

**STRATEGIES FOR REDUCING THE IMPACTS OF
SURFACE TRANSPORTATION ON GLOBAL
CLIMATE CHANGE:
*A SYNTHESIS OF POLICY RESEARCH AND STATE
AND LOCAL MITIGATION STRATEGIES***

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Prepared by:

Cynthia J. Burbank
Parsons Brinckerhoff
Washington, D.C.

February 2009

The information contained in this report was prepared as part of NCHRP Project 20-24(59), National Cooperative Highway Research Program, Transportation Research Board.

Acknowledgements

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of National Cooperative Highway Research Program (NCHRP) Project 20-24. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation (DOTs). Project 20-24 is intended to fund studies of interest to the leadership of AASHTO and its member DOTs. The report was prepared by Cynthia J. Burbank of Parsons Brinckerhoff, with major contributions by Kathy Leotta, Tiffany Batac, Katherine Vowles, and Kimberly Farley of Parsons Brinckerhoff; Adam Boies, David Kittelson, Jan Lucke, Julian Marshall, Laurie McGinnis, and Peter Nussbaum of the University of Minnesota; and Emil Frankel of Emil H. Frankel, LLC. The work was guided by a task group chaired by Joan Sollenberger, which included H. James Boice, Kevin Chesnik, Ed Cole, Ron Epstein, Charles Howard, Jr., Susan Mortel, Jackie Ploch, Caitlin Hughes Raymon, Brian Smith, Mary Lynn Tischer, John Zamurs, Shannon Eggleston, and Janet Oakley. The project was managed by Andrew C. Lemer, Ph.D., NCHRP Senior Program Officer.

Disclaimer

The opinions and conclusions expressed or implied are those of the research agency that performed the research and are not necessarily those of the Transportation Research Board or its sponsors. The information contained in this document was taken directly from the submission of the author(s). This document is not a report of the Transportation Research Board or of the National Research Council.

CONTENTS

LIST OF FIGURES AND TABLES..... vi

EXECUTIVE SUMMARY ix

CHAPTER 1: Background..... 1

1.1 Climate change is crucial to state DOTs and to the future of transportation in the United States (U.S.)..... 1

1.2 Climate change is real and poses extraordinary risks 2

1.3 Both climate adaptation and greenhouse gas (GHG) mitigation (reductions) are needed. Both will be expensive, but the cost of doing nothing will be higher..... 4

1.4 By 2050, worldwide GHG reductions of 60-80% below 1990 levels are being called for – a level of reductions that will require unprecedented changes in industries, households, and governments..... 4

1.5 Near- and mid-term GHG reductions are also called for – e.g., reduce GHG to 1990 levels by 2020 or 20% below 1990 levels by 2020..... 6

1.6 The U.S. is responsible for 30% of cumulative CO₂ emissions, and currently generates 22% of world CO₂. U.S. GHG per capita is over four times the global average GHG per capita..... 6

1.7 The U.S. will be expected to bear deeper GHG reductions than other countries..... 8

1.8 Transportation represents 5% of global GHG and 28% of U.S. GHG; highway vehicles represent 82% of U.S. transportation GHG 8

1.9 National cap-and-trade or carbon pricing can help reduce GHG – but will probably be less effective in reducing transportation GHG than GHG from other sectors 10

1.10 Cost-effectiveness should guide the selection of GHG reduction strategies. There is evidence of wide variations in the cost-effectiveness of transportation strategies. Further research is needed to estimate cost effectiveness, including accounting for co-benefits and dis-benefits of various strategies..... 11

1.11 \$50/ton of CO₂ is a useful initial reference point for cost-effectiveness of GHG reduction strategies through 2030. In the mid-long term, the cost/ton is difficult to predict 13

CHAPTER 2: Strategies to Reduce GHG in Surface Transportation 14

2.1 Surface transportation GHG reductions can be organized into 5 groups 14

- **Vehicle Efficiency 14**
- **Low-GHG Fuels..... 14**
- **Vehicle Miles Travelled (VMT)..... 14**
- **Vehicle/System Operations..... 14**
- **Construction, Maintenance, Operation, and Administration of Transportation Systems 14**

2.2 Conventional LDV technology/fuel improvements can reduce CO₂/mile up to 50% by 2030 20

2.3 Advanced vehicle/fuel technologies may achieve near-zero CO₂/mile for LDVs by 2050 – but only if major economic and technological issues are overcome..... 24

2.4	Alternative fuels hold promise for reducing GHG, but they vary widely and require careful analysis of life-cycle GHG emissions. Under some scenarios, certain alternative fuels can result in net GHG increases	25
2.5	On a global scale, the virtual decarbonization of surface transportation through technology/fuel improvements will be needed to meet GHG reduction targets and to offset the dramatic growth in VMT and GHG in developing countries.....	27
2.6	In the U.S., VMT growth will probably need to be moderated at or below 1% annual growth in order to meet GHG reduction targets	28
2.7	To reduce passenger VMT growth, there are 4 key clusters of strategies, each with different advantages and disadvantages.....	29
	• Pricing.....	29
	• Land Use.....	29
	• Mode Shifts.....	29
	• Telecommuting, Alternate Work Schedules, and Trip Chaining.....	29
2.8	Vehicle/system operations strategies could achieve 10-20% LDV GHG reduction	49
2.9	There are many strategies to reduce freight GHG, but they may be substantially offset by freight VMT increases of 1.7% annually	52
2.10	Various strategies are emerging to reduce GHG in construction, maintenance, administration, and operations of State DOTs	53
2.11	Authority and responsibility for GHG reduction strategies are dispersed and shared among state DOTs and others	57
CHAPTER 3: Scenarios to Achieve 70% GHG Reduction from LDVs by 2050.....		58
3.1	Light Duty Vehicle Fleet Scenarios:.....	58
	Baseline Scenario: 1.74% Annual VMT Growth and 36.4 mpgge LDV Fleet in 2050	65
	Scenario 1: 1% Annual VMT Growth, 100 mpgge LDV Fleet in 2050, Improving Operational Efficiency	66
	Scenario 2: 1% Annual VMT Growth, 75 mpgge LDV Fleet in 2050 (AASHTO Approximated Scenario), More Aggressive Operational Efficiency Improvements.....	67
	Scenario 3: 1% Annual VMT Growth, 75 mpgge for LDV Fleet in 2050, Improving Operational Efficiency	68
	Scenario 4: 0.9% Annual VMT Growth, 75 mpgge LDV Fleet in 2050, Improving Operational Efficiency	69
	Scenario 5: 0.9% Annual VMT Growth, 50 mpgge LDV fleet in 2050, Improving Operational Efficiency	70
	Scenario 6: 0.5% Annual VMT Growth, 50 mpgge LDV fleet in 2050, More Aggressive Operational Efficiency Improvements.....	71
3.2	Medium/Heavy Truck Scenarios.....	72
	Medium and Heavy Truck Baseline Scenario: Annual VMT Growth of 1.68% and Truck Efficiency to 7.5 mpgge in 2050.....	74
	Medium and Heavy Truck Fleet Efficiency Improvement Scenario: Annual VMT Growth of 1.68% and Truck Efficiency to 14 mpgge in 2050.....	75

CHAPTER 4: State, Regional, Local, and International Climate Action Plans	75
4.1 States: Over 30 states have developed or are in the process of developing climate action plans (CAPs). The surface transportation elements of these plans were often developed with limited state DOT input, are highly “aspirational,” vary erratically from state to state, and lack cost and specifics as to their implementation	75
4.2 State DOTs: State DOTs have begun to focus on climate change and are developing GHG reduction strategies.....	88
4.3 Regions: Three major multi-state/regional climate initiatives are underway in the U.S.	89
4.4 Cities: Nearly 800 mayors have signed the U.S. Conference of Mayors Climate Protection Agreement, agreeing to reduce community-wide GHG by 2012 to at least 7% below 1990 levels.	90
4.5 International: Other developed countries are adopting a wide variety of transportation GHG strategies	92
CHAPTER 5: Adapting Surface Transportation Systems to Climate Change.....	98
5.1 Climate changes are occurring, will intensify, and pose significant risks to transportation systems	98
5.2 Transportation agencies need to consider adjustments to planning, design, operation, and maintenance of transportation systems and facilities	99
5.3 The costs of climate adaptation for transportation are unknown at this time, but will be significant and will need to be factored into future transportation budgets, plans, and programs.....	101
REFERENCES.....	102
APPENDIX A: Conversion Factors.....	106
APPENDIX B: List of Acronyms.....	107
APPENDIX C: GHG Reduction Strategies for Medium and Heavy Duty Trucks.....	110
APPENDIX D: Literature Review	120

LIST OF FIGURES AND TABLES

Figures

1.1	Relationship among GHG Emissions	3
1.2	Impacts of Global Average Temperature Changes	3
1.3	Annual and Cumulative CO2 Emissions	7
1.4	Per Capita Annual Metric Tons CO2 Emissions for Selected Countries or Regions, and Global Average, 2005 [7]	7
1.5	U.S. GHG Emissions by Sector, 2006.....	8
1.6	U.S. Transportation Sector CO2 Emissions by Mode, Estimated.....	9
1.7	Passenger Miles per Capita for U.S., European Union (EU), and Japan.....	10
2.1	Comparison of LDV GHG Reductions.....	21
2.2	New Vehicle Fuel Economy Standards and Targets and Estimated “On Road” Values	22
2.3	Car Ownership Projections for India, China, Brazil, and the U.S.....	27
2.4	Household Trip Chaining and Consolidation Example	48
2.5	Commercial Truck GHG Emissions with Emission Reduction Measures Through 2030	52
3.1	Baseline Scenario: 1.74% Annual VMT Growth and 36.4 mpgge LDV Fleet in 2050	65
3.2	Scenario 1: 1% Annual VMT Growth, 100 mpgge LDV Fleet in 2050, Improving Operational Efficiency.....	66
3.3	Scenario 2: 1% Annual VMT Growth, 75 mpgge LDV Fleet in 2050, More Aggressive Operational Efficiency Improvements	67
3.4	Scenario 3: 1% Annual VMT Growth, 75 mpgge LDV Fleet in 2050, Improving Operational Efficiency.....	68
3.5	Scenario 4: 0.9% Annual VMT Growth, 75 mpgge LDV Fleet in 2050, Improving Operational Efficiency.....	69
3.6	Scenario 5: 0.9% Annual VMT Growth, 50 mpgge LDV Fleet in 2050, Improving Operational Efficiency.....	70
3.7	Scenario 6: 0.5% Annual VMT Growth, 50 mpgge LDV Fleet in 2050, More Aggressive Operational Efficiency Improvements	71
3.8	Medium and Heavy Truck Baseline Scenario: Annual VMT Growth of 1.68% and Truck Efficiency to 7.5 mpgge in 2050	73
3.9	Medium and Heavy Truck Baseline Scenario: Annual VMT Growth of 1.68% and Truck Efficiency to 14 mpgge in 2050	74
4.1	Cities and States Engaged in Climate Action Planning Efforts	75
4.2	Main Screen of LEAP 2000.....	82
4.3	LEAP 2000 Scenario Management	82
4.4	EU and UK GHG Reduction Targets	95
5.1	State Climate Adaptation Planning	100

Tables

1.1	Proposed or Adopted GHG Reduction Goals	5
2.1	Overview of GHG Reduction Strategies for Transportation	15
2.2	Estimates of LDV Fuel Economy Increases from Currently Available Technology Improvements, with Net Present value and Payback Period for Each Technology.....	23
2.3	National Average and Regional Example of CO2e Emissions by Mode Per Passenger Mile	31
2.4	Year 2006 Scenario Analysis of Estimated National Reduction from Current CO2e Emissions by Doubling Alternative Modes	34
2.5	Opportunities and Constraints in Doubling Alternative Mode Shares and Potential Longer-Term Effectiveness.....	36
2.6	Opportunities and Constraints in Reducing VMT/GHG through Pricing	40
2.7	Opportunities and Constraints in Reducing VMT/GHG through Telecommuting, AWS, and Trip Chaining	47
2.8	Opportunities and Constraints in Reducing VMT/GHG through Operational Efficiency Gains	50
3.1	Year 2050 Scenarios Evaluated and Changed in CO2e Emissions Compared to 2005	64
4.1	Statewide Climate Action Plans, Overall Goals/Targets.....	76
4.2	Statewide Climate Action Plans, Surface Transportation Shares of GHG Reductions.....	77
4.3	Statewide Climate Action Plans, Breakdown of Surface Transportation Elements.....	78
4.4	Guidelines for Quantification Approach, Center for Climate Strategies.....	83
4.5	State Climate Action Plan Resources	86

AUTHOR ACKNOWLEDGEMENTS

The research reported herein was performed under NCHRP Project 20-24 (59), by Parsons Brinckerhoff (PB) and the University of Minnesota Center for Transportation Studies.

Ms. Cynthia J. Burbank, National Planning and Environment Practice Leader, Parsons Brinckerhoff Americas, was the Project Manager and Principal Investigator. Contributors to this report are Kathy Leotta, Tiffany Batac, and Katherine Vowles of Parsons Brinckerhoff; Adam Boies, David Kittelson, Jan Lucke, Julian Marshall, Laurie McGinnis, and Peter Nussbaum of the University of Minnesota; and Emil Frankel of Emil H. Frankel, LLC.

At the mid-point of the project, valuable insights and information were provided by an Expert Panel of Vicki Arroyo of the Pew Center on Climate Change, David Greene of Oak Ridge National Research Laboratory, Ken Small of the University of California at Irvine, and Dan Sperling of the University of California at Davis.

EXECUTIVE SUMMARY

In the past five years, the science of climate change has advanced and it is now unequivocal that climate change is happening and poses significant risks to the planet. Climate scientists are calling for 60-80% reductions in greenhouse gases (GHG) below 1990 levels by 2050, and many countries and states have adopted targets in this range, as well as targets for 2020 and other intermediate years.

The U.S. has generated and continues to generate a substantial share of the GHG accumulating in the atmosphere. On a per capita basis, the U.S. generates four times as many GHG as the worldwide average per capita emissions. Transportation generates 28% of U.S. GHG, and 82% of the transportation emissions are from surface transportation – light duty vehicles and medium and heavy duty trucks and buses.

Climate change is likely to have more impact on the future of surface transportation than any other issue. The challenges and implications for surface transportation and for state DOTs include: the need to support major GHG reductions, the need to meet changing public expectations, the need to adapt transportation infrastructure to rising sea levels and other climate impacts, the need to prepare for major changes in vehicle technologies and fuels, the need to adjust transportation's revenue base to changes in vehicles and fuels, and the need to do so while meeting the mobility needs of a growing population in a global economy.

For the transportation sector, there are five key sets of strategies to reduce GHG:

- Vehicle improvements
- Low carbon fuels
- Moderating or reducing vehicle miles traveled (VMT)
- Improving operating efficiency of individual vehicles and highway systems
- Reducing energy/carbon associated with construction, maintenance, operation, and administration of transportation infrastructure and systems

Vehicle and fuel changes are the starting point. They are the largest potential contributor to reducing transportation GHG in the U.S. and around the world. Because of dramatic increases in vehicle ownership and use worldwide through 2050, international experts have emphasized the necessity of developing and deploying zero-carbon or near-zero-carbon vehicles, such as hydrogen fuel celled vehicles or electric vehicles drawing on low-carbon electric power. Experts have further concluded that:

- Improvements in conventional light duty vehicle (LDV) technology and fuels can reduce CO₂/mile up to 50% by 2030; and
- Advanced vehicle/fuel technologies may achieve near-zero CO₂/mile for LDVs by 2050 – but only if major economic and technological issues are overcome.

In addition to dramatic changes in vehicles and fuels, other changes will be necessary in the U.S. to meet near- and mid-term GHG reduction targets. These include:

- reducing the growth in VMT,

- increasing vehicle occupancies for all modes,
- adopting various forms of transportation pricing,
- encouraging carpooling, vanpooling, biking, walking, telecommuting, trip-chaining, and transit,
- supporting more compact land use,
- increasing “eco-driving,”
- reducing congestion,
- reducing high speeds,
- smoothing out traffic flow,
- adopting low-carbon pavement mixes and processes,
- installing LED traffic lights,
- improving freight logistics,
- accommodating double-stack freight trains, and
- many other strategies that are described in this report.

Cost-effectiveness is extremely important in the selection and implementation of transportation strategies to reduce GHG. Cost-effectiveness is always important in both the public and private sector, and is even more important in a period when transportation revenues are declining and national and world economies are in recession. McKinsey and Company has documented that significant GHG reductions can be achieved, in line with target reductions by 2030, with strategies that cost less than \$50 per ton, many of which actually have negative costs. Therefore, for the foreseeable future, \$50 per ton of GHG reduction is a useful benchmark for selecting transportation strategies to reduce GHG. Below that level, there are many transportation technology strategies and a wide range of eco-driving practices, many of which actually save money. Strategies costing significantly more than \$50/ton may not be prudent ways to achieve GHG reductions. Further research is needed to establish the cost-effectiveness of strategies to change travel behavior.

Many U.S. states and cities have adopted or are adopting climate action plans. However, the transportation elements of these plans were often developed with limited state DOT input, are highly “aspirational,” vary erratically from state to state, and lack valid cost information and specifics as to their implementation.

In addition to GHG reductions, there is substantial need for adapting transportation infrastructure to climate impacts that are already happening and will intensify in the future. Climate change puts transportation infrastructure at risk due to rising sea levels, more intense storms, higher temperatures, and other climate changes that have already begun to occur. The risk of temporary or permanent disruption of key parts of the U.S. transportation network is growing over time. Several valuable studies have been conducted in the U.S. and Europe on adaptation, but significantly more work is needed, especially to estimate the localized and regional risks to infrastructure and the changes needed to meet those risks.

Both climate change adaptation and GHG mitigation will be expensive but the cost of doing nothing will be higher. According to the Stern Review on the Economics of Climate Change, global gross domestic product could be 20 percent lower if the world fails to invest in climate adaptation and GHG reduction.

