low-carbon fuel standards in the future. If such standards are adopted, it will be important to consider the life-cycle emissions of GHGs associated with each fuel. Some of the benefits of using low-carbon fuels may be offset by the additional GHG emissions that result from clearing land and growing crops to produce the fuels.

Road Pricing/VMT Tax

In recent years, the concept of road pricing has received increased attention, primarily as a means of managing congestion and generating additional funding for transportation. If implemented on a broad scale, road pricing systems could reduce GHG emissions as well. Road pricing can take many different forms, from tolls to cordon-based permit pricing to parking pricing to VMT-based pricing to gasoline surcharges. Major metropolitan areas such as London, Stockholm, and Singapore have adopted road-pricing programs, primarily to manage congestion. These types of initiatives could also help limit GHG emissions.[90]

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[87] EPA, Notice of Decision Denying a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emissions Standards for New Motor Vehicles, 73 Fed. Reg. 156 (Feb. 29, 2008).

[88] K. Gallagher and others, "Policy Options for Reducing Oil Consumption and Greenhouse Gas Emissions from the U.S. Transportation Sector", p. 14.

[89] See http://www.energy.ca.gov/low_carbon_fuel_standard.

[90] For a description of the London program, see Victoria Transportation Policy Institute: *London Congestion Pricing: Implications for Other Cities.*

A potentially more significant change, in terms of road pricing, would be large-scale adoption of a "VMT tax" as a revenue source for transportation programs, as an eventual replacement for the fuel tax. This approach was suggested recently by the National Surface Transportation Revenue Policy and Revenue Study Commission, which was established by Congress in 2005 to develop long-term recommendations for the transportation system. The Commission suggested that a "mileage-based fee" should be "strongly considered as a long-term replacement for the fuel tax."[91] This recommendation was based mainly on the potential for a mileage fee to provide a viable revenue source and to assist in managing congestion; however, any system involving widespread road pricing would also help to manage demand for road travel.

In Europe, which faces many similar trends and conditions to the United States, the European Conference of Ministers of Transport (ECMT) reviewed a wide range of CO_2 abatement policies for transportation and placed high emphasis on pricing strategies. In a 2006 report, the ECMT concluded that "fuel tax increases and specific fuel carbon taxes are estimated to have had a powerful impact on emissions in the small number of countries reporting them as part of CO^2 policy….They have the highest impact of any of the reported CO_2 abatement measures."[92]

Cap-and-Trade Program/Carbon Tax

Any system for pricing carbon (whether it involves a cap-and-trade program or a carbon tax) could include transportation fuels. For the consumer, the increased cost of carbon would show up in the price of gasoline at the pump. Estimates differ about how much a system of carbon pricing would affect gasoline prices. However, there is general agreement that the effect on gasoline prices would be noticeable but not dramatic in relation to the price increases that have occurred in recent years. For example, a recent report issued by Resources for the Future stated that a carbon price of $10 per ton would increase the cost of gasoline by approximately 10 cents per gallon.[93]

[91] National Surface Transportation Policy and Revenue Study Commission, "Transportation for Tomorrow" (Dec. 2007), p. 5–34. This report is available at: http://www.transportationfortomorrow.org/final_report/.

[92] European Conference of Ministers of Transport, "Transport and Environment: Review of CO_2 Abatement Policies for the Transport Sector" (2006), p. 7.

[93] R. Kopp, "Policies to Reduce CO_2 Emissions from the Light-Duty Vehicle Fleet," in *Assessing U.S. Climate Policy Options*, Resources for the Future (Nov. 2007), p. 168, footnote 29.

There is some debate about whether an economy-wide carbon price would meaningfully affect travel behavior. Clearly, it would have some effect on gasoline prices, but as noted above, the effect may be relatively modest in comparison to recent price increases. Therefore, additional regulatory measures—e.g., fuel economy standards—often are recommended in addition to setting an economy-wide carbon price.[94]

Any system of carbon pricing has the potential to generate extremely large revenues. For example, a recent report by Resources for the Future estimates that the annual revenues from a cap-and-trade program could be $100 billion or more annually.[95] Thus, over just a 10-year period, the revenues could equal one trillion dollars. The revenue from a carbon tax would be similar in overall magnitude. One potential difference is that, with a cap-and-trade system, some emissions allowances would likely be granted (i.e., given away), while others would be auctioned. Giving allowances to existing emitters would tend to reduce the revenues generated by the cap-and-trade program.

