Executive Summary

INTRODUCTION

This study evaluates potentially viable strategies to reduce transportation greenhouse gas (GHG) emissions. The study was mandated by the Energy Independence and Security Act (P.L. 110-140, December 2007). The Act directed the U.S. Department of Transportation (DOT), in coordination with the U.S. Environmental Protection Agency (EPA) and consultation with the U.S. Global Change Research Program (USGCRP), to conduct a study of the impact of the Nation's transportation system on climate change and strategies to mitigate the effects of climate change by reducing GHG emissions from transportation. This study also examines the potential impact of these strategies on air quality, petroleum savings, transportation goals, costs, and other factors. Each GHG reduction strategy may have various positive impacts (including co-benefits) or negative impacts on these factors. Potential tradeoffs and interdependencies when reducing GHG emissions will need to be considered in order to develop balanced solutions.

This study does not take a position as to which strategy, or collection of strategies, should be adopted to accomplish the Nation's clean energy and GHG reduction goals. Rather, the study attempts to objectively examine numerous proposed strategies and assess their potential to reduce transportation GHG emissions. The assessments are based on published scientific literature, current policy studies, and best professional estimates. Each strategy is assessed relative to projections of future transportation GHG emissions based on U.S. Energy Information Administration Annual Energy Outlook (AEO) estimates.

The study is presented in two parts: Volumes 1 and 2. **Volume 1: Synthesis Report** provides an overview of the study's findings and discusses policy options that Congress may wish to consider to reduce transportation GHG emissions. **Volume 2: Technical Report** provides the technical details of the assessment.

GREENHOUSE GAS EMISSIONS AND GLOBAL CLIMATE CHANGE[1]

The Intergovernmental Panel on Climate Change (IPCC) estimates that in the absence of additional climate policies to reduce GHG emissions, baseline global GHG emissions from human sources will increase between 25 percent and 90 percent between 2000 and 2030, with CO_2 emissions from energy use growing between 40 and 110 percent over the same period. The IPCC projects that global temperatures will rise between 2°F to 11.5°F by 2100, and global sea level will rise between 7 to 23 inches. More recent estimates that include the effects of polar ice sheet melting suggest a possible 3 to 4 foot sea level rise. According to the Intergovernmental Panel, global GHG emissions must be reduced to 50 to 85 percent below year 2000 levels by 2050 to limit warming to 2.0°C to 2.4°C (3.6°F to 4.3°F). To reach this target, GHG emissions from all sectors must be reduced through a multi-generational effort.

U.S. TRANSPORTATION GREENHOUSE GAS EMISSIONS[2]

The primary greenhouse gases produced by the transportation sector are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFC).[3] Carbon dioxide, a product of fossil fuel combustion, accounts for 95 percent of transportation GHG emissions in the United States.

Transportation GHG emissions account for 29 percent of total U.S. GHG emissions, and over 5 percent of global GHG emissions.[4] Except otherwise noted, the estimates in this report account for "tailpipe" emissions from burning fossil fuels to power vehicles and do not account for greenhouse gases emitted through other transportation lifecycle processes, such as the manufacture of vehicles, the extraction and refining of fuels, and the construction and maintenance of transportation infrastructure.[5] Including these processes, U.S.

---

[1] Vol. 1, Sec. 2.1. The citation for all figures in this subsection is Vol. 1, Sec 2.1.

[2] Vol. 1, Sec. 2.2.

[3] This report focuses only on emissions of greenhouse gases themselves, rather than emissions of chemicals that interact with other chemicals in the atmosphere to create GHGs.

[4] Vol. 1, Sec 2.2. The citation for all figures in this subsection is Vol. 1, Sec 2.2. Base data is from U.S. EPA (2008). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 to 2006.*

[5] Life cycle emissions are discussed in Vol 1, Sec. 2.3.

transportation lifecycle greenhouse gases are estimated to account for about 8 percent of global GHG emissions.

Transportation GHG emissions have been growing steadily in recent decades. From 1990 to 2006 alone, transportation GHG emissions increased 27 percent, accounting for almost one-half of the increase in total U.S. GHG emissions for the period.

In 2006, emissions from on-road vehicles accounted for 79 percent of transportation GHG emissions. Emissions from light-duty vehicles, which include passenger cars and light duty trucks (e.g., sport utility vehicles, pickup trucks, and minivans) accounted for 59 percent of emissions. Emissions from freight trucks accounted for 19 percent, and emissions from commercial aircraft (domestic and international) for 12 percent. Emissions from all other modes accounted for less than 10 percent of total emissions.