CHAPTER 1: BACKGROUND

1.1 Climate change is crucial to state DOTs and to the future of transportation in the U.S.

The single biggest issue affecting the future of transportation in the U.S. may well be climate change. There are many reasons for this, and many reasons for state DOTs to place climate change high on their list of priorities:

- (a) *Public Expectations*: There is unequivocal scientific evidence that climate change is occurring and that it poses significant risks to the future of the planet. Public surveys show sharply rising concern about climate change and growing support for changes in transportation to reduce greenhouse gas emissions.
- (b) *Infrastructure Risk*: Climate change puts transportation infrastructure at risk due to rising sea levels, more intense storms, higher temperatures, and other climate changes that have already begun to occur. The risk of temporary or permanent disruption of key parts of the U.S. transportation network is growing over time. The costs of managing these risks, and for repairing damaged infrastructure, will be high.
- (c) *Revenue Deterioration*: Transportation revenues are already in decline as a result of the shift to alternative fuels and reduced driving in response to higher fuel prices. This decline will worsen in coming decades, as auto and truck fuel economy increases and as electricity, hydrogen, and other alternative energy sources provide a majority share of power for transportation vehicles.
- (d) *State and Federal Legislation and Policies*: A majority of states have set ambitious targets for reducing GHG, and have developed statewide climate action plans with a wide variety of transportation strategies. Several states have enacted or are considering climate change laws that would require major changes in transportation and land use, including reduction in per capita VMT. In the U.S. Congress, there is growing interest in enacting changes that would tie transportation funding to reductions in GHG, reductions in VMT, and changes in land use, and would shift more future federal transportation revenue to transit.
- (e) *Technological Change*: Significant technological changes in highway vehicles are highly likely, in response to increased R&D, higher energy prices, and regulatory requirements. These vehicle changes have implications for safety, highway design, and transportation revenue, and will require changes in fueling infrastructure – all of which affect state DOTs.
- (f) *Energy Security and Energy Costs*: The U.S., and especially the U.S. transportation system, are enormously and increasingly dependent on foreign petroleum. Even if climate change were not an issue, the U.S. economy and the transportation system are vulnerable to rising costs and supply disruptions. State DOTs have seen double digit increases in the cost of materials and energy used in construction, maintenance, and

operations. These energy costs and vulnerabilities could be ameliorated by policies that reduce petroleum consumption.

State transportation agencies have much to gain from becoming proactive on climate change issues. Perhaps most important of all, they can gain credibility and the opportunity to influence state and federal policy in ways that will support a trifecta that is critical to the future of the U.S.: climate change, energy, and the economy.

Opportunities for state DOTs to become proactive on climate change vary among different states, as there is tremendous variation in the awareness of climate change by the public and elected officials. In some states, like California, Washington, Oregon, and the New England states, public interest is strong and seems to favor significant changes in transportation technology and behavior and land use. In other states, including much of the southeast and Midwest, public awareness about climate change is low or skeptical. State DOTs in the former states need to be knowledgeable, engaged and proactive in order to ensure transportation strategies will be effective and cost-effective. In the latter states, state DOTs may need to play an educational and leadership role. In some states, it may be most productive for state DOTs to emphasize energy security and energy costs, instead of climate change, as the basis for transportation policy initiatives.

1.2. Climate change is real and poses extraordinary risks.

Unequivocally, the global climate is warming. This conclusion was reached by the United Nations Intergovernmental Panel on Climate Change (IPCC), in a report prepared by leading scientists from 130 countries. The report, released in November 2007, was the culmination of five years of study and analysis. Its conclusions are based on observed increases in global air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels. [1]

The IPCC further found that most of the observed increase in global temperature since the mid-20th century is *very likely* caused by anthropogenic greenhouse gas (GHG) emissions. ‘Very likely’ indicates greater than 90% certainty.

Increased temperatures in the last decade demonstrate a more rapid increase in temperature rise than previous decades, with 11 of the last 12 years (1995-2006) being among the warmest in recorded history. Changes have been the largest over landmasses and at the northern latitudes, including North America. Temperature changes impact other aspects of climate, such as wind patterns, storms and precipitation. Increased global temperatures since pre-industrial times have corresponded to an increase in atmospheric levels of GHGs. [1]

Damage from temperature rise is expected at as little as 1°C, with hundreds of millions of people exposed to increased water stress and extinction of species. Temperature rise of 2-2.5°C will include even more severe impact to human and natural habitat with increased threat of extinction for 30% of all species. Temperature rise up to or in excess of 3-4°C would likely surpass humanity’s ability to adapt, causing severe famine and loss of life throughout the world. [1]

The relationship between rising GHG emissions, rising GHG concentrations, temperature increases, and damage is illustrated below:

Figure 1.1 Relationship among GHG Emissions, GHG Concentration, Temperatures, and Climate Damage

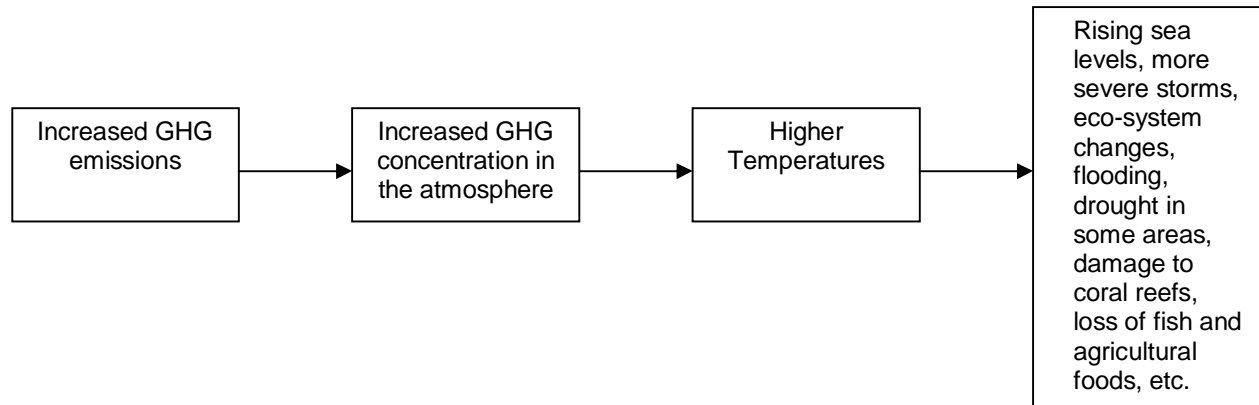
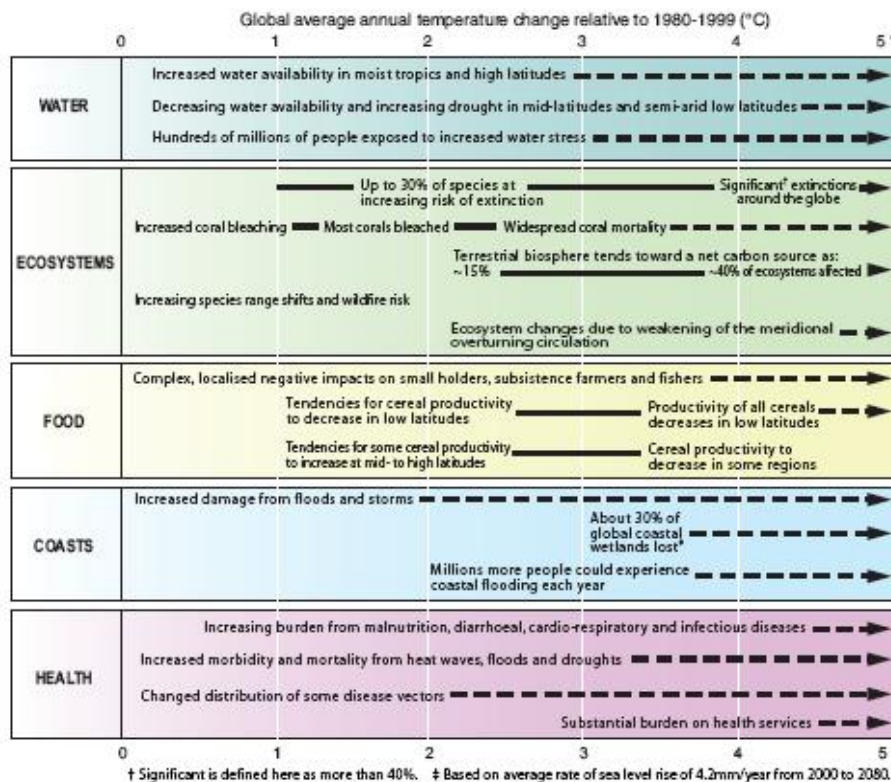


Figure 1.2 below illustrates a range of impacts associated with temperature changes as little as a 1°C temperature rise. These are illustrative examples of global impacts associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts; broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of the text indicates the approximate level of warming that is associated with the onset of a given impact.

Figure 1.2 Impacts of Global Average Temperature Change [1]



The climate has already changed by 0.7°C since pre-industrial levels. The world is already locked into an additional 0.5°C rise even if GHG emissions were reduced to 2000 levels.

Moreover, in 2007-2008 climate monitoring systems showed climate changes are occurring more rapidly and severely than climate models had been predicting.

1.3 Both climate adaptation and GHG mitigation (reductions) are needed. Both will be expensive, but the cost of doing nothing will be higher.

The Stern Review on the Economics of Climate Change [2] is the most comprehensive effort to estimate the costs of climate change. It was prepared by economist Nicholas Stern for the British government. Its primary conclusions are:

- 1% of global gross domestic product will need to be invested each year to hold world CO₂e concentrations below 550 parts per million (ppm) and thereby avoid the worst effects of climate change; and
- Global gross domestic product (GDP) could be 20% lower if the world fails to invest in climate adaptation and GHG reduction.

While many economists praised the Stern Review and its economic estimates, others have disputed it, arguing that the discount rate was too low and that risks and costs were consistently overstated.

In July 2008, based on more recent evidence of climate changes, Stern stated that the world needs to stabilize atmospheric levels of CO₂e below 500 ppm (instead of his earlier estimate of 550 ppm), which doubles the cost of reduction (to 2% of GDP by 2025).

1.4 By 2050, worldwide GHG reductions of 60-80% below 1990 levels are being called for – a level of reductions that will require unprecedented changes in industries, households, and governments.

The appropriate level of worldwide GHG reduction can be informed by science, but is ultimately a policy determination that must take many economic, social, geopolitical, and equity issues into account.

Based on the economic analysis in the Stern Review [2] and scientific information in the Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) [1], many governments and other organizations are calling for worldwide GHG reductions of 60-80% or more by 2050. The U.S. Climate Action Partnership, which includes a wide array of industry and environmental organizations, has endorsed a goal of reducing U.S. GHG emissions by 60-80% below 2005 levels by 2050.

The table below shows the GHG reduction targets adopted by various governments or proposed in several bills pending in Congress at the end of 2008.

Table 1.1 – Proposed or Adopted GHG Reduction Goals [3]

Region/Bill	2050 Goal
California: State-wide	80% below 1990 by 2050
Florida: State-wide	80% below 1990 levels by 2050
Massachusetts: State-wide	75-85% below 1990 long-term (after 2020)
Oregon: State-wide	75% below 1990 by 2050
Climate Stewardship Act (Olver-Gilchrest) H.R.620 (proposed)	70% below 1990 level in 2050
Global Warming Reduction Act (Kerry-Snowe) S.485 (proposed)	62% below 1990 level in 2050
Climate Stewardship and Innovation Act (McCain-Lieberman) S.280 (proposed)	60% below 1990 level in 2050
United Kingdom	80% below 1990 by 2050
Illinois: State-wide	60% below 1990 levels by 2050
Washington: State-wide	50% below 1990 levels by 2050
New Mexico: State-wide	75% below 2000 by 2050
New England Governors and Eastern Canadian Premiers: Regional economy-wide	75-85% below 2001 long-term (after 2020)
Minnesota: State-wide	80% below 2005 levels by 2050
Lieberman-Warner Climate Security Act of 2008 (proposed)	71% below 2005 level in 2050
New Jersey: State-wide	80% below 2006 levels by 2050
Maryland: State-wide	90% below 2006 by 2050

Many of the target reductions are based on preventing the world’s average temperature from rising more than 2-3° C above pre-industrial levels. The ultimate rise in temperature will be determined by the level at which atmospheric GHGs stabilize.

Recently, James Hansen, Director of the Goddard Institute for Space Studies at the National Aeronautics Administration, and several other leading climate scientists have argued for greater GHG reductions, based on evidence of climate changes occurring more rapidly than climate models had predicted:

“If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO₂ will need to be reduced from its current 385 ppm to at most 350 ppm.”
[4]

Based on several models of emission scenarios, worldwide emissions would have to level off immediately and decrease by 80% by 2050 in order to keep CO₂ concentrations at or below the 350 ppm level recommended by Hansen and others.

1.5 Near- and mid-term GHG reductions are also called for – e.g., reduce GHG to 1990 levels by 2020 or 20% below 1990 levels by 2020.

CO₂ is the dominant human-produced greenhouse gas. Some of the other major greenhouse gases include methane (CH₄) and nitrous oxide (N₂O). Greenhouse gases can be converted into CO₂ equivalent emissions (CO₂e emissions) according to the global warming potential (GWP) of these other gases. For transportation sources, CO₂ represents about 96% of the sector's GWP-weighted emissions. [5]

CO₂ emissions have a long life. As shown by Hooss et al., 50% of CO₂ emissions remain in the atmosphere for greater than 100 years and more than 20% will remain in the atmosphere for 400 years. [6] This makes it important to begin reducing GHG emissions as soon as possible.

At least 23 states in the U.S. have set near-term targets (variously pegged to 2010, 2015, and 2020). For example, California, Hawaii, Montana, Washington, Illinois, Wisconsin, and New Jersey have adopted a target of reducing GHG to 1990 levels by 2020.

As noted in section 1.4, Hansen and other leading climate scientists are calling for even more urgent reductions. They provide scientific evidence that the world's current GHG concentration (385 ppm) already exceeds the level (350 ppm) necessary to prevent significant and irreversible changes to the earth. On this basis, they argue for immediate reductions in worldwide GHG emissions. [4]

1.6 The U.S. is responsible for 30% of cumulative CO₂ emissions, and currently generates 22% of world CO₂. U.S. GHG per capita is over four times the global average GHG per capita.

With just 5% of the world population, the U.S. is responsible for disproportionately larger shares of CO₂ emissions. As shown below, the U.S. has generated 30% of cumulative CO₂, 1850-2000, and currently is responsible for 22% of annual CO₂ emissions.

As shown in the bar graph below, on a per capita basis the U.S. emits more than four times the global average of per capita GHG emissions, and significantly more than most countries. [7]

Figure 1.3 Annual and Cumulative CO₂ Emissions [7]

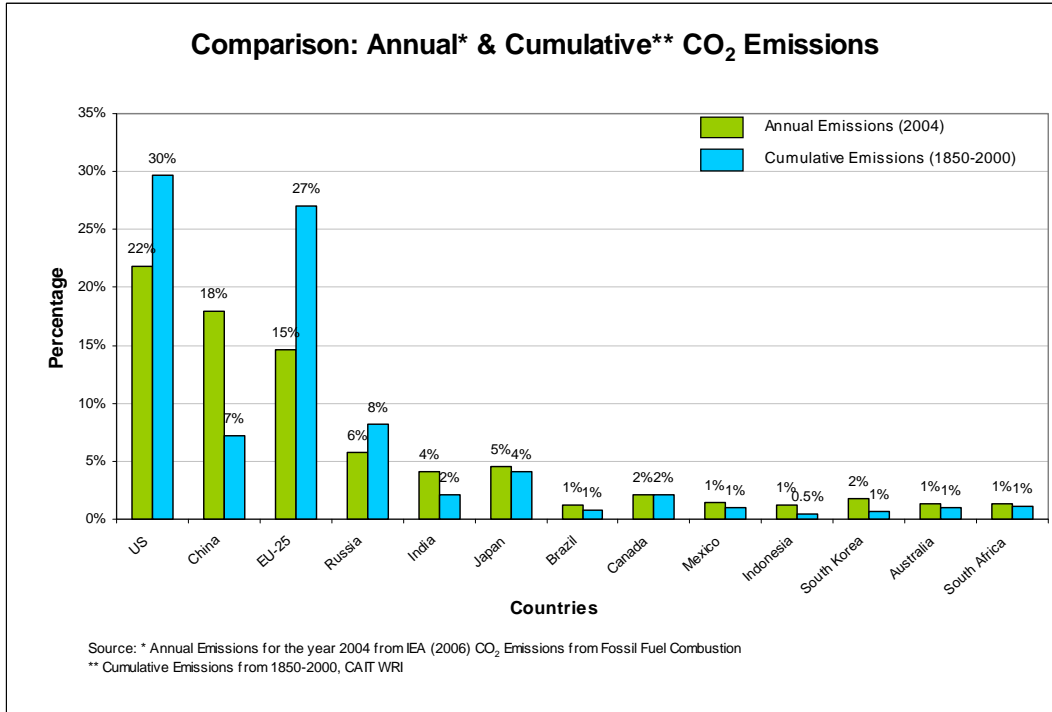
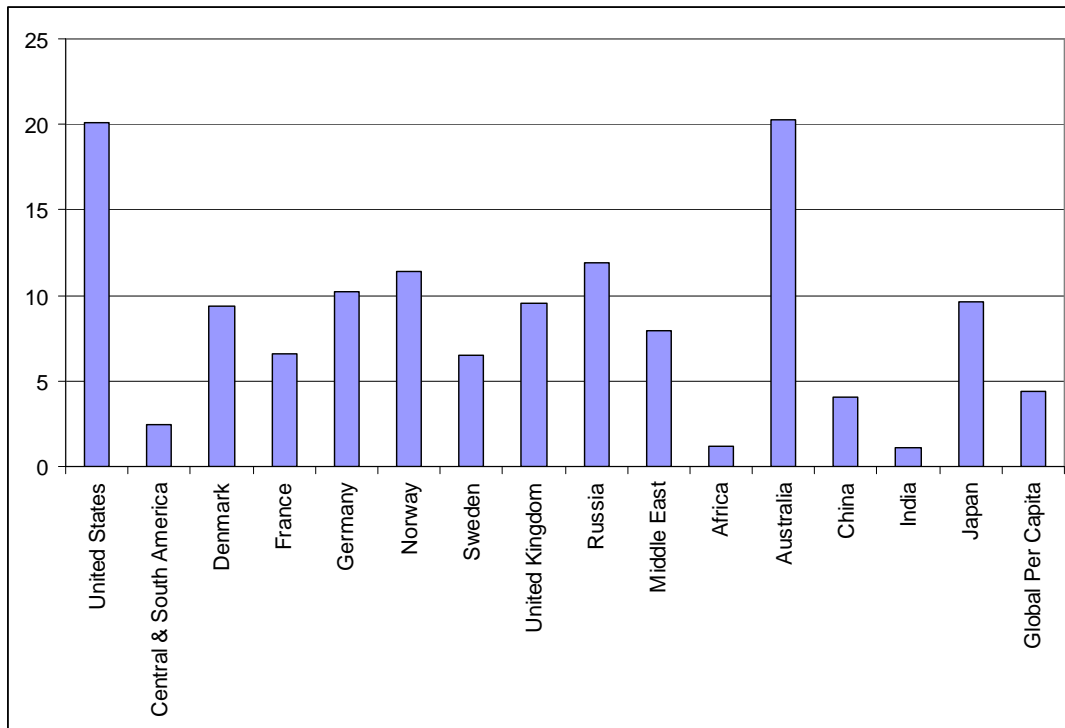