The enormity of the potential revenues from a carbon tax or cap-and-trade program would give rise to important policy decisions about how to spend those revenues and whether to make offsetting tax cuts. Certainly, there would be a strong policy preference for funding activities that help to reduce GHG emissions, both in the short and long term.

Consumer Incentives

Carbon pricing would create an economic incentive for consumers to reduce their usage of carbon-based fuels, simply because it would make gasoline more costly. There are other policy options that also could encourage consumers to purchase and operate motor vehicles in ways that reduce GHG emissions.[96] These include:

- ***Feebates.*** The term "feebate" refers to a system of fees and rebates, which are applied when consumers purchase motor vehicles. A fee—in essence, a tax—would be charged when a consumer purchases a vehicle that emits a high level of GHGs per mile traveled. This additional cost would provide a disincentive to the purchase of those vehicles. A rebate—in essence, a payment from the government to the individual—would be paid when a consumer purchases a vehicle that emits a low level of GHGs per mile traveled. The rebate would be an additional incentive to purchase low-emitting vehicles. The fees would be used to fund the rebates.
- ***Pay-as-You-Drive Insurance.*** This policy would change the way motorists pay for auto insurance. In essence, the amount of the insurance payment would be based on miles traveled (or on some combination of miles traveled and fuel used), and the payment itself would be made when the consumer purchases fuel for the vehicle. This policy would effectively incorporate insurance premiums into the price of gasoline, thus creating an additional incentive to minimize fuel usage and thereby minimize GHG emissions.

Education Campaigns

Governments also can help educate the public about ways to reduce GHG emissions. For many years, the EPA has published fuel economy ratings for automobiles and required the ratings to be prominently posted on all new vehicles. Similarly, the DOE's EnergyStar program, which is voluntary, provides energy efficiency ratings for appliances. Similar programs are now being adopted in a number of states for GHG emissions. For example, EPA has begun rating all new motor vehicles on a scale of 1 to 10 based on their GHG emissions.[97] A number of states, including Connecticut, have passed legislation requiring GHG emissions ratings to be posted on all new motor vehicles. Education campaigns also could address other issues, such as the role of vehicle maintenance, tire pressure, and driver behavior in reducing GHG emissions.

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[94] R. Kopp, "Policies to Reduce CO_2 Emissions from the Light-Duty Vehicle Fleet," in *Assessing U.S. Climate Policy Options*, Resources for the Future (Nov. 2007), p. 170.

[95] R. Kopp, "Allowance Allocation," in *Assessing U.S. Climate Policy Options*, Resources for the Future (Nov. 2007), p.88.

[96] For further information, see K. Gallagher and others, "Policy Options for Reducing Oil Consumption and Greenhouse Gas Emissions from the U.S. Transportation Sector" and R. Kopp, "Policies to Reduce CO_2 Emissions from the Light-Duty Vehicle Fleet."

[97] See http://www.epa.gov/greenvehicles/Aboutratings.do#aboutgreenhouse.

Part V: Issues for Further Study

There are many unresolved issues concerning GHG emissions from the transportation system that warrant further research and analysis.

Is VMT Growth Flattening?

Since 2005, the growth rate of VMT has been less than 0.5 percent every year—far below the average growth rate for VMT from 1990 to 2005 (2.2 percent). This recent flattening of VMT growth coincides with sharply increased fuel prices, leading some researchers to conclude that the recent decline in VMT growth rate may be just the first sign of long-term reduction in travel demand.[98] In addition, changing demographics may reduce the growth in VMT over the coming decades. If VMT growth continues to remain low, most current predictions of GHG emissions from the transportation system will need to be adjusted downward.