STRATEGIES TO REDUCE TRANSPORTATION GREENHOUSE GAS EMISSIONS

The study evaluated four groups of strategies to reduce transportation GHG emissions:

- Introduce low-carbon fuels;
- Increase vehicle fuel economy;
- Improve transportation system efficiency; and
- Reduce carbon-intensive travel activity.

The study also evaluated two cross-cutting strategies:

- Align transportation planning and investments to achieve GHG reduction objectives; and
- Price carbon.

Introduce Low-Carbon Fuels[6]

Petroleum-based fuels presently account for 97 percent of U.S. transportation energy use. Low-carbon fuel strategies include the development and introduction of alternative fuels that have lower carbon content and generate fewer transportation GHG emissions. The alternative fuels evaluated in this report include ethanol, biodiesel, natural gas, liquefied petroleum gas, synthetic fuels, hydrogen, and electricity. Alternative fuels strategies have primarily been investigated and quantified for the light-duty vehicle (LDV) sector, although some advances could potentially be applied to other sectors as well.

[6] Vol. 2, Sec. 2.

- Renewable fuels such as ethanol and biodiesel offer potential for GHG emission reduction. The GHG emissions benefits of biofuels depend on a variety of factors, including the feedstock, production method, carbon intensity of energy used in production, prior land use, and the evaluation timeframe. Advanced biofuels from cellulosic sources will likely offer much steeper GHG reductions than first generation biofuels, though more research and development is needed, and commercialization has not yet occurred at high volumes. Existing vehicles can operate with low blends of ethanol and biodiesel, but vehicle modifications are needed for higher blends. Adequate distribution of infrastructure is also a key factor. A detailed analysis of renewable fuels is not provided in this report due to rulemaking in this area and readers are directed to http://www.epa.gov/OMS/renewablefuels/ for more information.
- In the long-term (25 years or more), if technical successes in fuel cell development and low-carbon hydrogen production, distribution, and on-board storage can be achieved, hydrogen fuel cell vehicles could reduce per-vehicle GHG emissions by 80 percent or more. Aggressive deployment could reduce total transportation emissions by 18-to-22 percent in 2050 if a 60 percent LDV market penetration could be achieved, which is the optimal end discussed in the literature.[7]
- If significant advances were to occur in battery technology and the use of low-carbon energy sources for electricity generation, electricity (through battery-electric vehicles) could also substantially reduce transportation GHG emissions by 80 percent or more per vehicle in the long term. Aggressive deployment could reduce total transportation emissions by 26-to-30 percent in 2050 if a 56 percent LDV market penetration could be achieved, which is the optimal end discussed in the literature.

Increase Vehicle Fuel Economy[8]

Vehicle and fuel efficiency strategies include developing and bringing to market advanced engine and transmission designs, lighter-weight materials, improved vehicle aerodynamics, and reduced rolling resistance, which would result in lower fuel use and reduced transportation GHG emissions. Many of these technological improvements (such as hybrid-electric powertrains, truck aerodynamic improvements, and more efficient gasoline engines) are well-developed and could be further incorporated into new vehicles in the near future. In the long-term, propulsion systems relying on more efficient power conversion and low- or zero-carbon fuels (such as hydrogen fuel cells or plug-in

[7] National Research Council (NRC) (2008). *Transitions to Alternative Transportation Technologies – A Focus on Hydrogen*.

[8] Vol. 2, Sec. 3.

hybrids) may be developed. Many of these strategies have the potential to provide net cost savings as fuel cost savings over the life of the vehicle outweigh the higher cost of the technology. The speed of market penetration of new technologies is limited by the turnover time of the fleet. Passenger cars and light trucks last about 16 years on average before retirement, compared to 20 years or more for trucks, up to 40 years for locomotives and marine vessels, and about 30 years for aircraft.