Figure 1.4 Per Capita Annual Metric Tons CO₂ Emissions for Selected Countries or Regions, and Global Average, 2005 [7]



1.7 The U.S. will be expected to bear deeper GHG reductions than other countries.

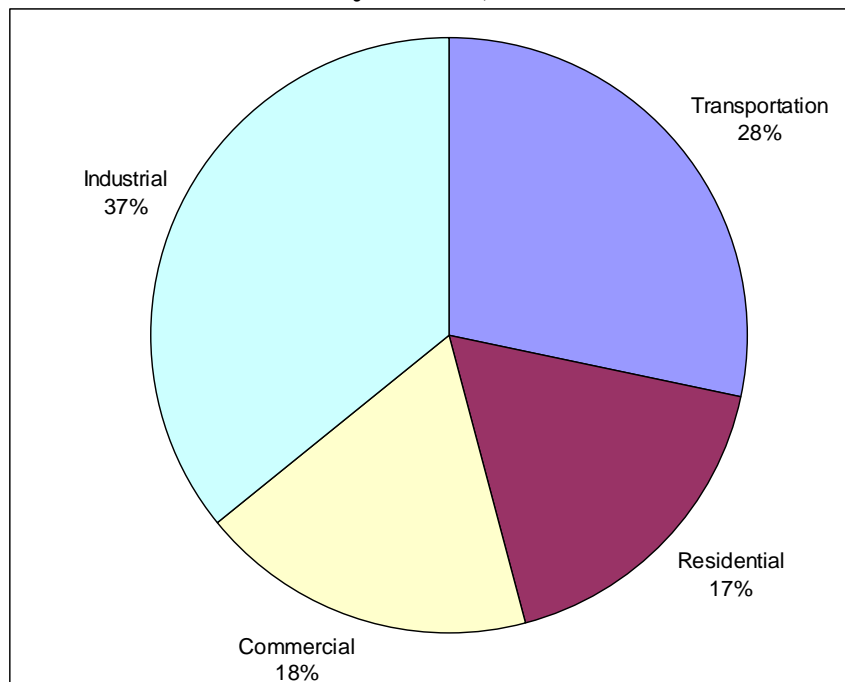
Because there are very wide disparities among countries in GHG/capita, there is a strong case for expecting those countries with the highest GHG/capita to bear a much higher responsibility for GHG reductions. It would be hard to make a case that relatively poor countries in Africa and Asia should have to make the same percentage reduction in GHG as the U.S., whose GHG/capita is four times the average of the rest of the world.

While the majority of the emissions currently in the atmosphere are from the U.S. and Western Europe, emissions from developing nations are increasing as their economies grow. For worldwide emissions to stabilize, and for developing nations to increase their economic output and standard of living, the U.S. will be expected by many inside and outside the U.S. to cut emissions more deeply and also help non-industrialized countries develop in a low carbon manner.

1.8 Transportation represents 28% of U.S. GHG, and highway vehicles represent 82% of U.S. transportation GHG

Based on end-use sectors in the U.S., transportation accounts for 28% of GHG, which is second only to the industrial sector in total GHG emissions in 2006.

Figure 1.5 U.S. GHG Emissions by Sector, 2006

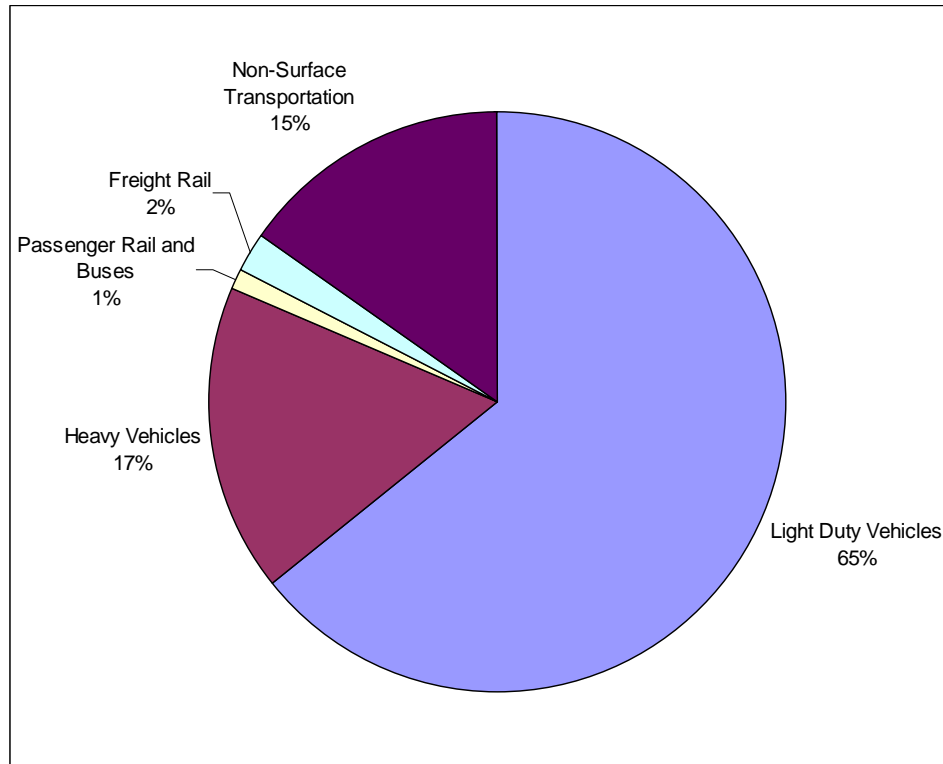


Source: EIA, Emissions of Greenhouse Gases in the United States 2006, November 2007. [8]

Within the U.S. transportation sector, light duty vehicles are responsible for about 65% of GHG emissions, followed by heavy duty highway vehicles at 17% of GHG emissions. The non-surface

transportation GHG is primarily air and waterborne travel, with freight rail, passenger rail, and bus transit making up a small portion of GHG emissions.

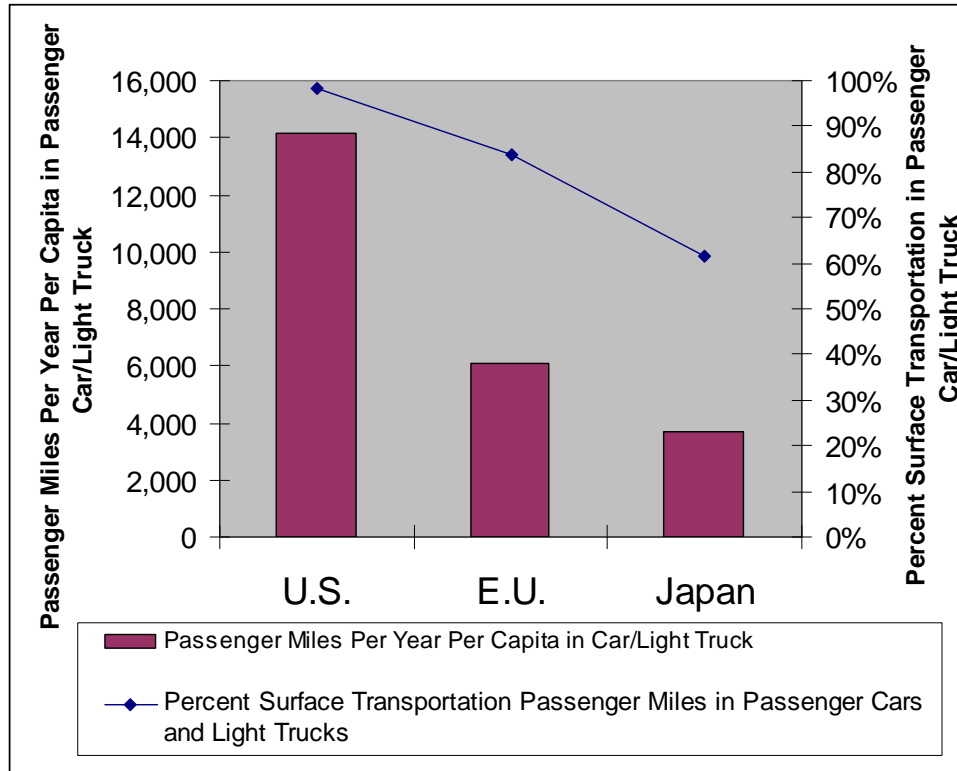
Figure 1.6 U.S. Transportation Sector CO₂e Emissions by Mode, Estimated



Source: EIA, Emissions of Greenhouse Gases in the United States 2006, November 2007. [8] Estimated Mode Level for 2006 based on 2005 Shares.

The U.S. relies more heavily than other countries on cars and light trucks for passenger travel, generating high per capita VMT. As shown in the figure below, the average per capita passenger miles of travel in cars and light duty trucks is about 6,069 miles in the European Union (EU), about 3,666 miles in Japan, and about 14,166 miles in the U.S. The percent of passenger miles of surface transportation in cars and light duty trucks is about 84% in the EU, 62% in Japan, and 98% in the U.S.

Figure 1.7 Passenger Miles Per Capita, U.S., EU, and Japan



(Source: For U.S. passenger miles of travel in cars and light trucks and surface transportation mode share, National Transportation Energy Data Book, Edition 26. For EU and Japan passenger miles of travel and mode share for passenger vehicles, source is *Panorama of Transport*, Eurostat Statistical Books, European Commission, Table 5.24, 2007.)

1.9 National cap-and-trade or carbon pricing can help reduce GHG – but will probably be less effective in reducing transportation GHG than GHG from other sectors.

It is generally acknowledged that an economy-wide carbon price or cap-and-trade program could achieve higher GHG reductions than any other strategy – depending on how it is designed. Both carbon prices and cap-and-trade programs cause prices to rise for goods and services that generate GHG and that are covered by the price or the cap. As prices rise, consumers are motivated to make adjustments to reduce GHG and, equally important, investors and business are motivated to develop and market lower-GHG goods and services. The higher the price of carbon emissions, the greater is the response by consumers and investors – and the greater the GHG reduction.

Economists have argued that a carbon tax is more efficient than a cap-and-trade program, but legislators have been reluctant to support carbon pricing directly, because of concerns that voters will perceive it as a tax. Legislators have been much more supportive of cap-and-trade programs, because their price effect is more indirect. As a result, there were at least 10 cap-and-trade bills pending in the U.S. Congress in 2008. Most of them would apply to petroleum refiners and importers, thereby effectively encompassing the surface transportation sector, as

well as to power plants and industrial sources. The amount of GHG reductions depends on the particulars of the bill, but most of the 2008 bills were designed to achieve 60-80% GHG reductions by 2050 (some bills peg the reductions to 1990, while others are pegged to more recent years). One of the 2008 bills, S.3036, known as the Lieberman-Warner cap-and-trade bill, would achieve a 60-70% GHG reduction by 2050, depending on assumptions used for the analysis.

However, most analysts expect that carbon pricing or cap-and-trade programs will not reduce transportation GHG as much as GHG in other sectors. This is because there are inefficiencies in transportation markets, many transportation strategies entail high initial costs, and transportation users are less responsive to price increases than consumers in other sectors (e.g., electricity). On the other hand, higher fuel prices in the U.S. in 2007-2008 have triggered significant changes by transportation users to reduce costs by buying more fuel-efficient vehicles, foregoing low-value trips, trip-chaining, and shifting to carpools, vanpools, and transit. It remains to be seen what price elasticities are implied by the latest developments, whether these are lasting, and the extent to which cap-and-trade programs will reduce surface transportation GHG.

1.10 Cost-effectiveness should guide the selection of GHG reduction strategies. There is evidence of wide variation in the cost effectiveness of transportation strategies. Further research is needed to estimate cost effectiveness, including accounting for co-benefits and dis-benefits of various strategies.

It is important to estimate the cost-effectiveness of different GHG reduction strategies and to factor those estimates into the selection of reduction strategies. It is important because most countries, households, and businesses have many unmet needs and wants, and because climate change adaptation and mitigation will bring substantial additional costs.

The European Conference of Ministers of Transport (ECMT) has emphasized that:

“Cost-effectiveness (cost per tonne of CO₂ abated) is the fundamental determinant of which abatement policies to adopt and how much the transport sector should contribute towards economy-wide CO₂ abatement goals...” [9]

“It is important to achieve the required emissions reductions at the lowest overall cost to avoid damaging welfare and economic growth. ... Some of the potential measures for the transport sector have relatively low costs, others very high costs at the margin.” [9]

The ECMT statements are supported by McKinsey and Company’s 2007 analysis, “Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?” [10] McKinsey and Company estimated the cost-effectiveness of a wide variety of strategies and identified many that would have negative costs (through energy and other savings), plus many more that would cost less than \$50/ton of GHG reduction. Altogether, McKinsey and Company estimated in their “mid-range” U.S. scenario that by 2030:

- 1.3 billion tons of GHG could be reduced annually through strategies with negative costs
- 3.0 billion tons of GHG could be reduced annually through strategies costing less than \$50/ton reduced (including the above 1.3 billion tons)

These reductions are substantial. They compare to 7.2 billion tons of GHG emissions in the U.S. in 2005 and a projected 9.7 billion tons of GHG emissions in 2030 under a “business as usual” scenario. However, transportation’s share of the reductions is relatively small – 0.34 billion tons annually in the mid-range case, based on the following:

- cellulosic biofuels (0.1 billion tons of GHG reduced annually at a negative cost of \$18/ton);
- increased fuel economy for cars and light trucks (0.165 billion tons of GHG reduced annually at a negative cost of \$81);
- increased fuel economy from heavy trucks (0.03 million tons of GHG reduced annually at a negative cost of \$8/ton);
- light-duty plug-in hybrids (0.02 tons of GHG reduced annually, at a positive cost of \$15/ton); and
- other – reducing vehicle air conditioning leakage, hybridizing medium and heavy trucks, and aircraft fuel efficiency (0.025 million tons of GHG reduced annually, at a cost of less than \$50/ton). [10]

McKinsey did not evaluate strategies that require changes in consumer behavior or “consumer utility” – i.e., no downsizing of vehicles or homes; no changes in temperature settings in residences, no reductions in VMT, etc. Thus, additional work is needed to ascertain the cost-effectiveness of downsizing vehicles, using transportation pricing strategies, reducing VMT, shifting travelers to carpools/vanpools, transit, and bike/ped, telecommuting, etc.

It will be very challenging to estimate cost-effectiveness for strategies which affect consumer utility, as it requires making judgment calls about people’s willingness to change behavior, about the value of lost utility (such as the value of smaller houses, less comfortable thermostat settings, sacrificed trips, or utility lost by shifting to another mode), and about “co-benefits” (such as reduced congestion associated with lower VMT, or reduced infrastructure costs).

It is likely, however, that transportation pricing strategies will have relatively high cost-effectiveness, as they cost relatively little to implement, save motor vehicle operating costs, are more effective in changing behavior than most other strategies, and have significant co-benefits from reducing congestion and infrastructure costs. Offsetting these benefits would be the lost utility from sacrificing trips or being forced to shift to a mode which would lack some of the utility associated with driving alone.

Similarly, it is likely that carpool/vanpool programs would have relatively high cost-effectiveness, for similar reasons – low cost to implement, savings in motor vehicle operating costs, and co-benefits from reduced congestion and infrastructure costs. Offsetting these benefits would be lost utility from sharing a vehicle, potentially somewhat longer trips for drop-off and pick-up of carpoolers, and somewhat longer trip times.

Estimating cost-effectiveness for transit will be especially challenging. Compared to pricing and carpool/vanpool initiatives, bus and rail transit costs are substantial because of the costs of building additional transit capacity and the costs of operating transit systems. In the absence of pricing measures, compact land use, or highly congested highways, it can be difficult to attract people from autos to transit, especially for non-work trips, so relatively significant transit investments might be required. On the other hand, if state and local governments are willing to adopt significant price increases for auto travel as well as commit to compact land use and transit-oriented development, the cost-effectiveness of transit investments may be increased (although the associated GHG reductions need to be attributed to pricing and land use as much or more than to transit). Also, increased transit investments and ridership can have meaningful co-benefits, by serving transit-dependent populations and potentially displacing the need for some increased highway investments.

Estimating cost-effectiveness for land use strategies is likely to be even more challenging, as (a) both the co-benefits and disbenefits are likely to be substantial and difficult to estimate and (b) there is substantial disagreement and variation among studies on the extent of VMT reduction that is likely for different levels of land use change.

1.11 \$50/ton of CO₂ is a useful reference point for cost effectiveness of GHG reduction strategies through 2030. In the mid-long term, the cost/ton is difficult to predict.

The economically optimal cost-ton is not yet known. For the U.S., it will depend on the U.S. GHG reduction target as well as information about the costs and benefits of current and emerging technologies and policies. The higher the GHG reductions required, the higher the cost/ton is likely to be. On the other hand, if new technologies are developed and brought to market at relatively low costs and relatively large GHG reductions, then targets can be met at a lower cost/ton. (In this section and elsewhere in the report, both “ton” and “tonne” are used, according to the original source of the information. A ton is 2,000 pounds, whereas a tonne is 2,204.6 pounds.)

However, \$50/ton is a useful starting point, and it was the cut-off selected by McKinsey and Company in the ground-breaking 2007 analysis, “Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?” [10]

Moreover, in his 2008 Ph.D dissertation, Nicholas Lutsey shows that GHG reduction strategies at or below \$50/tonne (based on lifetime analysis) can reduce U.S.GHG 43% below the 2030 baseline and 17% below the 1990 GHG level. (These estimates are for all U.S. GHG, not just for the transportation sector.) [11]

The McKinsey and Lutsey analyses provide a strong case for concentrating U.S. GHG reduction strategies on those that cost less than \$50/ton, at least initially, without reducing consumer utility. Beyond 2030, higher cost strategies may be necessary to achieve higher GHG reduction targets, especially if the U.S. adopts a target of reducing GHG 80% below 1990 levels by 2050, as many have proposed. On the other hand, costs could be lower if there are major technological breakthroughs in transportation, electric power production, and other sectors.