Can Dramatic Improvements in Fuel Economy Be Achieved?

Current forecasts assume that average fuel economy will improve incrementally between now and about 2020, and then will level off. This forecast is roughly consistent with past trends—that is, fuel economy rises in response to increases in CAFE standards, but otherwise remains roughly constant. But rising fuel prices and concerns about climate change have created enormous economic incentives for technological innovation. It is possible, although by no means assured, that the next 20 years will be quite different from the past 20. Instead of incremental gains, we could see dramatic breakthroughs, which could greatly lessen GHG emissions from the transportation system.

What Is the Optimal Role for Transit in Reducing GHG Emissions?

Shifting single-occupant vehicle trips to transit can reduce GHG emissions, especially when there is no off-setting increase in GHG emissions due to the need to construct new transit facilities. There also are many benefits to expanded transit service, independent of any benefit in terms of reducing GHG emissions. But, if transit is to be considered as a means of reducing GHG emissions, it will be important to understand the magnitude of the GHG reduction benefit in relation to the cost of the proposed improvement. Key questions to resolve include:

98 S. Polzin, "The Case for Moderate Growth in Vehicle Miles of Travel: A Critical Juncture in U.S. Travel Behavior Trends" Univ. of South Florida, Center for Urban Transportation Research (April 2006).

What types of transit projects are most effective at reducing GHG emissions? How much would these reductions contribute to reducing overall GHG reductions from the transportation sector?

How Much Can Land-Use Contribute to Reducing GHG Emissions?

Some researchers have concluded that "Smart Growth" development can produce meaningful reduction in GHG emissions from the transportation system. But there are still significant uncertainties about how much land-use changes can contribute to reducing GHG emissions and over what time period. Key questions to investigate include: What specific land-use changes are most effective at reducing GHG emissions? What role can and should each level of government play in encouraging such land use changes? What are the trade-offs in terms of mobility, quality of life, and consumer choice? It would be helpful to examine these issues in the context of specific metropolitan and rural areas.

How Can the United States Support Global Efforts to Reduce GHGs Emissions?

Progress made in reducing GHG emissions in the United States will have little benefit if GHG emissions continue to rise dramatically in China, India, and other developing countries. Therefore, in developing strategies for reducing GHG emissions in the United States, it is important to consider the potential for United States innovations to contribute to reducing GHG emissions on a global scale. For example, what vehicle and fuel technologies have the greatest potential application in the

developing world, where the greatest growth in vehicle travel is expected to occur? Investing in such technologies would not only reduce GHGs in the United States, but would contribute to solving the global problem.

What Can Be Done to Reduce GHG Emissions from Freight Traffic?

Heavy trucks contribute a small percentage of the total GHG emissions from road transportation. However, freight travel is expected to increase significantly in the next several decades, and the vast majority of that freight will be delivered by trucks. Focusing solely on passenger travel would ignore the contribution of freight shipments to GHG emissions, potentially overlooking opportunities to reduce GHG emissions cost-effectively. Therefore, research will be needed to develop a better understanding of freight's contribution to GHG emissions and potential strategies for reducing those emissions.

What Lessons Can Be Learned from Previous Attempts to Reduce VMT?

There were many efforts during the 1970s energy crises to reduce energy usage from transportation vehicles. Some of these efforts focused on vehicle technologies (e.g., CAFE standards), while others focused on driver behavior (speed limits, carpool/vanpool programs, odd/even days). These efforts and others over the past several decades have met with varying degrees of success, as documented by David Greene and Andreas Schafer in "Reducing Greenhouse Gas Emissions from U.S. Transportation" (2006).[99] Additional research would be helpful to develop a better understanding of "lessons learned" from previous efforts to limit VMT growth and energy usage.

[99] See the Reference Materials section below for a link to this report.

Reference Materials

The table below lists the key reference materials used in preparing this primer. A review of this literature, consisting of excerpts from these documents, has been prepared as an appendix to the primer. The literature review is available on the AASHTO web site at www.transportation.org.