- Increased fuel economy in light-duty vehicles could reduce total transportation GHG emissions significantly. On a per vehicle basis, compared to a conventional vehicle, GHG reductions are 8-to-30 percent for advanced gasoline vehicles; about 16 percent for diesel vehicles; 26-to-54 percent for hybrid electrics; and 46-to-75 percent for plug-in hybrid electrics.
- Retrofits can be used to expedite improvements. Heavy-duty trucks retrofitted to use aerodynamic fairings, trailer side skirts, low-rolling resistance tires, aluminum wheels, and planar boat tails can reduce per truck GHG emissions by 10-to-15 percent. For new trucks, combined powertrain and resistance reduction technologies are estimated to reduce per vehicle emissions by 10 to 30 percent in 2030.
- Significant fuel economy improvements could also be realized in the rail, and marine sectors—perhaps 20 percent per vehicle for rail and marine and 1.4-2.3% annual improvement for aircraft during 2015-2035—through more efficient engines and resistance reduction technologies. However, total gains are somewhat limited due to the relatively smaller contributions of these sectors.

Improve Transportation System Efficiency[9]

System efficiency strategies reduce the energy use and GHG emissions of travel by optimizing the design, construction, operation, and use of transportation networks.

- Lowering speed limits on national highways would generate moderate and immediate benefits, reducing total transportation GHG emissions by up to 2 percent depending upon enforcement and compliance.
- Strategies such as traffic management and bottleneck relief—including targeted capacity increases at points where demand exceeds capacity—have the potential to modestly reduce GHG emissions by decreasing fuel consumption associated with congestion and stop-and-go traffic (congestion wastes nearly 3 billion gallons of fuel each year[10]). These strategies can also

[9] Vol. 2, Sec. 4.

[10] *See* "What Does Congestion Cost Us?" in *2009 Urban Mobility Report*, published by the Texas Transportation Institute.

provide significant cost savings to travelers and businesses. However, the initial GHG benefits of these measures may be partly or fully offset by additional travel resulting from improved travel conditions, known as "induced demand." Because of the uncertainty presently associated with these potentially offsetting effects, the GHG impact of these strategies is not quantified in this report. The DOT is designing research to gain a better understanding of the role of induced demand in offsetting GHG improvements from congestion reduction strategies.

- Direct routing and more efficient takeoff and landing profiles could potentially increase air traffic operational efficiency by 2.5 to 6 percent through 2035. However, these benefits could be offset by induced demand effects which were not quantified for aviation.

Reduce Carbon-Intensive Travel Activity[11]

These strategies would reduce on-road vehicle-miles traveled by reducing the need for travel, increasing vehicle occupancies, and shifting travel to more energy-efficient options that generate fewer GHG emissions. The collective impact of these strategies on total U.S. transportation GHG emissions could range from 5-to-17 percent in 2030, or 6-to-21 percent in 2050.

- Transportation pricing strategies, such as a fee per vehicle-mile of travel (VMT) of about 5 cents per mile, an increase in the motor fuel tax of about $1.00 per gallon, or pay-as-you-drive insurance—if applied widely—could reduce transportation GHG emissions by 3 percent or more within 5-to-10 years. Lower fee or tax levels would result in proportionately lower GHG reductions.
- Significant expansion of urban transit services, in conjunction with land use changes and pedestrian and bicycle improvements, could generate moderate reductions of 2 to 5 percent of transportation GHG by 2030. The benefits would grow over time as urban patterns evolve, increasing to 3-to-10 percent in 2050. These strategies can also increase mobility, lower household transportation costs, strengthen local economies, and provide health benefits by increasing physical activity.
- Studies based on limited European experience suggest that "eco-driving" strategies to teach efficient driving and vehicle maintenance practices could potentially reduce emissions by as much as 1-to-4 percent. However, this would require comprehensive driver training as well as in-vehicle instrumentation. As such, the European findings may not be replicable in the United States.

[11] Vol. 2, Sec. 5.

Transportation Planning and Investment[12]

Transportation planning and investment decisions can integrate transportation and land use planning to reduce travel distances, fund low carbon alternatives, and improve the operating efficiency of the multimodal transportation network .

Coordinating transportation and land-use decisions and investments enhances the effectiveness of both, and increases the efficiency of federal transportation spending. In most communities, jobs, homes, and other destinations are located far away from one another, often necessitating a separate car ride for every errand and long delivery routes for goods. Strategies that support mixed-use development, mixed-income communities, and multiple transportation options can enable travelers to lower trip lengths, reduce trip frequencies, and select more carbon efficient means of travel. These changes in behavior would lower household transportation costs and reduce dependence on foreign oil, while also reducing greenhouse gas emissions. Mixed-use development combined with an increased transit market share may also improve access to jobs and opportunities for those that rely on public transportation.