CHAPTER 2: STRATEGIES TO REDUCE GHG IN SURFACE TRANSPORTATION

2.1 Surface transportation GHG reduction strategies can be organized into five groups:

- **Vehicle Efficiency**
- **Low-Carbon Fuels**
- **VMT**
- **Vehicle/System Operations**
- **Construction, Maintenance, Operation, and Administration of Transportation Systems**

For each of these five groups of GHG reduction strategies, the table below lists near-term and longer-term measures, together with supporting measures and policies.

Table 2.1 Overview of GHG Reduction Strategies for Transportation

GHG Category	Today's Measures (2008-2015)	Tomorrow's Measures (2010-2030)	Supporting Measures and Policies
Vehicle Efficiency	<ul style="list-style-type: none"> • Incremental improvements in conventional gasoline LDVs and diesel heavy duty vehicles (HDV) • Low carbon auxiliary equipment on LDVs and HDVs • Increased use of conventional hybrid gas electric vehicles • Accelerated retirement of older LDVs 	<ul style="list-style-type: none"> • Electric vehicles (hybrid gas electric, plug-in hybrid, battery electric) in conjunction with low-carbon electricity • Fuel cell vehicles • More advanced low carbon auxiliary equipment on LDVs and HDVs 	<ul style="list-style-type: none"> • R&D for vehicles • Regulatory standards (fuel economy or GHG emission rate) • Feebates and other vehicle purchase incentives • Economy-wide pricing (carbon tax, carbon cap-and-trade) • Vehicle registration rates based on carbon emissions • Transportation pricing (carbon-based usage fees) • Vehicle buy-backs for older high-GHG vehicles • Government and corporate fleet vehicle purchasing • Low-rolling resistance replacement tires • Tires with automatic pressure detection and inflation

GHG Category	Today's Measures (2008-2015)	Tomorrow's Measures (2010-2030)	Supporting Measures and Policies
Low GHG Fuels	<ul style="list-style-type: none"> • 1st generation biofuels (corn and sugarcane, as long as they are truly low-carbon after considering well-to-wheel and land use GHG impacts) added to petroleum fuels • Low carbon fossil fuels (e.g., compressed natural gas) 	<ul style="list-style-type: none"> • Electricity (plug-in hybrids and battery electrics) from low-carbon power plants • Cellulosic and municipal waste biofuel • Algae-based biofuel • Hydrogen from renewable sources • Mobile air conditioning refrigerant replacement 	<ul style="list-style-type: none"> • R&D for fuels • Biofuel blending mandates (based on lifecycle GHG) • Low-GHG fuel mandates (based on lifecycle GHG) • Carbon tax on fuels (or carbon cap-and-trade programs) • Limits on production and use of high GHG fuels (e.g., tar sands and liquefied coal) • Fuel infrastructure (e.g., .plug-in hybrid or electric vehicle recharging stations, hydrogen fuel stations, low-carbon power plants, fuel pipelines, etc.) • Government and corporate fleet usage of alternative fuels

GHG Category	Today's Measures (2008-2015)	Tomorrow's Measures (2010-2030)	Supporting Measures and Policies
VMT Moderation or Reduction	<ul style="list-style-type: none"> • Pricing (congestion pricing, parking pricing, pay-as-you-drive insurance, mileage fees, higher fees for carbon fuel use, cordon pricing, etc.) • Carpool/vanpool incentives • Mode shift incentives – passenger • Mode shift incentives – freight • Telecommuting, teleconferencing, tele-shopping, and tele-education • SOV disincentives 	<ul style="list-style-type: none"> • Intensified pricing policies • Compact, mixed land use and transit-oriented development • Expanded infrastructure for high occupancy vehicle (HOV) travel, transit, and bike/ped • Expanded freight rail (including doublestack trains) and marine systems • Enhanced electronics/virtual reality to support telecommuting, teleconferencing, tel-shopping, and tele-education • Tele-medicine 	<ul style="list-style-type: none"> • Carbon taxes or cap- and-trade programs that raise fuel prices • Pay-as-you-drive insurance • Congestion pricing and cordon pricing • Mileage-based highway user fees • Parking fees • Reduced parking capacity • Dynamic carpool/vanpool programs for both work and non-work trips • Telecommute programs • Car sharing programs • Zoning policies • Compact/mixed land use incentives • Transit-oriented development incentives • Constraints on low-density land use • Doublestack trains (including necessary infrastructure changes) • Improved freight logistics (e.g., intermodal transfers and reduced back hauls)

GHG Category	Today's Measures (2008-2015)	Tomorrow's Measures (2010-2030)	Supporting Measures and Policies
System/Vehicle Operations	<ul style="list-style-type: none"> • Eco-driving and other driver behavior changes • Transportation system management changes (e.g., traffic flow improvement, speed management, elimination of bottlenecks) 	<ul style="list-style-type: none"> • Intensified driver behavior changes, aided by information technology and other technology, as well as shifts in public support for GHG reductions • Intensified system management, aided by both technology and shifts in public opinion to support GHG-reduction strategies heretofore considered unacceptable • Synchronized and adaptive traffic controls, updated frequently 	<ul style="list-style-type: none"> • Eco-driving programs to train and increase awareness of eco-driving techniques for both LDV and HDV drivers • Real-time MPG readouts on dashboards • ITS traffic management centers and ITS traveler information systems • Adaptive traffic signal control systems • Active traffic management • Faster incident response to clear traffic incidents • Elimination of highway bottlenecks • Roundabouts • Speed enforcement • Lowered speed limits • Design of highways to reduce high speeds and low speeds • Traffic management to suppress shock waves after traffic interruptions • Electric plug-ins for truck auxiliary equipment at rest stops • Other programs to reduce HDV and LDV idling

GHG Category	Today's Measures (2008-2015)	Tomorrow's Measures (2010-2030)	Supporting Measures and Policies
Transportation Construction, Maintenance, Agency Operations, and Administration	<ul style="list-style-type: none"> • Energy efficient construction, maintenance, and operational practices • Low-GHG materials (cement, concrete, asphalt, etc.) • Low carbon fuels for transportation agency vehicle fleets • Energy efficiency and/or renewable power in buildings (for new buildings and retrofitting existing buildings) • Vegetation management in highway ROW (reduced mowing, maximizing vegetative cover) • Consideration of GHG in selecting preferred alternatives and designing new projects 	<ul style="list-style-type: none"> • Longer-life pavements • “Negative carbon” concrete being developed in the U.K. • Optimum asset management to reduce need for replacement/rehab • Low carbon fuels for transportation equipment • Energy-efficient transportation equipment 	<ul style="list-style-type: none"> • R&D for construction practices and materials • Light-emitting diode (LED) traffic and street lighting • Landscaping and vegetation that reduces need for mowing highway right-of-way (ROW) • Solar panel noise walls or solar panels in ROW • Education/training of transportation employees • Construction traffic management to minimize back-ups • Incentives for employees to use carpools/vanpools and transit and to telecommute, where feasible • Low-GHG pavements and paving practices, including smoother pavements, long-lasting pavements, in-place pavement recycling, and higher fly ash content in pavements

NOTE: The above table expands on a table created by Dan Sperling and Nic Lutsey, in “Transportation and Greenhouse Gas Mitigation,” Climate Action, United Nations Environmental Program, 2007, pages 191-194.

2.2 Conventional LDV technology/fuel improvements can reduce CO₂/mile up to 50% by 2030.

Many experts have concluded that by 2030 current or emerging technology could reduce new LDV GHG per mile by 50%, at relatively low cost. (Nobuo Tanaka, Executive Director, International Energy Agency, Paris, David Greene, Oak Ridge National Laboratory, Tennessee, and Julia King, author of “The King Review of Low-Carbon Cars,” for the U.K. government.)

As Professor Julia King noted in a recent report to the U.K. government:

“In 10 years, we could be driving equivalent cars today but at 30% less CO₂/KM.... In the medium term, as we progress towards 2030, per KM emissions reductions of some 50% could be achieved through a combination of battery-electric hybrids – including plug-in versions – and biofuels, while more radical clean technologies continue to develop in niche applications.” [12]

Professor King was referring to potential improvements in the U.K., where vehicles are already substantially more efficient than in the U.S., so the potential percentage improvement would be even greater in the U.S.

Vehicle Efficiency: Light-Duty Vehicles

Light-duty vehicles (LDVs) account for 65% of transportation GHG emissions in the U.S. Historically, sector-wide LDV fuel efficiency improvements have been driven by legislative mandates, high fuel prices, or a combination of these. U.S. consumers have undervalued fuel economy, reducing the effect of higher fuel prices on fleet efficiency, which strengthens the case for mandated standards playing a role in achieving efficiency improvements. Dr. David Greene of Oak Ridge National Laboratory summarizes studies showing that consumers have historically valued only the first 3 years of fuel savings and want a payback in an average of 2.8 years on a vehicle with a typical life of 14 years. [13]

However, in 2008 high fuel prices (high by historical U.S. standards) have clearly been providing a strong push to both consumers and manufacturers in the direction of more efficient vehicles. For the first time in 17 years a high efficiency compact car, the Honda Civic, became the best selling vehicle, a position typically occupied by a full size truck. [14] In mid to late 2008, because of the consumer shift in purchases, automobile manufactures cut production of trucks and SUVs and examined options for converting manufacturing lines to more efficient compact car production in anticipation of this trend continuing. GM announced a production cut of 170,000 trucks which followed an announced reduction by Ford of 90,000 trucks. [15]

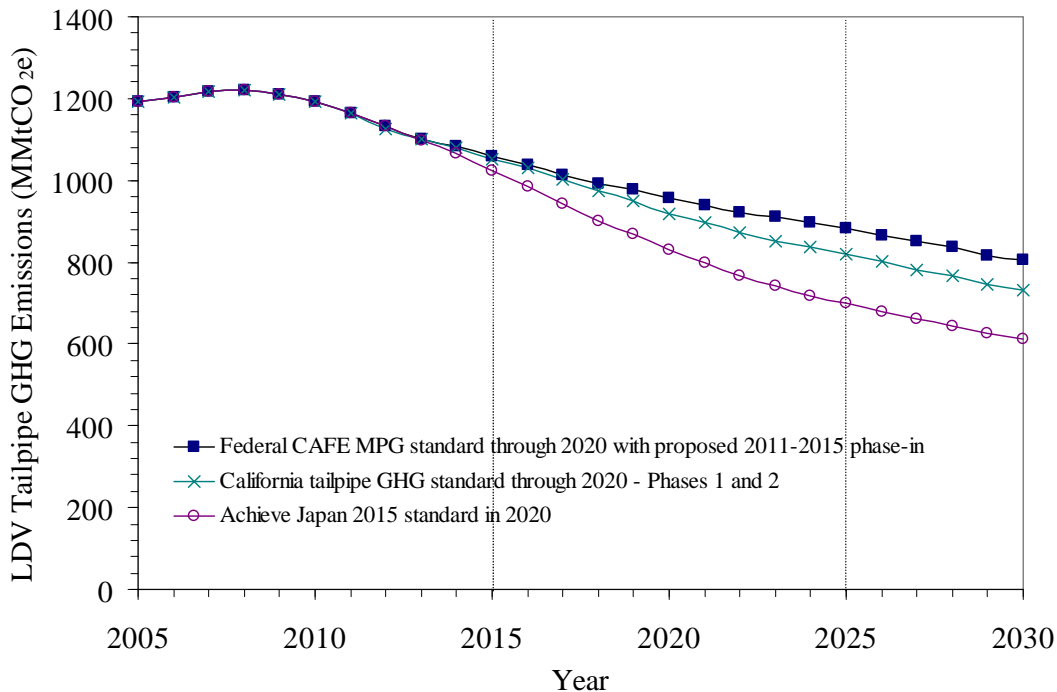
The 2007 Energy Independence and Security Act (EISA) increases corporate-average fuel economy (CAFE) standards for new LDVs to 35 mpg by 2020. This would achieve an estimated CO₂e emission reduction for the entire on-road LDV fleet of 11% in 2015 and 27% in 2030, relative to 2005 levels (basis: 0.9% annual population growth; no change in annual VMT per person; no change in carbon content of fuel).

As of early 2009, California is expected to receive authority from U.S. EPA to establish GHG emission standards which would reduce GHG/mile from new cars sooner and somewhat greater

than the U.S. CAFÉ standards. If authorized by EPA, California’s GHG emission standards are estimated to be equivalent to 42 MPG. The California standards would reduce cumulative on-road LDV emissions in California by 45% in 2020 relative to the federal CAFE standard as mandated by the 2007 EISA, with the proposed NHTSA implementation schedule. At least 17 other states have committed to voluntarily adopt these standards if and when EPA approves the California standards, with expectations for reductions of LDV emissions of 12% and 34% for 2015 and 2030, respectively (same basis as above). [16]

Figure 2.1 show U.S. LDV emissions under CAFE and the California standards, if adopted in the entire U.S. An important assumption in this graph and the percentage reductions noted above is that the standards are achieved under actual on-road conditions. (Other assumptions for these projections are: implementation of the CAFE MPG and California Phases 1 and 2 GHG emissions standards through 2020; 2005 LDV tailpipe GHG emissions at 1194 mmtCO_{2e}; [17] LDV GHG emissions from VMT growth at 0.9% per year; new LDV fleet sales mix is assumed at 50/50 cars and light trucks. Neither the federal CAFÉ standard nor the California standards mandates improvements beyond 2020, so this analysis assumes continued 2% efficiency improvement per year from 2021 to 2030.)

Figure 2.1 Comparison of LDV GHG Reductions if CAFE, California and Japan Efficiency Standards were implemented in the U.S.



Current or near term technologies for engine improvements and other techniques are available to achieve higher LDV efficiencies than required by either the California or CAFE standard. When compared to international standards and goals for fuel economy and GHG emissions, existing or proposed U.S. standards are among the least aggressive in the world, lagging behind those in Japan, the EU, Australia, and China. Figure 2.1 also projects U.S. LDV GHG emissions

assuming that the Japanese standard for 2015 is achieved in the U.S. in 2020 under actual on-road conditions. (Other assumptions are as stated above.) Even with a five year delay, Japan’s goal would result in U.S. LDV emission reductions greater than either CAFE or California standards produce; 14% by 2015 and 43% by 2030 for LDVs. [16]

When comparing different countries’ fuel economy standards, several differences should be noted. First, some countries have established mandates (e.g., CAFE), others have set voluntary goals being considered for mandates (e.g., Japan) while others are in the process of converting goals to mandates (e.g., EU). Second, the test cycles used to determine efficiency vary from country to country and are subject to change. Third, the actual “on-road” efficiencies achieved are all lower than the test cycles project, and the variation is different for different countries. Actual on-road efficiencies are a function of the intrinsic efficiency of the vehicle, driver behavior (e.g., acceleration and top speed), traffic conditions (e.g., congestion levels), and other factors. These factors vary -- driving behavior is influenced by the price of fuel, for example -- and therefore the actual on-road efficiencies are variable.

As shown in Figure 2.2, emissions per kilometer are higher (i.e., efficiencies are lower) than the test cycles project by 12%, 18% and 33% respectively for the EU, U.S. and Japanese targets. [17] While this comparison of on-road efficiencies partly mitigates the theoretical advantage of the foreign standards, the points remain that the technology to achieve greater LDV efficiency is available and that other countries are targeting greater new vehicle efficiencies than the U.S.

Figure 2.2 New Vehicle Fuel Economy Standards and Targets and Estimated “On Road” Values [17]

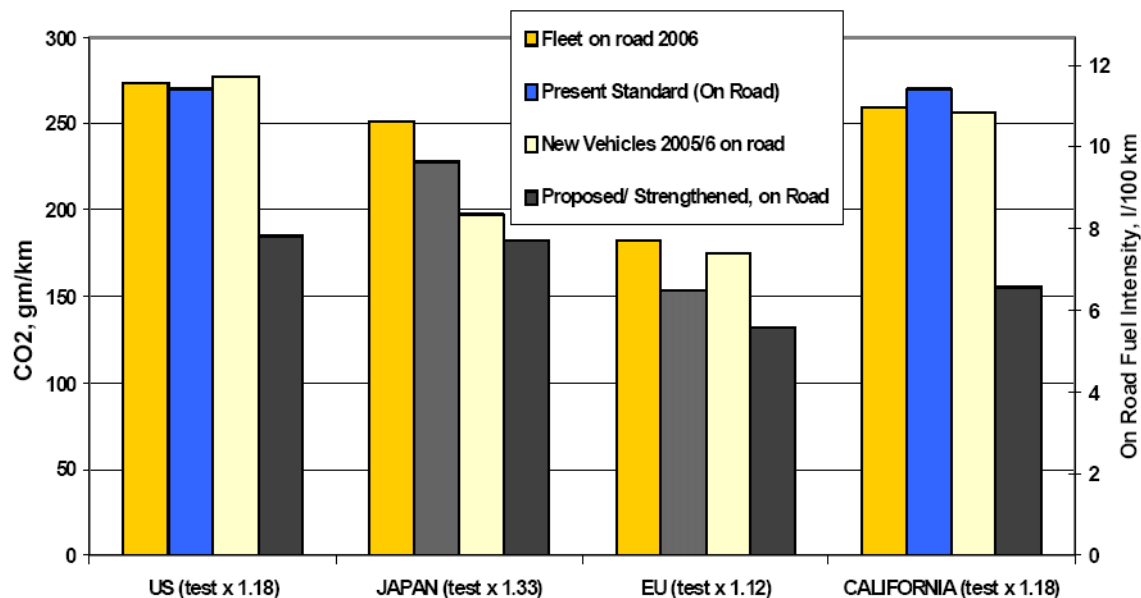


Table 2.2 lists U.S. Department of Energy estimates of LDV efficiency improvement technologies and associated vehicle cost increases. These technologies are available today or in the near-term. (The table presents examples only and is not intended to be comprehensive.) A 27 MPG vehicle is assumed for the baseline case. All else equal, GHG reductions from

increased efficiency technologies in the LDV fleet will depend on the efficiency improvement from the technology and the rate at which it enters the fleet. The table also shows estimates of the net present value (NPV) and payback period for a vehicle consumer assuming \$4/gallon gasoline. Payback periods and NPVs are clearly attractive with gasoline at this price, providing a strong incentive for consumers to buy more efficient vehicles that have the co-benefit of reducing GHG emissions per mile. Unfortunately, however, as noted earlier in this section, Dr. David Greene has documented that U.S. consumers have historically valued only the first 3 years of fuel savings, making decisions based on payback within an average of 2.8 years on LDVs with a typical life of 14 years. [13]

Table 2.2: Estimates of LDV Fuel Economy Increases from Currently Available Technology Improvements, with Net Present Value and Payback Period for Each Technology

Technology	Fuel Economy Improvement	Estimated Cost per Vehicle	Net Present Value*	Payback Period*
Reduced Engine Friction	2% - 5.3% (0.6 - 1.4 mpg)	\$33 - \$151	\$545	<2 years
Cylinder Deactivation	4.2% - 6.4% (1.1 - 1.7 mpg)	\$112 - \$252	\$700	2 years
Improved Transmission	4.2% - 8.7% (1.1 - 2.4 mpg)	\$140 - \$350	\$870	<3 years
Integrated Starter Generator	4.2% - 7.5% (1.1 - 2.0 mpg)	\$210 - \$350	\$720	3 years
Reduced Parasitic Losses	5% - 9.3% (1.4 - 2.5 mpg)	\$225 - \$500	\$830	3 years
Vehicle Lightweighting (10% to 30% reduction)	6% - 24% (1.6 - 6.4 mpg)	\$350 - \$2,100	\$1,060	5 years

* Net present value and payback period are based on midpoints of mpg improvement and additional cost ranges
 Assumptions: \$25000 vehicle with \$5000 downpayment, five year loan, 8.64% annual interest
 Baseline vehicle 27 mpg. Gas \$4/gallon. Inflation 3% annual.
 Net present value calculated for 15 year vehicle life with 5% discount rate
 Source for fuel economy improvement and cost per vehicle estimates: U.S. Department of Energy, 2007

There are trade-offs in achieving higher fuel efficiency. Many Americans value larger vehicles for various reasons and standards that effectively dictate smaller vehicles will cause some of this utility to be lost, possibly resulting in some consumer resistance even in a period of relatively expensive gasoline. It is unknown, for example, to what extent the highly efficient “minicars,” popular in Japan and Europe, will penetrate the U.S. market and therefore if the U.S. can achieve on-road efficiencies comparable to some other countries.