Author	Title	Year
Matthew Barth and Kanok Boriboonsomsin	"Real-World CO_2 Impacts of Traffic Congestion" (paper presented to January 2008 annual meeting of Transportation Research Board) http://www.cert.ucr.edu/research/pubs/TRB-08-2860-revised.pdf.	Nov. 2007
European Conference of Ministers of Transport	"Transport and Environment: Review of CO_2 Abatement Policies for the Transport Sector" http://www.cemt.org/online/council/2006/CM200604Fe.pdf	June 2006
Reid Ewing et al.	"Growing Cooler: The Evidence on Urban Development and Climate Change" (Urban Land Institute)	Oct. 2007
FHWA	"Information on Climate Change and Transportation" http://environment.transportation.org/environmental_issues/air_quality/	March 2008
FHWA	"Highway Statistics" http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm	2006
Kelly Gallagher et al.	"Policy Options for Reducing Oil Consumption and Greenhouse Gas Emissions from the U.S. Transportation Sector" (John F. Kennedy School of Government, Harvard University)	July 2007
David Greene and Andreas Schafer	"Reducing Greenhouse Gas Emissions from U.S. Transportation" (Pew Center on Global Climate Change). http://www.pewclimate.org/docUploads/ustransp.pdf	May 2003
ICF Int'l Inc.	"The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure, Phase I Final Report" http://climate.dot.gov/publications/.	Nov. 2007
Intergovt'l Panel on Climate Change	"Climate Change 2007: Synthesis Report" (also known as "Fourth Assessment Report") http://www.ipcc.ch/	Nov. 2007

Author	Title	Year
McKinsey & Co.	"Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost" http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf	Dec. 2007
Pew Center on Global Climate Change	"Climate Change 101" (series of issue papers) http://www.pewclimate.org/global-warming-basics/climate_change_101	undated
Steven Polzin	"The Case for Moderate Growth in Vehicle Miles of Travel: A Critical Juncture in U.S. Travel Behavior Trends" (Univ. of South Florida, Center for Urban Transportation Research) http://www.cutr.usf.edu/pdf/The%20Case%20for%20Moderate%20Growth%20in%20VMT-%202006%20Final.pdf.	April 2006
Resources for the Future	"Assessing U.S. Climate Policy Options" (report contains a series of research papers) http://www.rff.org/rff/Publications/CPF_AssessingUSClimatePolicyOptions.cfm	Nov. 2007
Resources for the Future	"Forest and Biological Carbon Sinks After Kyoto" http://www.weathervane.rff.org/policy_design/Carbon%20Sinks/RFF-BCK-CarbonSinks.pdf	March 2006
Sir Nicholas Stern	"Stern Review on the Economics of Climate Change" http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm	Oct. 2006
Timothy Searchinger	"Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change" Science, Vol. 319 no. 5687 http://www.sciencemag.org/cgi/content/abstract/1151861	Feb. 2008
TRB	"Special Report 290: Potential Impacts of Climate Change on U.S. Transportation" http://trb.org/news/blurb_detail.asp?ID=8794	March 2008
U.S. Climate Action Partnership (U.S. CAP)	"A Call to Action" http://www.us-cap.org/	2007
USDOE (Energy Information Admin.)	"Annual Energy Outlook 2008" (revised early release) http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.	March 2008
USDOE (Oak Ridge National Laboratory)	"Transportation and Energy Data Book" http://cta.ornl.gov/data/download26.shtml	2007
U.S. EPA	"Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990–2005" http://www.epa.gov/climatechange/emissions/usinventoryreport.html	2007
U.S. DOT	Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1—Final Report	March 2008
U.S. DOT	"2006 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance" http://www.fhwa.dot.gov/policy/2006cpr/pdfs.htm	Jan. 2007
Univ. Of Washington and King County, Washington	"Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments http://www.iclei.org/documents/USA/download/0709climateGUIDEweb.pdf.	Sept. 2007

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ISBN: 978-1-56051-417-6
Publication Code: PCRT-1