Planning and investment that increases the share of transportation utilizing low carbon alternatives can reduce GHGs. Examples include public transportation, pedestrian facilities for biking and walking, and lower carbon freight options, including rail or marine.

System efficiency strategies also have potential for GHG reduction and can be instituted through transportation planning processes. These strategies include signal timing, real-time traveler information, more effecive incident management, freeway ramp meeting, and other intelligent transportation systems applications.

There are a range of options for the Federal government to work with State and local governments to incorporate climate change considerations into transportation planning and investment decisions.

Price Carbon[13]

Increasing the cost of carbon economy-wide, through a cap and trade system or carbon tax, provides an economic incentive to consumers and businesses to reduce CO_2 emissions. Policies to price carbon emissions affect all four strategy groups by encouraging use of low carbon fuels and energy efficient vehicles, spurring efficiency improvements in transportation systems, and reducing travel demand. A cap and trade system consistent with recent proposals could potentially reduce transportation GHG by about 4 percent in 2030, relative to the baseline, and more in future years.

---

[12] Vol. 1, Sec 4.

[13] Vol. 1, Sec. 4.

The intent of pricing carbon is to shift activities to lower carbon alternatives. The availability of alternatives to carbon-intensive travel are crucial to the ability of pricing strategies to reduce carbon emissions in the transportation sector without harming quality of life or the economy. These alternatives include purchasing more fuel efficient vehicles, using lower carbon fuels, taking public transportation or intercity rail, telecommuting, carpooling, and compact development that reduces the need to travel long distances. Without alternatives, consumers are faced with higher costs or reduced quality of life.

FEDERAL POLICY OPTIONS TO ACHIEVE KEY STRATEGIES[14]

Individually and in combination, many of the strategies discussed could significantly reduce transportation greenhouse gases emissions. As Congress considers policy options to pursue, it should be noted that the U.S. Department of Transportation has already committed to pursuing sustainability and livability in transportation programs and making these issues central elements of the surface reauthorization legislation. These elements are critical to achieving a reduction in the GHG emissions of the transportation sector, more transportation choices, and lowering household costs for transportation; while retaining the unique characteristics of our neighborhoods, communities, and regions.

A variety of the strategies discussed in this report are already reflected in DOT's work as it continues to focus on ways to reduce growth in VMT, integrate land use, transportation planning, and investment; and implement system efficiencies necessary to reduce GHG emissions from transportation. In addition, DOT is working on reducing aviation greenhouse gases including developing more efficient aircraft and engine technologies, adopting more energy efficient operational procedures, and advancing the use of renewable fuels.

Building on this work and on the findings of this report, several categories of policy options can be applied to implement the strategies analyzed in this report. Each strategy—vehicle efficiency, low carbon fuels, system efficiency, and reducing carbon intensive travel activity—would require government policies for implementation and to achieve GHG reductions beyond the business-as-usual scenario. This report does not provide recommendations. Instead, it analyzes the potential of each strategy and the policy options for implementing them.

Five broad categories of prospective policy action at the federal level are identified below that could implement the strategies analyzed in this report. The approaches discussed below may be pursued individually or jointly, and in many cases would have synergistic or reinforcing effects when implemented together.

[14] Vol. 1, Sec. 5.

Efficiency standards

New standards for fuels and vehicles can achieve significant reductions in carbon emissions from transportation by decreasing the amount of carbon consumed per mile of travel. There is strong evidence that, on average, regulations can achieve fuel consumption and emission reductions while delivering net cost savings to consumers over the life of the vehicle. Equally important, standards would help stimulate research and development. By way of example, the National Highway Transportation Safety Administration (NHTSA) and the United States Environmental Protection Agency (EPA) are working in concert to develop a consistent, harmonized national program that will deliver substantial improvements in fuel economy and reductions in GHG emissions for new cars and light-duty trucks.

Transportation planning and investment allocation policies

Federal transportation planning and investment programs can support integrated transportation and land use planning, provide alternatives to carbon intensive travel, and improve the efficiency of the system—all of which will reduce greenhouse gas emissions. There are three main ways in which the federal government can influence GHG reduction through transportation planning and infrastructure investment: technical assistance, federal transportation planning regulations, and aligning incentives for the tens of billions of dollars of federal transportation investment provided each year.