Safety is another important consideration. The relationship of occupant safety to vehicle size and weight is complex but clearly a factor in the decision on how to “downsize” the LDV fleet for increased efficiency. Vehicle weight is strongly correlated to efficiency, but with lightweight materials and advanced design, vehicle size and weight are not as closely correlated as previously. Some research indicates that the predominant factor in occupant safety is vehicle

design, not weight, and that fatalities actually decrease with weight reduction but increase with track/wheelbase reduction. [18] Another aspect of the safety discussion is how a downsized/lightweighted LDV fleet will interact with heavy trucks. More research is necessary to understand these parameters fully.

Vehicle Feebates or “Gas Guzzler” Taxes to Encourage Use of More Efficient Vehicles

Implementing vehicle feebates or gas guzzler taxes would encourage the purchase of more efficient vehicles by rewarding those who purchase more fuel efficient vehicles, while allowing others to purchase less fuel efficient vehicles if they are willing to pay the higher price. Revenues from feebate penalties can all be shifted into feebate rewards, so as to avoid being criticized as a tax.

Potential Benefits:

- Analysis by the University of Minnesota found that an \$18 per g/mi feebate would reduce LDV fleet-wide emissions by 17% in 2016 compared to 2002. [16]
- David Greene estimates that feebates set on the order of \$1,000 to \$1,500 per 0.01 gallons per mile can boost fleet average fuel economy 30% to 50%. [13]
- Rewards those who purchase more fuel efficient vehicles, while allowing others to purchase less fuel efficient vehicles if they are willing to pay the higher price.
- Revenues from feebate penalties can all be shifted into feebate rewards, so as to avoid being criticized as a tax.

Potential Constraints:

- If government retains any feebate revenue, it may be criticized as a tax, especially on small businesses.
- Would require new mechanisms to set up the feebate/rebate system.
- Imposes a hardship on those who need vehicles with lower fuel economy (e.g., larger, heavier vehicles needed for various work purposes).

2.3. Advanced vehicle/fuel technologies may achieve near-zero CO₂/mile for LDVs by 2050 – but only if major economic and technological issues are overcome.

Projecting vehicle technology and fuel changes to 2050 is highly speculative, but some researchers are optimistic that almost complete de-carbonization of road transport through electric or hydrogen-powered vehicles is a realistic long-term objective.

“Long term, clean electric or hydrogen-powered vehicles are a probability. There are many exciting technical challenges to overcome – e.g., batteries with an order of magnitude increase in energy density and new storage systems for hydrogen...” -- Professor Julia King [12]

“In the long run (possibly 2050 in the developed world), almost complete decarbonization of road transportation is a possibility.” -- Professor Julia King [12]

Professor King and others emphasize, however, that decarbonization of the transport sector will require major technological breakthroughs and substantial progress towards de-carbonizing the power sector

The use of electricity to power part or all of a vehicle's daily travel is an attractive choice that may soon be available to consumers, though the GHG impact of plug-in hybrid vehicles depends on the source of electricity. For plug-in hybrid vehicles in areas where electricity comes mostly from coal, such as Ohio and Minnesota, GHG emissions per mile are lower when the hybrid vehicles are operated using conventional gasoline than when using electricity. In other areas such as Oregon, Vermont, and Washington, with low-GHG electricity (e.g., from wind, solar, or nuclear), the reverse holds. [19] In the future, as the electrical sector decarbonizes by increasing production from renewable (or nuclear) sources, transportation modes that use such electricity can reduce their GHG emissions per mile. The extent of each state's use of these sources for electrical generation and the pace of further decarbonization of the sector, therefore, is one key factor for determining the rate at which its conversion of surface transportation to electricity should be made for GHG reduction goals.

2.4. Alternative fuels hold promise for reducing GHG, but they vary widely and require careful analysis of life-cycle GHG emissions. Under some scenarios, certain alternative fuels can result in net GHG increases.

There is a wide variety of different alternative fuels, each with different advantages and disadvantages. When comparing the GHG potential of different fuels, it is extremely important to focus on lifecycle emissions, not just the GHG emissions from the tailpipe of a vehicle. Following is a brief discussion on some important considerations for alternative liquid fuel sources.

- **Cellulosic**: Ethanol derived from cellulosic sources can reduce emissions by 70% or greater. [20]. Cellulosic material is the most abundant feedstock in the U.S.; it can come from perennial grasses, fast growing woody material and municipal and industrial waste streams. A recent report by the National Renewable Energy Laboratory stated that with a mature cellulosic ethanol industry the U.S. could produce 60 billion gallons of ethanol per year, or approximately 30% of the U.S. gasoline fuel consumption in 2030.[21] This displacement of gasoline with ethanol could reduce GHG emissions by 20% or greater depending on the efficiency of the process and the GHG emissions of the feedstock production.
- **Food-Based Biofuels (Corn and Sugarcane Ethanol)**: Several recent studies have examined the GHG impact of converting virgin land and found that emissions from conversion for biofuel production are 17 to 420 times the annual carbon savings that the biofuel provides when used in the place of fossil fuels. [22] While no broadly accepted method currently exists to account for all land use effects, ultimately the inclusion of land use emissions may negate the benefits of current food-based biofuels. Efforts can be made now to reduce land use emissions by encouraging biofuel production from harvesting of abandoned farm land and growth of energy crops in concert with food crops

on existing farmland. The recent effect that food-based biofuel production demands has had on food prices and the GHG emissions from virgin land conversions have made the strategy of increasing crop-based biofuel usage for GHG reduction and energy security quite controversial. For corn biofuels, the one-time emissions associated with conversion of virgin land to crop land must be included in the lifecycle emissions accounting – and can be substantial. To date, there is no agreed upon method for accounting for these indirect land use emissions. Further research is necessary to develop a standard methodology for the virgin land conversion factor.

- **Biodiesel**: In order to lower emissions of the HDV fleet, low carbon diesel must be produced to displace a fraction of the diesel consumed. Low carbon alternatives currently exist, such as biodiesel, which has 58% lower GHG emissions per unit of energy of fuel.[21] Despite biodiesel's low emissions, yields for biodiesel from soybeans are significantly lower than corn ethanol (16 GJ/ha versus 89 GJ/ha).[23] Additionally, use of soy-based biodiesel in the U.S. could worsen GHG through increased soy crops that displace carbon sinks, similar to the land use impacts associated with corn and sugarcane ethanol. The National Renewable Energy Laboratory estimates that roughly 5% of our diesel needs can potentially be met with biodiesel.[24] Other fuel alternatives, such as dimethyl ether (DME) and Fischer Tropsch diesel, are under development. These alternatives have potential to provide GHG reductions when produced from low carbon feedstocks and can be produced in larger quantities than soy-based biodiesel.
- **Coal-to-Liquids Fuels and Gasoline derived from Tar Sands**: These fuels could be helpful to U.S. energy security goals, but have GHG emissions that are much higher than conventional gasoline. Their potential value for reducing transportation GHG would require that facilities producing these fuels successfully develop and deploy carbon capture and Sequestration (CCS) to reduce their upstream emissions, which has yet to be realized at any meaningful scale. Even with successful CCS, the emissions from such fuels would be at best equal to the direct emissions from petroleum and thus would provide no GHG reductions.
- **Emerging fuels, such as dimethyl ether, produced from sources such as municipal waste or algae**: These emerging fuels have the potential to significantly reduce the emissions associated with liquid fuels.

The 2007 EISA contains a Renewable Fuel Standard (RFS) that requires that by 2022 nearly 20% of the fuel sold in the U.S. will be biofuels that meet specific lifecycle emission reductions relative to conventional petroleum products. The RFS in EISA categorizes gasoline alternative fuels into three categories, which are *renewable fuel*, *advanced biofuel* and *cellulosic biofuel*. These are required to have GHG reductions of 20%, 50% and 60%, respectively, relative to the fuel being displaced. Biomass-based diesel is mandated to have a 50% GHG reduction from conventional diesel fuel. The resulting emission reduction for on-road vehicles in 2030 from the EISA fuel standard is estimated at 5.6%, relative to 2030 emissions without the mandates.[16] More stringent fuel standards are possible, as through the low-carbon fuel standard (LCFS) discussed below.

A LCFS differs from the EISA RFS because it specifies an overall target carbon intensity, which directly correlates to GHG emissions, and allows fuel producers and blenders to choose which fuels they use to comply with the standards. To meet an LCFS a variety of production and research phase fuel options exist, including fossil fuels, biofuels, electricity, and other emerging alternatives. LCFSs must consider fuel lifecycle emissions, rather than only tailpipe emissions, because the emissions from a fuel can vary greatly depending on the fuel’s feedstock and the manner in which it is produced. An LCFS policy as envisioned by states such as Minnesota mandates a 10% reduction in fuel carbon intensity by 2020 and 12% by 2025 for fuels sold to the LDV fleet. [25] This reduction in carbon intensity could result in reduced LDV GHG emissions of 4% by 2015 and 13% by 2030.[23]

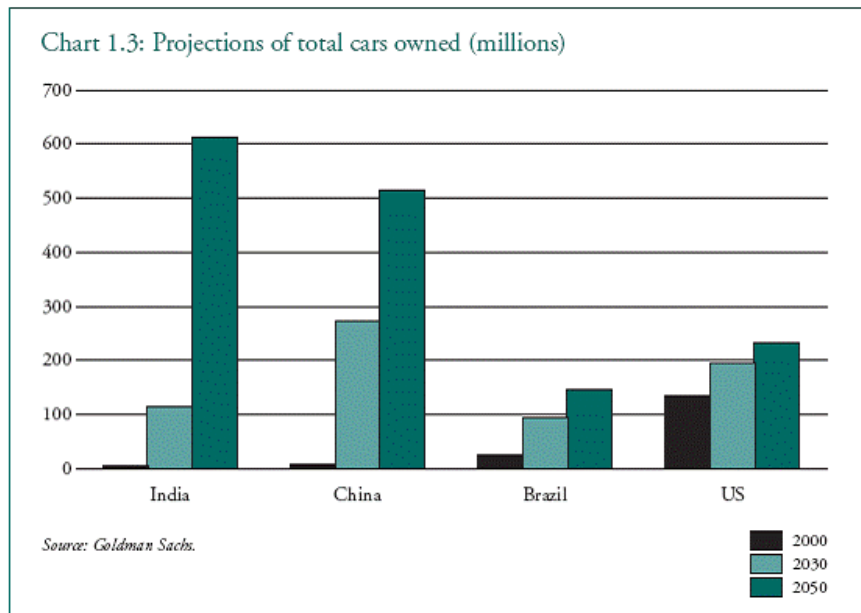
2.5 On a global scale, the virtual decarbonization of surface transportation through technology/fuel improvements will be needed to meet GHG reduction targets and to offset the dramatic growth in VMT and GHG in developing countries.

In October 2007, Professor Julia King issued the first of a 2-part report to the U.K. government on the potential for low-carbon cars, with this observation:

“In the long term, carbon free road transport fuel is the only way to achieve an 80-90% reduction in emissions, essentially “decarbonization.” (The King Review for the U.K. Government, by Professor Julia King, Vice-Chancellor of Aston University and former Director of Advanced Engineering at Rolls-Royce plc, March 2008). [12]

This point is supported by the following projected increases in car ownership throughout the world:

Figure 2.3 Car Ownership Projections for India, China, Brazil, and US



Source: The King Review, Table 1.1. [12]

Noting the above data, Professor King stated:

“Demand for road transport is expected to rise in the future. This will bring benefits for personal mobility and economic growth. For these two reasons, it will generally be preferable to reduce CO₂ by improving fuel, vehicle, and driver efficiency rather than by reducing demand for travel.” [12]

There are many reasons for the U.S. to be in the forefront of technological efforts to achieve worldwide decarbonization of highway vehicles:

- The U.S. is responsible for almost 30% of cumulative GHG emissions, despite representing only 5% of the world population.
- As one of the wealthiest countries in the world, the U.S. has the financial ability to support a massive R&D effort.
- Decarbonizing U.S. transport could eliminate the enormous transfer of wealth from U.S. payments for petroleum imports, and would also virtually eliminate U.S. energy security concerns.
- U.S. leadership in future LDV and HDV technology would provide enormous economic benefits to the U.S. economy and reduce U.S. trade deficits. (Conversely, if other countries dominate future LDV and HDV technology, the U.S. economic and trade situation could markedly worsen.)

As noted in Section 2.3, a significant R&D investment and deployment commitment will be required to overcome the technological and economic barriers to decarbonized transport vehicles and fuels. This means it is likely to take several decades to develop and deploy new vehicles and fuels -- during which time the U.S. will need to use a variety of strategies to reduce GHG, including strategies to moderate the growth in VMT.

2.6 In the U.S., VMT growth will need to be moderated at or below 1% annual growth in order to meet GHG reduction targets for 2050.

In Chapter 3, several scenarios are analyzed to ascertain the combination of VMT growth rates and vehicle fuel economies that would support attainment of a target of reducing LDV GHG by 70% below 2005, by 2050. (This target is in the middle of the targets that have been suggested by climate experts and that have been proposed or adopted by states and national governments.)

The key point is that if VMT grows by 1% annually through 2050, it will take an LDV fleet with a fuel economy equivalent to 100 mpg (mpgge) to meet a target of reducing LDV GHG by 70% below 2005 levels by 2050.

That is, 1% VMT annual growth plus fleet-average 100 mpgge could achieve 70% reduction in LDV GHG by 2050 – but if VMT grows more rapidly than 1% annually, an LDV fuel economy of more than 100 mpgge would be necessary to meet the 70% reduction target.

On the one hand, LDV fuel economy of 100 mpgge is extremely ambitious and would require transformative changes in auto technology and fuel/power source. Major technological and economic breakthroughs would be required to achieve this, vehicle and fuel costs would be much higher than today, and an enormous supporting infrastructure would need to be put in place. Perhaps most limiting, strong government policies impelling change would also likely be needed, requiring lawmakers in U.S. and state governments to reach agreement and adopt necessary supporting laws and policies – which, in turn, requires public acquiescence and support for major changes that will inevitably have or be perceived to have adverse impacts for different regions, income groups, and economic sectors.

On the other hand, promising research is now underway on electric and hydrogen-fueled vehicles and on decarbonization of power plants. In the modern era, technological breakthroughs can come rapidly, and the 2050 horizon allows 42 years for technology, economics, and supporting infrastructure to be put in place.

2.7 To reduce passenger VMT growth, there are 4 key clusters of strategies, each with different advantages and disadvantages:

- **Mode Shifts**
- **Pricing**
- **Land Use**
- **Telecommuting, Alternate Work Schedules, and Trip Chaining**

This section describes four key clusters of strategies that can be considered to reduce passenger VMT growth. These are mode shifts; pricing; land use; and telecommuting, alternate work schedules, and trip chaining.

Synergistic Effects of Combined Strategies

The sections below describe the potential effectiveness and constraints in implementing a variety of strategies to reduce VMT. However, it is important to keep in mind that most of these strategies will be most effective when combined with other strategies. For example, if land use strategies are combined with pricing strategies and the expansion of alternative mode options (carpool/vanpool programs, better sidewalks, bike paths, and transit services), the combined effectiveness may be much greater than would each individual strategy on its own. In fact, for many of these the effectiveness depends on the implementation of other strategies. For example, if transit service is extended to low density developments without either very supportive land use changes (to encourage higher density development) or pricing incentives to encourage transit ridership, then simply expanding transit service is unlikely to be very effective in reducing GHG emissions. Similarly, if land use policies are changed to support higher density development, but sidewalks and transit service are limited, the land use changes will be much less effective in reducing GHG emissions than they would otherwise be. If pricing strategies are implemented

without incentives for ridesharing or without transit, telecommuting, or other travel options available, their effectiveness in reducing VMT may be limited.

Setting Statewide VMT Reduction Goals:

Washington State House Bill 2815 (the Greenhouse Gas Emissions and Green Collar Jobs bill) was signed by the Governor into law March 13, 2008. [26]

Compared to a business as usual baseline, the state would commit to a plan to reduce annual per capita VMT by:

- 18% by 2020
- 30% by 2035
- 50% by 2050

Throughout 2008, the state is considering monitoring tools and strategies, potential impacts, and how to implement programs to achieve these goals.

Mode Shifts: Reducing VMT through Mode Shifts

CO₂ emissions per passenger mile depend on both vehicle occupancies and on the energy intensity of different transportation vehicles. The table below provides data on CO₂/PMT for various modes, for the nation as a whole as well as for Seattle, a metropolitan area that has relatively high transit ridership.

The Seattle example is provided because the Transportation Energy Data Book (which is the source for much of the data) cautions that great care should be taken when comparing modal energy intensity data among modes, due to the inherent differences between the transportation modes in the nature of services, routes available, and many additional factors that make it not possible to obtain truly comparable national energy intensities among modes.

Table 2.3 National Average and Regional Example of CO₂e Emissions by Mode Per Passenger Mile

NATIONAL AVERAGE*	Energy Intensities		Load Factor	CO₂e
	(Btu or kWhr per vehicle mile)	(Btu or kWhr per passenger mile)	Persons Per Vehicle	(Estimated Pounds CO₂e Per Passenger Mile)
SOV Light Duty Vehicles (Cars & Personal Trucks)	5,987	5,987	1.00	0.99
Personal Trucks	6,785	4,329	1.72	0.71
Transit Bus	37,310	4,318	8.80	0.71
Cars	5,514	3,496	1.57	0.58
Electric Trolley Bus**	5.2	0.39	13.36	0.52
HOV (2+) Light Duty Vehicles (Cars & Personal Trucks)	5,987	2,856	2.10	0.47
Intercity Rail (Amtrak)***	54,167	2,760	20.50	0.39
Light and Heavy Rail Transit***	62,797	2,750	22.50	0.39
Motorcycles	2,226	2,272	1.20	0.37
Commuter Rail***	92,739	2,569	31.30	0.36
Vanpool	8,048	1,294	6.10	0.21
Walking or Biking	-	-	1.00	0.00
REGIONAL EXAMPLE (SEATTLE/PUGET SOUND REGION)	Energy Intensities		Load Factor	CO₂e
	(Btu or kWhr per vehicle mile)	(Btu or kWhr per passenger mile)	Persons Per Vehicle	(Estimated Pounds CO₂e Per Passenger Mile)
Cars (64%) and Personal Trucks (36%)	5,987	4,468	1.34	0.74
King County Metro Diesel and Hybrid Buses	33,024	2,854	11.57	0.47
Sound Transit Buses	33,024	2,517	13.12	0.42
King County Electrically-Powered Trolley Buses**	5.33	0.44	12.12	0.11

*Most of the national average energy intensity data is from 2006 from The Transportation Energy Data Book, Edition 27 which cautions that it is not possible to obtain truly comparable national energy intensities among modes, and the values presented below are averages, with a great deal of variability even within a mode.

**For electrically-powered vehicles, CO₂e per vehicle mile varies greatly by region, according to fuel sources used for power generation. The national assumption shown here is based on a national average for CO₂e per kWhr for power generation. Currently four cities in the U.S. have bus trolley systems operated by transit agencies: San Francisco, Boston, Seattle, and Dayton. The CO₂e emissions for each system will be either higher or lower than the national average according to that region's power generation. For Seattle/Puget Sound example, CO₂e emissions per vehicle and passenger mile for trolley buses are significantly lower than the national average due to the predominance of hydroelectric power generation in the region.

***Estimate of CO₂e assumes same CO₂e per btu weighted by all passenger rail energy sources (diesel and electricity).

The national data on energy intensity and CO₂e emissions by mode per passenger mile indicate that walking and biking are the most energy-efficient/lowest GHG modes, with vanpools being the most energy efficient motorized mode, with lowest GHG/PMT. After vanpools, the rail modes of passenger travel are more energy efficient, on a passenger mile basis, than the bus, car, or personal truck modes. Contrary to perception, cars are, on average, less carbon-intensive per passenger mile, than transit buses. Nationally, electric trolley buses have lower CO₂e emissions per passenger mile than transit buses, likely owing largely to the higher average load factor for trolley buses, although the source of power generation for electric trolley buses can also greatly influence their CO₂e emissions compared to diesel buses.

It should be pointed out that values represent average national values and are very sensitive to the load factors assumed. For example, in the table above, CO₂e per passenger mile for a single occupancy vehicle is quite different from the CO₂e per passenger mile for an average car (at 1.57

occupancy) or a carpool with two, three, or four persons per vehicle. For buses, the load factor represents how full the buses are (i.e., the fuller the bus, the fewer vehicle miles required to transport passengers on a passenger mile basis). Trolley buses, with an average load factor of 13.36 have lower CO₂e emissions per passenger mile than buses, with an average load factor of 8.8 persons. This difference is due largely to the higher average load factor of trolley buses. Using these average vehicle load factors and assumed energy intensity per vehicle mile by mode, the national analysis indicates higher CO₂e emissions per passenger mile for transit buses than for cars and light trucks.

The 2008 increase in fuel prices, along with general economic factors in 2008-2009, undoubtedly increased the load factor for all modes. People shifted to carpools, vanpools, and transit to save on fuel costs and cope with a sluggish economy. It is not clear whether this may have affected the relative GHG/PMT among the modes.

As pointed out in the Transportation Energy Data Book, this national data is unlikely to reflect local conditions. To illustrate how CO₂e emissions by mode for a local system may differ greatly from the national average, a local example from the Seattle/Puget Sound region is provided in the table above.

Two primary factors result in lower CO₂e emissions for bus travel in the Puget Sound region when compared to the national average: higher ridership and more energy efficient buses. The average systemwide load factor for buses in the Puget Sound region is about 11.6 for King County buses, and 13.1 for Sound Transit buses (compared to the national average of 8.8). This factor alone would result in the CO₂e per passenger mile being considerably lower in the Puget Sound region than the national average.

An additional factor, however, is the bus vehicle fleet, which is more efficient in the Puget Sound region than the national average (estimated at 4.2 miles per gallon in the Puget Sound region, compared to the national average of 3.6 miles per gallon according to the APTA 2007 Fact Book). King County and Sound Transit's bus fleets both include a number of hybrid electric buses.

Due to the higher average bus load factor and the use of more energy efficient buses, the King County Metro Transit and Sound Transit systems average about 0.47 and 0.42 pounds of CO₂e per passenger mile, respectively, compared to the national estimate of 0.71 pounds of CO₂e per passenger mile. Furthermore, some bus routes in the Puget Sound region are much more efficient than the systemwide average. In 2006 some of King County Metro's buses achieved a peak period load factor averaging more than 20 persons per vehicle. At a load factor of 20 persons per vehicle, the CO₂e emissions per passenger mile is 0.27 pounds.

Transit in the Puget Sound regional also compares favorably to car and light truck CO₂e emission per passenger mile because of the lower average load factor for cars and other light duty vehicles in the Puget Sound compared to the national average. Therefore, the CO₂e emissions per passenger mile are higher for cars and light trucks in the Puget Sound region than the national average (0.74 pounds CO₂e emissions per passenger mile in the Puget Sound region for cars and light trucks, compared to the nationwide average of 0.58 and 0.71 for cars and light trucks, respectively).

King County Metro also runs electrically-powered trolley-buses, which represented about 7% of King County's transit vehicle miles in 2006. Because the trolley buses are also relatively well-utilized, and because electric power generation in the Puget Sound region is primarily from hydroelectric power and therefore significantly lower in CO₂e emissions than the national average, trolley buses have much lower CO₂e emissions per passenger mile than the rest of the bus fleet.

This regional example highlights that transit's ability to reduce GHG emissions is highly dependent on both the utilization and energy efficiency of the buses, which may vary considerably from region to region. Just as Seattle illustrates near-optimal transit conditions, there are other regions and cities which illustrate the opposite end of the spectrum, with low transit occupancies, higher auto occupancies, and fleets with higher average LDV fuel economy.

The table above did not include high speed rail because no true high speed rail is currently in operation in the U.S. Due to the long-distances served by high speed rail, it is more comparable to air travel than typical surface transit. High speed rail is also much more energy intensive than the other modes of surface transportation. Recent analysis of a proposed high speed rail system in California [27] used an assumed energy consumption for high speed rail of 924,384 btu/vehicle mile, along with an assumed energy consumption of 326,894 btu/vehicle mile for airplanes. However, there because there is no high speed rail system in operation in the U.S. no actual data on average passenger loads is available to estimate CO₂e emissions per passenger mile. However, modeling analysis of the high speed rail system in California indicated that if the system achieves an average of 994 passengers per 16-car train set (62 passengers per train car), the CO₂e emissions per passenger mile for high speed rail would be lower than airplanes or most other modes of surface transportation. [27]

Vanpooling and Worker/Driver Programs in the Puget Sound Region

Vanpools are one of the most energy efficient forms of transportation (because they generally do not run empty or nearly empty for long distances. Many vanpool programs offer financial incentives for the vanpool driver. King County Metro, for examples, has a large vanpooling program that includes use of a van and incentives for the vanpool driver. While vanpool passengers must pay a fee to participate in the vanpool, the vanpool driver does not. For 30 round-trip miles five days a week, the fixed rate for an eight-passenger van is \$55.71 per rider per month, with the driver riding for free. In addition to not paying the monthly fee, the driver can also use the van up to 40 miles per month for personal reasons.

Another example is a Worker/Driver program. Kitsap Transit in Bremerton, Washington, operates a Worker/Driver bus program. In Bremerton, this program originated during World War II, with the need to transport thousands of Puget Sound Naval Shipyard employees to and from work during a time of fuel rationing. [28] Today, the current program operates 28 routes [29] to the shipyard and Naval Station Bremerton. Buses are driven by full time employees of the military facilities who are also part time employees of Kitsap Transit. The average number of riders is 30 passengers per route. As part time transit agency employees, they are paid an hourly wage when they operate the bus, varying from 2 to 4 hours per day. Each driver makes one morning run to the shipyard, and an afternoon run at the end of the day.

Mode Shifts: Doubling Alternative Mode Share

To test the potential for achieving GHG reductions through mode shifts, an analysis was done of doubling passenger miles for transit, passenger rail, carpools of 2 or more occupants, vanpooling; walking, and biking. This analysis was intended to focus on what might be possible without dramatic changes to land use and infrastructure, and that could be achieved in the relative near-term (e.g., perhaps within a decade or two under aggressive supporting policies). However, with higher bus load factors, fewer bus vehicle miles are needed to carry the same number of bus passengers (i.e., buses are fuller), so CO_{2e} emission reduction benefits on a per passenger mile basis would generally be higher.

As shown in the table below, these mode change assumptions result in a modest decrease in CO_{2e} emissions of 4.2% of surface transportation GHG for passenger vehicles. Most of these reductions were from an increase in 2+ HOVs.

Table 2.4 Year 2006 Scenario Analysis of Estimated National Reduction from Current CO_{2e} Emissions by Doubling Alternative Modes

	2006				2006 Data With Mode Change Scenario			
	Annual Passenger Miles (Millions)	Share of Trips Analyzed (Passenger Miles)	Average Vehicle Load (Persons Per Vehicle)*	Estimated Metric Tons CO _{2e}	Double Mode Changing Miles (Million Passenger Miles)	Share of Trips Analyzed (Passenger Miles)	Estimated Metric Tons CO _{2e}	Portion of CO _{2e} Emissions Reduction
SOV Light Duty Vehicles	1,125,319	26.17%	1.0	503,383,762	931,500	21.66%	416,683,973	-
HOV (2+) Light Duty Vehicles**	3,082,069	71.68%	2.1	656,486,657	3,199,112	74.40%	681,416,954	60.4%
Passenger Rail	31,000	0.72%	24.2	5,422,553	62,000	1.44%	10,845,107	16.0%
Bus Transit	21,998	0.51%	8.8	7,105,746	43,996	1.02%	14,211,491	11.3%
Demand Responsive	930	0.02%	1.0	1,025,697	930	0.02%	1,025,697	-
Walking	16,573	0.39%	NA	-	33,145	0.77%	-	8.6%
Biking	6,600	0.15%	NA	-	13,200	0.31%	-	3.4%
Motorcycling	14,881	0.35%	1.2	2,525,162	14,881	0.35%	2,525,162	-
Vanpools	605	0.01%	6.1	58,516	1,210	0.03%	117,031	0.3%
Total	4,299,975		NA	1,176,008,092	4,299,975		1,126,825,415	
Percent Reduction								-4.2%

*Assumes average vehicle load factor remains constant.

**For 2+ HOVs, assume doubling only of assumed portion of HOVs for work trips.

Does not include doubling of motorcycles and demand responsive vehicles, or all possible alternative modes.

Sources: For 2006 passenger miles data, walking estimate based on National Household Travel Survey 2001, using assumption of average walk trip length of 0.5 miles. Biking estimated on National Bicycling and Walking Study - Ten Year Status Report October 2004, with assumption of average bike trip length of 2.0 miles. Carpool estimate based on assumption of work trips of all household travel from the National Household Travel Survey 2001, with portion of work carpools based on The American Housing Survey of 2005. All other mode share passenger mile estimates from Transportation Energy Data Book, Edition 27.

The somewhat modest CO_{2e} emission reduction possible nationwide from doubling mode shares for the alternative modes is primarily a reflection of the fact that the alternative mode shares to begin with are so low. As indicated in the preceding table, of the modes analyzed in this scenario analysis, about 0.72% is passenger rail, 0.51% is bus transit, 0.39% is walking, and 0.15% is biking.

Therefore, at a national level, doubling these alternative modes doesn't have a large effect. Even with this doubling, about 96% of travel is still in the personal truck or car, either in the form of single occupancy vehicles or carpools. In addition, because vehicles used for carpooling and vanpooling, and transit vehicles themselves emit GHG emissions, shifting a mile of passenger travel from a passenger vehicle to a transit vehicle, carpool, or vanpool does not reduce GHG emissions for that mile by 100%. Instead, it might reduce it by anywhere from zero % to 70% or more, depending on how many people are in that vehicle and the vehicle efficiency. Among other things, this analysis illustrates the CO₂e emissions benefits of higher vehicle load factors for transit and other vehicles, even given the same number of transit passenger miles and share of transit trips.

NOTE: For this analysis, carpool trips were doubled only for the estimated number of work carpool trips. Nonwork carpooling was not doubled for this analysis. An approximation of current work carpool trips was based on National Household Travel survey data, which indicates that about 27% of household VMT is for work-related trips, and from American Housing Survey 2005, which indicates that about 10% of work trips are carpools. From these estimates, it was assumed that 117,043 million annual passenger miles in cars are work-related carpool trips (about 3% of all car trips), and this number was doubled for this analysis.

The table below briefly summarizes some of the potential opportunities, issues, or obstacles to doubling the use of alternative modes in the near-term. It also indicates potential long-term effectiveness.

Table 2.5 Opportunities and Constraints In Doubling Alternative Mode Shares, and Potential Longer-Term Effectiveness

Mode Change Type	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness
Walking:	<ul style="list-style-type: none"> • Highest energy efficiency of all travel modes. • Minimal or no cost. • 100% reduction in CO₂e emissions per trip. • Co-benefits of increased walking (such as improved health and reduced health care costs, reduced energy costs, etc.). • Effective both for work and non-work trips, and in most parts of metropolitan areas. 	<ul style="list-style-type: none"> • On nationwide basis, walking trips represent a very small portion of all trips, so doubling does little to reduce CO₂e emissions nationally, although it may have a much more meaningful contribution regionally and in the longer-term with more significant increases. • Longer trip times. • May need to improve or expand sidewalks and trails to improve safety for pedestrians. • Especially in rural and low density urban areas, unclear if existing land use patterns would support a doubling of walking in near-term. 	<ul style="list-style-type: none"> • Over the longer-term, more compact development with high quality pedestrian facilities and expanded transit services and facilities could increase the percentage of walk trips in the U.S. • Long-term benefits same as short-term.
Biking:	<ul style="list-style-type: none"> • Very high energy efficiency. • Low cost. • 100% reduction in CO₂e emissions per trip (not counting manufacture of bikes). • Co-benefits of increased biking (such as improved health and reduced health care costs, reduced energy costs, etc.). • Effective for short-medium length work trips and some non-work trips. 	<ul style="list-style-type: none"> • Longer trip times in most cases. • May need to improve or expand bike lanes and trails. • Especially in rural or low density urban areas, unclear if existing land use patterns would support a doubling of biking in near-term. 	<ul style="list-style-type: none"> • Over the longer-term, more compact development with safe biking facilities and expanded transit services and facilities could increase the percentage of bike trips in the U.S. • Long-term benefits same as short-term.
Vanpools:	<ul style="list-style-type: none"> • Highest energy efficiency of all motorized modes, on passenger mile basis, at current occupancies of all modes • Very low cost for public sector. • Saves money for users. • Applicable in all types of areas – rural, low density, etc.. • No empty backhauls. 	<ul style="list-style-type: none"> • Little potential for non-work trips. • Requires cooperation and schedule coordination among participants. 	<ul style="list-style-type: none"> • Might be possible in the much longer-term to consider transforming use of vans and smaller vehicles to operate similar to fixed bus routes, but at a potentially lower operating cost (depending on whether the drivers are paid by transit agencies, under transit labor rules) and at lower CO₂e emissions per passenger mile than traditional fixed-route bus service.

Mode Change Type	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness
Three-Person Carpools:	<ul style="list-style-type: none"> • Second-highest energy efficiency of all modes, on passenger mile basis, at current occupancies of all modes. • Very low cost for public sector. • Saves money for users. • Applicable in all types of areas – rural, low density, etc. • No empty backhauls. • Large number of underutilized vehicles available for use as carpools. • Requires no additional infrastructure. 	<ul style="list-style-type: none"> • Limited potential for non-work trips. • Requires cooperation and schedule coordination among participants. 	<ul style="list-style-type: none"> • Opportunities and constraints in long-term similar to opportunities and constraints in nearer-term.
Passenger Rail:	<ul style="list-style-type: none"> • Twice as energy-efficient as single-occupant cars, on passenger mile basis and at current rail occupancies. • Underutilized passenger rail can be filled up first. • It may be possible to increase service through use of additional rail cars on existing infrastructure. • A number of co-benefits of increased passenger rail ridership (such as reduced energy costs, fewer automobile accidents, etc.). • Effective both for work and some non-work trips. 	<ul style="list-style-type: none"> • Applicability limited to dense urban areas (in medium-lower density areas, occupancy will be too low to have a GHG/PMT advantage). • On nationwide basis, passenger rail represents less than 1% of travel, so doubling does little to reduce CO₂e emissions nationally, although it may have a more meaningful contribution regionally. • Comparatively high operating and capital subsidy requirements. • Will require purchase of new rail cars. • In many areas, it may not be possible to double rail ridership using existing rail infrastructure. • Unclear if existing land use patterns would support a doubling of ridership in near-term. • Construction of new rail transit generates high levels of GHG. • Less flexible than auto travel 	<ul style="list-style-type: none"> • Over the longer-term, an increase in passenger rail transit, if combined with aggressive land use changes to increase density, can offer more potential for reducing CO₂e emissions in urban areas. • One estimate indicates that very aggressive land use and transit policies could reduce transportation sector GHG emissions by 3.5-5% cumulatively over the 43 year period 2007-2050, reaching a 7 to 10% reduction in 2050. [30] • Rail transit can contribute to synergistic co-benefits through supporting land use changes.