The U.S. DOT and other federal agencies can provide technical assistance to help transportation agencies conduct GHG inventories and analysis, improve data collection and modeling techniques, and consider GHG emissions in scenario planning, visioning, and integrated transportation and land use planning.

There are a range of options for incorporating climate change considerations. Options range from including GHG emissions as a planning factor, to requiring states and MPOs to develop strategies for reducing transportation GHGs, to establishing mandatory GHG reduction targets. Each option will have differing levels of impact on GHG emissions and require different levels of effort.

Finally, federal transportation funding programs can provide incentives for GHG reduction. Funding incentives could take the form of competitive pools of funding that encourage projects and programs to reduce GHGs. Another option is to align federal funding for transportation infrastructure with performance-based criteria, including climate change objectives that reward effective GHG emission reductions plans and programs.

Market-based incentives

Several market signals specific to the transportation sector could be used to encourage consumers and businesses to more quickly adopt less carbon-intensive vehicles and technologies. By increasing demand for low-carbon technologies, these market signals would spur more rapid private sector research

and development. Consideration could be given to continuing and expanding Federal incentives such as those in the Energy Independence and Security Act of 2007.

At the consumer level, rebates and "feebates" could encourage the purchase of high-efficiency and noncarbon-based vehicles. When appropriate, increased motor fuel taxes, variable road pricing, or VMT fees could provide incentives to travelers to reduce trip lengths and shift to less carbon-intensive modes. Tax incentives or low-interest loans for energy-efficient retrofits and new vehicles in heavy-duty, rail, air, and marine sectors, could encourage cross-sector efficiency improvements. Further analysis is needed on options for encouraging fuel efficiency in the rail, marine and aviation sectors, and the potential impacts of these actions.

Research and development

A strong Federal program of interdisciplinary research and technology deployment can advance the effectiveness of the transportation sector in addressing climate change. This research could include both basic and applied research on fuels and vehicles; development of decision support data and tools; research on relationships between climate change and transportation, including risk and adaptation analysis; development of information technologies to support system efficiency; policy research on the interactions among GHG reduction strategies, economic impacts, and institutional issues; and research on equity implications, such as mitigating or avoiding any negative equity impacts from transportation GHG reduction strategies.

Economy-wide price signal

The implementation of carbon pricing—assuming a sufficiently strong price is established—would result in reductions in fuel consumption and an ongoing shift to non-carbon-based fuels and technologies across all sectors. Over the long-term, a cap and trade policy should reinforce technological advances and promote efficiencies in transportation. In order to achieve steep reductions in the transportation sector, complementary policies in addition to a cap and trade system may be required.

CONCLUSION

The ingenuity of transportation planners and engineers has produced a vast network of transportation infrastructure and services to support the mobility and economic vitality of the Nation. However, our historic approach to transportation and land use has created an energy-intensive system dependent on carbon-based fuels and automoibles.

Our national talents and resources must now focus on shaping a transportation system that that serves the Nation's near and long-term goals, including meeting the climate change challenge.

The analysis provided by this report to Congress evaluates the greenhouse gas emission reduction potential of numerous strategies, as well as the co-benefits, costs, and implementation considerations linked to these strategies.

The U.S. Department of Transportation is committed to reducing the impact of the Nation's transportation system on climate change and is already taking action. The Department's livability initiative, along with the Sustainable Communities Partnership with the EPA and HUD, supports low carbon transportation options, such as public transportation, walking and biking. The partnership also promotes mixed-use development that enables residents to easily access goods and services. As shown by this study, all of these actions can reduce greenhouse gas emissions. The Department's high-speed rail initiative will also provide a low carbon travel alternative. Furthermore, in April 2010, the Department and EPA announced the final rulemaking for a national greenhouse gas and fuel economy program for cars and light-duty trucks. The DOT also received new statutory authority under the Energy Independence and Security Act of 2007 to create a fuel efficiency program for medium and heavy duty vehicles and work trucks, which will result in new regulations. In aviation, DOT has put energy and environmental concerns at the core of NextGen—the initiative to modernize the U.S. air traffic system. Likewise, the Maritime Administration is focused on the potential of new technologies to reduce harmful emissions from marine diesel engines through cooperative efforts with the EPA and maritime industry.

Yet there is more to be done. The DOT looks forward to working with Congress on transportation policies that will reduce greenhouse gas emissions, facilitate economic vitality, and enhance our quality of life.