Mode Change Type	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness
<p style="text-align: center;">Bus Transit:</p>	<ul style="list-style-type: none"> • More energy efficient than single occupant cars, on passenger mile basis and at nationwide average 2004 bus occupancies, although efficiency varies greatly from system to system. • Underutilized buses can be filled up first, which will increase the energy efficiency of buses on a passenger mile basis. • Co-benefits of increased bus transit (such as reduced energy costs, fewer automobile accidents, increased walking/health benefits from users accessing bus transit, etc.). • Increasing service does not usually require new infrastructure other than additional buses. • Effective for work trips and some non-work trips in metropolitan areas. 	<ul style="list-style-type: none"> • At current occupancies, bus transit generates more GHG per passenger mile than average LDV use. • Applicability limited to urban areas (in non-urban areas, occupancies are too low to have a GHG/PMT advantage over LDVs). • On nationwide basis, bus transit represents less than 1% of passenger travel, so doubling does little to reduce CO2e emissions nationally, although it may have a more meaningful contribution in major metropolitan regions. • Increasing bus service can be expensive due to relatively high operating costs and need for purchase of additional buses. • Longer average trip times (in most cases) and other disadvantages compared to auto functions. • Unclear if existing land use patterns would support a doubling of bus ridership in near-term. 	<ul style="list-style-type: none"> • If combined with aggressive land use changes, longer-term effectiveness could be similar to passenger rail, assuming very high occupancy rates on buses, although bus transit tends to shape land use development less than passenger rail. • May be possible to use innovative transit services to increase the energy efficiency and reduce the cost of transit operations, as in Kitsap Transit's Worker/Driver bus program.

Reducing/Moderating VMT through Pricing

A wide variety of pricing strategies can be implemented to encourage moderation or reduction in vehicle miles of travel. There are a great number of studies on all of these strategies that document the effectiveness, different implementation strategies, and constraints. Table 2.6 below is not a comprehensive summary of the opportunities, benefits, and constraints of these various strategies, but rather it represents a broad overview of issues for each strategy with a general indication of the level of magnitude of effectiveness in changing travel behavior. This table focuses on the following pricing strategies:

- **Fuel Surcharges or Taxes:** Increasing the price of fuel through surcharges or an increase in fuel taxes. One possible policy option is to set a price floor for transportation fuels so prices will remain high even if market prices fall.
- **Congestion Pricing or Road Tolling:** Using electronic toll collection system to charge drivers a toll in order to use a road. This toll could be mileage based, could be reduced for HOV LDVs and buses, and could change according to congestion levels (with a higher toll charged when roads are more congested).
- **Parking Pricing:** Either charging for parking or increasing an existing fee for parking, to discourage SOV travel.
- **Mileage-Based Fees (VMT Tax):** Charging road users a fee based on the number of vehicle miles of travel. Fees can be collected electronically, either through a centralized collection system where users are periodically billed based on mileage, or fees can be assessed when paying for fuel.
- **Pay-at-the-Pump or Pay-As-You-Drive Insurance:** Drivers pay a vehicle's insurance premiums based on how much a vehicle is driven. According to one estimate, this could result in a cost of 6.6 cents/mile for insurance – which is equivalent to increasing the price of gasoline by \$1.65/gallon (based on average fuel economy of 25 MPG). This could provide a substantial incentive for drivers to conserve on VMT. (See Chapter 4 for information on states including these strategies in their statewide climate action plans, as well as other countries which are implementing these strategies.)

Table 2.6 Opportunities and Constraints In Reducing VMT and GHG Through Pricing

Pricing/TDM Strategy	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness or Issues
Fuel Surcharges or Taxes	<ul style="list-style-type: none"> • Sustained high fuel taxes in some parts of the world are likely at least partially responsible for the use of more fuel efficient vehicles, and lower rates of private vehicle ownership and use. 	<ul style="list-style-type: none"> • May be difficult to enact fuel surcharges when fuel prices already considered high by recent historical standards. <p>In general, fuel consumption is inelastic with respect to price. [31] One recent research analysis indicated demand is even more inelastic than previous decades, with a short-run elasticity from -0.034 to -0.077 in more recent years (e.g., a 1% increase in price reduces demand for fuel by 0.034 to 0.077%), compared to historical elasticity of -0.21 to -0.34. [32].</p>	<ul style="list-style-type: none"> • One possible policy option is to set a price floor for transportation fuels so prices will remain high even if market prices fall. Sustained high fuel prices through taxes could help to continue the momentum building over the last few years in the use of more fuel efficient vehicles and a reduced growth in VMT.
Congestion Pricing or Road Tolling	<ul style="list-style-type: none"> • Depending on scale of effort and price charged, can influence travel behavior (modeling analysis suggest it can reduce VMT by several percent). • A program in Stockholm reduced traffic volumes in the area by up to 22%. [33] • One study summarizing findings of other tolling studies indicates that short-term toll road price elasticities range from -0.21 to -0.83. [34] 	<ul style="list-style-type: none"> • Can be politically challenging to implement, especially if viewed as a new tax/charge. 	<ul style="list-style-type: none"> • Could supplement the fuel tax as a transportation revenue source.

Pricing/TDM Strategy	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness or Issues
Parking Pricing	<ul style="list-style-type: none"> • Modeling analyses have predicted regional VMT reductions ranging from -0.8 to 2.9% for work trip parking pricing. [35] • However, parking demand in general is inelastic with respect to price. Demand elasticities for areawide changes in parking price generally range from -0.1 to -0.6, with -0.3 being the most frequently cited value (e.g., a 0.3% reduction in parking demand in response to each 1% parking fee increase). [36] • In urban areas and some suburban areas, people are already accustomed to paying to park. • Parking pricing often considered to change travel behavior for the work trip; nationwide, only 5% of auto commuters pay for parking. [37] 	<ul style="list-style-type: none"> • Pricing parking in just one area may simply shift vehicle trips to other locations with little reduction in overall vehicle travel. • If parking pricing is implemented in an area that was previously not priced, it may face public opposition. • Businesses may use free parking to attract customers and as a benefit to employees. • Priced parking requires payment system and enforcement, although pay station technologies may be useful. 	<ul style="list-style-type: none"> • Where appropriate, it may be possible to adjust parking pricing to meet travel behavior change goals.
Mileage-Based Fees (VMT Tax)	<ul style="list-style-type: none"> • A study for Washington State estimated that a \$0.04 VMT tax would lower vehicle travel by approximately 18.6 billion miles in the year 2010. [38] • A 1996 study by Deakin and Harvey found that a VMT fee of about 2¢ per mile in 1991\$ (an average of \$250 per year) could reduce regional VMT by about 4%. [39] • Oregon DOT conducted pilot-test of mileage-based fee (in 2006/2007). • Mileage-based fees can be collected electronically (either when uses buy fuel or through a centralized collection system). 	<ul style="list-style-type: none"> • May be politically unpopular to implement; although if implemented as replacement for fuel tax may be viewed more favorably. • Would require new system for charging fees based on miles traveled. 	<ul style="list-style-type: none"> • Could supplement or eventually replace the fuel tax as a revenue source for transportation. [40]

Pricing/TDM Strategy	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness or Issues
Pay-at-the-Pump or Pay-As-You-Drive Insurance^a	<ul style="list-style-type: none"> • Reduces VMT by tying insurance costs to miles driven. • One study indicates it can reduce regional VMT by 0.76% with 11.3% penetration in a Pay-As-You-Drive Insurance Program. If extrapolated to 100% penetration, the regional VMT reductions would be about 6.7%. [41] • Pilot programs are active in several European cities. • Rewards those who drive less, who often have lower incomes • Can offer consumers a way to save money on insurance. 	<ul style="list-style-type: none"> • In some states, insurance laws would need to be changed to permit PAYD insurance. • For PAYD payments at gas stations, electronics would be needed for gas pumps to read mileage from devices in vehicles. • Mileage readings would need to be tamper-proof. May require new rate structures by insurance companies. • Drivers would not know in advance how much they would be paying for car insurance over the course of a year. 	<ul style="list-style-type: none"> • May currently be prohibited by law in some areas.

^a With this strategy, the amount of the insurance payment would be based on miles traveled and the payment itself would be made when the consumer purchases fuel for the vehicle.

Washington State Commute Trip Reduction and Growth and Transportation Efficiency Centers:

The Washington State Legislature passed the Commute Trip Reduction (CTR) Law in 1991, incorporating it into the Washington Clean Air Act. The goals of the program are to reduce traffic congestion, reduce air pollution, and petroleum consumption through employer-based programs that decrease the number of commute trips made by people driving alone. The employee drive-alone rate at CTR worksites has decreased considerably. The percentage of people who drove alone to work to CTR worksites declined from 70.9% in 1993 to 65.5% in 2007, a decrease of more than 5%. The effects of these individual choices supported by the CTR Program can be seen in statewide numbers as well. The miles of travel to CTR sites have also decreased significantly. Statewide, employees' round-trip commutes to CTR worksites accounted for just over 2.4 billion VMT in 2007. Without the changes in employee travel, the commute VMT to these sites would have been 6.7% higher – an estimated difference of nearly 170 million miles. [42]

The Growth and Transportation Efficiency Centers (GTEC) program was created in 2006 as part of the Commute Trip Reduction (CTR) Efficiency Act to increase the efficiency of the state's transportation system in areas of the state containing high concentrations of jobs and housing. The program is part of the CTR Law which encourages employees to ride the bus, vanpool, carpool, walk, bike, work from home, and use other commute options besides driving alone. [43] A GTEC is a defined boundary of dense mixed development with major employers, small businesses and residential units, within an established urban growth area. The goal of the GTEC program is to provide greater access to employment and residential centers while decreasing the proportion of commuters driving alone during peak periods on the state highway system.

Compact, Mixed Use Land Use

In 2007, the Urban Land Institute published "Growing Cooler," [30] which estimates that cumulative transportation GHG could be reduced by 3.5-5% over the 43-year period from 2007-2050, attaining a 7-10% transportation GHG reduction in the year 2050, if significant changes occur in land use to achieve compact, mixed-use development.

The authors use several key assumptions to reach their GHG reduction estimates:

- 67% of all development in place in 2050 is constructed or rehabbed after 2005;
- 60-90% of that development is "smart growth" (equivalent to 13 housing units per acre); and
- 30% VMT reduction (including freight as well as passenger VMT) will occur in "smart growth" areas.

The authors emphasize that the estimated GHG reductions rely on land use changes alone, and do not assume pricing policies or other programs to reduce VMT.

Land use policy is controlled by local governments. Transportation agencies can play a supporting role, by helping local governments understand the implications of their land use policies and by designing and investing in infrastructure to support compact, mixed-use development. Below are some Federal and state transportation policies that could help advance these land use changes:

- Scenario planning by Metropolitan Planning Organizations (MPOs) and local governments to estimate GHG/capita for various alternative land use choices
- Public outreach and education on the GHG implications of various land use choices
- Funding for transportation improvements that support compact, mixed use development (including funding for street and highway improvements consistent with the new land use, as well as funding for transit, biking, and walking infrastructure)
- Parking management policies that support compact, mixed use developments
- Transportation pricing policies that support compact, mixed use developments
- Street and road design that is pedestrian-friendly, bike-friendly, and transit-friendly

California SB 375 – Leveraging Land Use Changes through Transportation

In September 2008, California enacted a new law intended to reduce GHG through land use and transportation changes. SB 375 requires:

* the California Air Resource Board to establish regional GHG reduction targets for LDVs for 2020 and 2035, in consultation with affected agencies and with public input;

*MPOs to prepare “Sustainable Communities Strategies” that are designed to achieve the regional GHG target reductions for LDVs and are to be included in each MPO’s Regional Transportation Plan;

*if the Sustainable Communities Strategy does not achieve the target GHG reductions for the region, then the MPO is to prepare an Alternative Planning Strategy which would demonstrate how the GHG reduction targets could be met through alternative development patterns and other policies and infrastructure investments;

SB 375 also provides for streamlined state environmental procedures for transit priority projects (i.e., transit oriented development).

While SB 375 states that it does not intend to supersede local land use authority, it is clearly intended to provide incentives for local officials to adopt land use plans that reduce GHG.

For more information on the concept of setting metropolitan GHG budgets for transportation and land use, see “City Carbon Budgets: Aligning Incentives for Climate-

Friendly Communities,” by Deborah Salon, Dan Sperling, Alan Meier, Sinnott Murphy, Roger Gorham, and James Barrett, Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-08-17, 2008.

Other sectors, too, will need to adopt supporting policies. Currently, there are many federal and state policies that work against the land use changes described in “Growing Cooler, including:

- Federal interest deductions for second homes and for large houses in low-density areas (replicated in state tax policies that are based on Federal tax deductions);
- Federal/state funding and permitting of drinking water facilities outside “smart growth” areas;
- Federal/state funding and permitting of wastewater treatment facilities outside “smart growth” areas;
- Federal wetlands permitting decisions that allow for development at less than the assumptions in the “Growing Cooler” report;
- Federal or state actions that allow for construction of new schools outside “smart growth” areas;
- Small business loans by Federal or state agencies for businesses outside “smart growth” areas.
- Federal and state funding to rebuild areas after floods, hurricanes, and other disasters, if the rebuilt area is lower than 13 housing units per acre or otherwise inconsistent with the “Growing Cooler” assumptions.

The kind of land use changes outlined in “Growing Cooler” will require a concerted effort by all sectors, encompassing all of the above. If the above policies are not changed, they will undercut or even cancel out efforts by the transportation sector to influence land use.

State Involvement in Land Use Planning

Maine DOT: Maine DOT and the Sensible Transportation Policy Act: In 2003, the 121st Legislature directed the Maine DOT to work in collaboration with the State Planning Office (SPO) to draft a rule to link the transportation planning processes of the Sensible Transportation Policy Act (STPA) with those of the Comprehensive Planning and Land Use Regulation Act. The rule provides a framework for examining a range of choices in transportation, and recognizes that the livability of a community can be significantly influenced by transportation and land use decisions. The rule identifies policies and management strategies for the analysis of these diverse issues. [44]

Oregon Transportation and Growth Management Program: A partnership of the departments of transportation and land conservation and development, the Oregon Transportation and Growth Management Program (TGM) [45] encourages smart growth and reducing reliance on automobiles by providing grants and technical assistance to local communities to achieve three objectives: more transportation alternatives (in

addition to driving), economically vibrant, livable communities, and sound future plans. Projects are guided by four objectives: coordinating transportation and land use, improving connectivity of routes, enhancing transportation efficiency, and preserving and enhancing existing transportation resources.

A few examples [45]:

- Irrigon, Oregon spread out along U.S. Highway 730 without a clearly defined downtown, and Irrigon now wants one. TGM consultants have helped the city identify outdated zoning policies and update them so that local codes encourage the kind of economic development Irrigon desires. This project builds on a TGM Outreach workshop and a Quick Response design session held in 2005 that helped Irrigon determine where to locate its downtown core and a key economic anchor for the new city hall.
- In Portland, the city has benefited from the successful revitalization of its New Columbia neighborhood, which opened in 2006. A TGM Quick Response team worked with neighbors and city staff to design a walkable main street enhanced by housing, stores, plazas, and public services. A nearby elementary school and community center complement New Columbia's Main Street.
- In Redmond, the population has more than tripled since 1985, from 6,740 to over 23,500 today, and it is expected to double during the next ten years. To accommodate this growth, the city obtained approval to expand its Urban Growth Boundary by 2,300 acres in 2006. With TGM assistance, the city is now developing a detailed land use, street, and trail connectivity plan for the Northwest Area being incorporated into the Urban Growth Boundary. A task force of local citizens has formed to help the city set priorities, balance competing goals, and generally ensure that the Northwest Area is efficiently laid out. Because many in the community want to see Redmond grow sustainably, principles that emphasize the efficient use of land and other resources are receiving special attention.

Telecommuting, Alternative Work Schedules (AWS), and Trip Chaining

Meaningful GHG reductions may be achievable by increasing telecommuting, alternative work schedules, and trip chaining (up to about five percent of transportation sector GHG emissions from each). These strategies have the advantages of being easily implementable, publicly and politically acceptable, quickly implementable and low cost compared with many other emission reduction strategies. Table 2.7 discusses the advantages, constraints, and long term possibilities associated with these strategies to reduce GHG emissions.

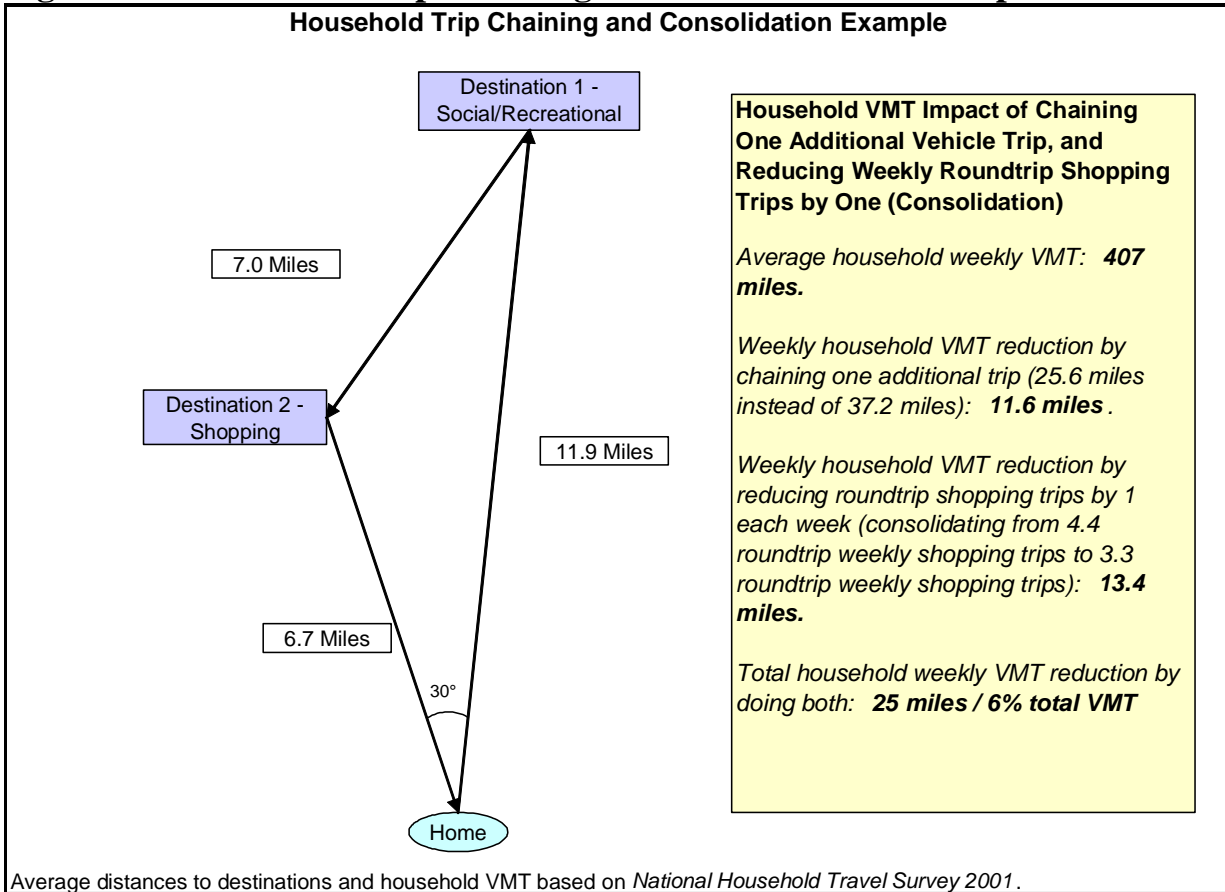
Table 2.7 Opportunities and Constraints for Reducing VMT/GHG through Telecommuting, AWS, and Trip Chaining

Strategy	Opportunities and Potential Benefits	Constraints
<p style="text-align: center;">Alternative Work Strategies: Telecommuting or Compressed Work Schedule</p>	<ul style="list-style-type: none"> • Comparatively low cost for employers and government. • Saves money and time for workers. • One study indicated that at two-days per week telecommuting, would save 1.1 to 4.4% of regional transportation fuel, depending on level of participation. [46] • One study indicated that at implementing a regionwide compressed work week would save 0.8 to 4.1% of regional transportation fuel, depending on level of participation, and whether it is a four-day/forty hours, or nine-day/eighty hours schedule. [46] • Can be implemented in urban and rural areas. • An employer implementing a compressed work week company or agencywide could also reduce other energy or organizational costs through reduced heating or cooling, and electricity cost. 	<ul style="list-style-type: none"> • Requires employer participation and cooperation. • Vehicle use may rise on telecommute or “off-work” days. • Only affects commute trips. • Not appropriate for all types of employment.
<p style="text-align: center;">Increased Trip Chaining</p>	<ul style="list-style-type: none"> • Can be effective in rural and urban areas. • Saves time and money for users. • Using a hypothetical example (see box below), if each household chained one additional trip and also reduced weekly shopping trips by one roundtrip per week, the total reduction in VMT per household would be about 25 miles a week, or about 6% total.* • Effective for non-work and work-related trips. • Very low cost. • Already practiced to some degree. In 2001 Census, about 27% of workers reported chaining trips, with most of these trips chained with the work to home trip. [47] 	<ul style="list-style-type: none"> • Difficult to measure or monitor how much people may be increasing trip chaining behavior.

* This is a hypothetical example. Assumes average one-way shopping trip distance is 6.74 miles and each average one-way social/recreation trip is 11.91 miles (National Household Travel Survey 2001), for linked trip combining recreational/social trip with shopping trip, angle distance between home and each destination is 30 degrees.

The diagram below illustrates potential VMT reductions from trip-chaining

Figure 2.4 Household Trip Chaining and Consolidation Example



Oregon’s Drive Less, Save More Program

Jointly launched by the Oregon Department of Transportation, Metro, TriMet, Washington County and many other public and private partners, the Drive Less, Save More Campaign aims to increase public awareness about transportation choices to reduce single person car trips. [48] Research shows that nearly two-in-three residents believe it would not be difficult to take one less car trip each week. If each household in the region eliminated just two single person car trips (one round-trip) each week, there could be a four to five percent reduction in the number of cars on the road.

Other benefits of trip chaining or using alternative transportation include saving money at the gas pump and time on the road. To help people make the choice to drive less and save more, the coalition created a web site with information to help people use alternative modes of transportation. It is <http://www.DriveLessSaveMore.com>.

2.8 Vehicle/system operations strategies could achieve 10-20% LDV GHG reduction.

Several strategies can be implemented to reduce CO₂e emissions by improving the operational efficiency of a transportation system and driver behavior. These include traffic smoothing or congestion reduction, enforcing speed limits, setting speed limits to 55 mph, and promoting “Ecodriving.”

Below are a few estimates of GHG associated with congestion, which could be reduced through system management strategies:

Congestion in the U.S. wastes an estimated 2,900 million gallons of gas per year, which equates to 263 million metric tons of CO₂ annually. A significant portion of that could be saved through reducing congestion. [49]

If traffic congestion associated with poor signal timing could be limited through ITS and other strategies, 145 million gallons of gas could be saved annually, which is 1.315 million metric tons of CO₂ each year. [49]

The following table offers a broad overview of issues for each strategy with a general indication of the level of magnitude of effectiveness in reducing CO₂e emissions.

Table 2. 8 Opportunities and Constraints In Reducing CO₂e Emissions Through Operational Efficiency Gains

Operational Efficiency Strategy	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness and Issues
<p>Traffic Smoothing or Congestion Reduction:</p>	<ul style="list-style-type: none"> • Researchers from U.C. Riverside concluded that innovative traffic operations improvements (i.e., mitigating congestion, reducing excessive speeds, and smoothing traffic flow) can have a significant impact on vehicle CO₂e emissions and this impact can be realized in the near-term (reductions of up to almost 20% in certain situations through congestion mitigation strategies, speed management, and shock wave suppression techniques that eliminate the acceleration and deceleration events associated with stop-and-go traffic). [50] 	<ul style="list-style-type: none"> • Some analysts do not recommend congestion-relief as a method for reducing GHG emissions because they believe congestion reduction will result in increased vehicle miles traveled over the long-term. [30] • Congestion reduction can be very expensive if it requires the expansion of roadway capacity. 	<ul style="list-style-type: none"> • If congestion can be reduced such that it does not result in increased vehicle miles of travel (such as might be possible through pricing schemes), both congestion reduction and CO₂e emissions reduction are possible.
<p>Enforcing Speed Limits or Setting Speed Limits to 55 mph Maximum:</p>	<ul style="list-style-type: none"> • One study indicated that with a change in the legal speed and enforcement, this could result in a reduction in fuel consumption of 3.2% of road transportation fuel for the U.S. [46] • A national 55 mph maximum speed limit established in the 1970s was found to reduce transportation/highway fuel consumption by about 2%, but with 90% compliance could approximately double fuel savings. [51] • Can be implemented relatively quickly and at a relatively low cost. • Saves lives and reduces injuries and property damage, with significant cost savings for society and individuals. • Already being implemented by some (trucking companies, for example) to reduce fuel costs. 	<ul style="list-style-type: none"> • Would require enforcement, although could potentially be enforced via camera enforcement. • Would increase travel time. 	<ul style="list-style-type: none"> • Long-term benefits same as near-term. • Could consider modifying design or operation of highways to support lower speed limits.

Operational Efficiency Strategy	Opportunities and Potential Benefits	Constraints	Potential Longer-Term Effectiveness and Issues
“Ecodriving”	<ul style="list-style-type: none"> • Ecodriving campaigns typically focus on strategies such as efficient driving styles, avoiding idling, avoiding stopping and starting where possible, driving at more efficient speeds, and proper vehicle maintenance (e.g., tire pressure). • Very inexpensive strategy for public sector, involving promotion and education. • Saves money for users. • For individual LDV drivers, eco-driving can reduce energy use and GHG by 15% or more. [52] • Many European countries are implementing major eco-driving campaigns. 	<ul style="list-style-type: none"> • Difficult to monitor for effectiveness. • Modest increase in driving time. 	

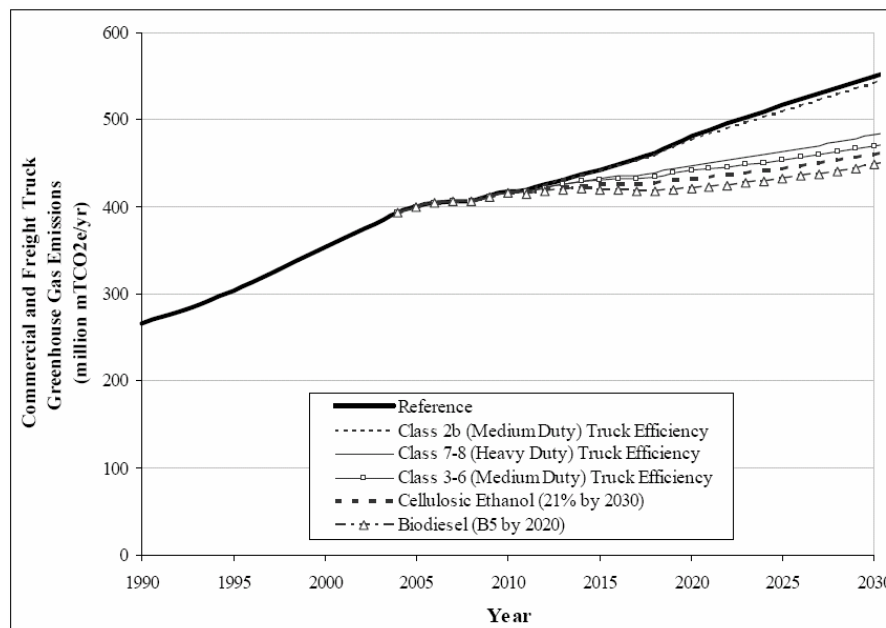
2.9 There are many strategies to reduce freight GHG emissions, but they may be substantially offset by freight VMT increases of 1.7% annually.

Heavy-duty highway vehicles (HDVs) account for 17% of transportation GHG emissions. However, based on Annual Energy Outlook 2008, this percentage is expected to increase to nearly 30% of U.S. transportation GHG by 2030, due to projected increases in on-road freight VMT of 1.7% annually through 2030. [54]

There are many promising technological and operational strategies to reduce GHG emissions per mile for heavy and medium duty trucks – but if freight VMT does increase at 1.7% annually, it will be difficult to achieve overall freight GHG reductions or meet GHG reduction targets in the short, medium, or long term.

Figure 2.4 below illustrates this point. It is based on the 2008 PhD dissertation of Nicholas Lutsey of the University of California at Davis. [11] It assumes (a) 1.7% annual VMT increases for medium and heavy duty trucks; and (b) a wide array of GHG reduction strategies (engine efficiency, aerodynamics, low rolling resistance tires, lightweight materials, closing/covering the cab-van gap, and many more), each with a cost of \$50 or less for each tonne of CO₂e reduced from the 2030 reference case.

Figure 2.5 Commercial Truck GHG Emissions with Emission Reduction Measures Through 2030 [11]



As shown above, total GHG emissions from medium and heavy duty highway trucks are likely to increase through 2030 – in contrast to state, regional, and international targets of reducing 2030 GHG to 1990 levels or below.

Appendix C contains detailed information on strategies to reduce medium and heavy duty freight truck GHG, drawn from state climate action plans and a variety of other sources. Most of these strategies lie within the domain of trucking companies, federal regulatory action or federal financial incentives. Nonetheless, state DOTs can help reduce freight GHG emissions through such actions as:

- Policy support for freight R&D and regulations to develop and deploy cost-effective technology and fuel improvements that reduce freight GHG emissions;
- Speed management, traffic flow improvement, and bottleneck reductions that reduce inefficiencies in truck travel;
- Programs to clear traffic incidents quickly and reduce construction zone congestion that tie up trucks;
- Incentives for truck owners to retrofit or upgrade trucks to reduce GHG emissions;
- Programs to support efficient intermodal freight facilities and efficient access to seaports, rail, and marine facilities;
- Programs to support freight logistics (e.g., efficient clearance at border crossings);
- Programs and policies to reduce truck idling;
- Truck driver educational programs focusing on low-GHG driving practices;
- Infrastructure changes to allow for doublestack trains; and
- Improvements to highway-rail grade crossings.

2.10 Various strategies are emerging to reduce GHG in construction, maintenance, administration, and operations of State DOTs.

State DOTs are undertaking a wide variety of strategies to reduce GHG emissions through changes in construction, maintenance, administration, and operations practices. Some of these strategies were being practiced already for other reasons, but can be expanded or intensified or taken to new levels to reduce GHG emissions and also reduce energy consumption.

Many of these strategies can help reduce state DOT costs, which is especially helpful in view of the rapid increases in energy and materials costs. If carbon cap and trade programs are adopted in the U.S., it is a virtual certainty that the costs of energy and carbon-intensive materials will increase significantly further, putting even more pressure on state DOT budgets and making these strategies more attractive. In addition, most of these strategies support broader commitments of state DOTs to environmental stewardship and sustainability.

Carbon Footprint Analysis and Asset Management:

- Determine the agency's carbon footprint, to serve as a baseline from which improvements can be measured and to reveal potential priority areas for carbon reduction.

- Heighten asset management practices that reduce the need for repaving, reconstruction, and other energy-intensive, GHG-intensive activities.

Design:

- Incorporate non-polluting and renewable energy, such as solar photovoltaics, wind, geothermal, low-impact hydro, biomass and bio-gas strategies, into project design.
- Take advantage of net metering with the local utility.
- Design project alignments to minimize energy consumption by vehicle operators.
- Consider solar panels on noise walls or on highway rights of way (ROW).
- Incorporate design features that support mid-range speeds of 40-60 MPH and reduce very high speeds and very low speeds.
- Incorporate more energy efficient materials when choices are available.
- Incorporate fiber optic lighting to provide low levels of light in tunnels using a minimum of fixtures (to reduce energy consumption as well as simplify the operation and maintenance of the lamps).
- Design buildings and systems to maximize energy performance.
- Incorporate natural ventilation into building designs where possible to conserve energy.
- Use materials with "low embodied energy," such as local timber and stone.
- Incorporate landscaping on highway rights of way to minimize mowing and other equipment needs and maximize trees and shrubs that serve as carbon sinks.

Construction

- Use low carbon fuels and energy efficient engines in construction equipment.
- Lay long-lasting pavements so as to reduce the need for repaving, reconstruction, and maintenance.
- Evaluate new information on pavement types and mixes to identify opportunities to reduce GHG associated with paving and with pavements.
- Re-engineer construction processes and practices to maximize energy efficiency.
- Route and manage traffic in and around construction zones so as to minimize GHG emissions.
- Incorporate performance specifications for minimizing dust and emissions (that can be measured and monitored).

Operations

- Use energy efficient and/or alternative fuel vehicles.
- Convert to LED traffic lights and street lighting.
- Avoid ROW mowing unless necessary for safety reasons.
- Review snow and ice removal practices with an eye to minimizing energy consumption.

Administration

- Provide carpool/vanpool/transit incentives to employees.
- Support telecommuting by employees where feasible.

- Retrofit buildings to maximize energy efficiency.
- Design new buildings to minimize energy consumption.
- Site new buildings and other facilities to minimize VMT for employees and visitors.
- Train/educate employees in practices that lower energy consumption and GHG emissions.

Special Case -- Use of Fly Ash in Pavement: Enormous amounts of GHG are associated with cement as well as pavements and paving generally (1 pound of cement equals almost 1 pound of CO₂), so there are potentially high GHG reduction opportunities in focusing on this area. California Department of Transportation (Caltrans) has been requiring the use of fly ash in concrete paving projects for several years, and more recently has been exploring the benefits of using fly ash in concrete mixes to help reduce GHG emissions. Typically, a Caltrans project uses at least 25% fly ash replacement for Portland cement in mix designs. The listing of pre-approved sources of fly ash is found on the Caltrans web site, where it has posted relevant engineering standards. Further, based on experience with the San Francisco Oakland Bay Bridge (SFOBB) project, Caltrans is creating the first-ever Structural Concrete Greenhouse Gas Reduction Standard. This standard will encourage contractors and designers to build more bridges and highways with very high amounts of fly ash.

In the SFOBB project (largest bridge project in Caltrans history, designed to carry 350,000 vehicles per day and have a lifespan of 150 years), Caltrans incorporated fly ash into the concrete to address design problems relating to the bridge's location in salt water, a salt fog environment, and seismic requirements of an active earthquake zone. Fly ash helps to improve the workability, hardening, and permeability properties of concrete. A concrete mix with 50% fly ash was used in the footings and high salt zones. The use of fly ash prevented the cracking of the cement when it hardened, a common problem in a salt-water environment. It also helped in the concrete's placement, since fly ash particles are round and act like ball bearings, to improve flow and workability in the mix. Moreover, concrete containing fly ash is denser and stronger, making it better able to carry loads as well as to prevent salt from entering the hardened product.

Fly ash was also used in 32 footing boxes, which are supported on deep piles and hold approximately 1,600 yards of concrete each. A special lightweight concrete mix containing 50% fly ash mineral admixtures was used.

LED Lighting: Replacing sodium vapor and other older streetlights with new light-emitting diodes (LEDs) can significantly reduce GHG, energy consumption, and costs. Based on work by Robert Grow for the Ford Foundation, LED lights could cut kilowatts, GHG, and costs for street lighting in half, with an additional benefit of lowering light pollution. Although cost of initial installation is expensive, Grow estimates costs could be recouped in about five years through energy savings.

In the top 10 metropolitan areas of the U.S., Grow estimates that LED lighting can save the equivalent of 132 million gallons of gasoline annually – which works out to a reduction of 1.3 million metric tons of GHG per year.

Oslo, Norway is installing a LED network connected to Internet servers that will log and report energy consumption and make continuous adjustments for natural sunlight and moonlight.

Virginia DOT Environmental Leadership in Design of Safety Rest Area

The Virginia Department of Transportation received the 2007 Green Leadership Award from the James River Green Building Council for its design and construction of the new Interstate 64 West Safety Rest Area in New Kent County. [54] The 9,000 square foot safety rest area not only has traveler amenities such as restroom facilities, vending and information kiosks, but it also has environmentally friendly features that reduce GHG emissions.

Overall, the new facility is approximately 75% more efficient in energy consumption than its predecessor, and the ground source heating is predicted to save 36.7 tons of CO₂ emissions over 30 years. [55]

GHG emissions reductions strategies include:

- * A 32-well geothermal system that uses the constant temperature 400 feet below the surface of the earth to reduce the need for supplemental heating and air conditioning.
- * Energy efficient lighting that provides maximum visibility with minimal energy consumption.
- * Preservation of the previous concrete structure of the parking area.
- * Use of local building materials, which reduces transportation energy use and emissions.

In addition, the rest area includes other sustainable features, such as:

- * A system to collect more than 250,000 gallons of rainwater from the roof annually that is used for flushing the restroom facilities.
- * A stormwater bio-retention facility to control and filter runoff from the parking lots.
- * A terrazzo floor made from recycled mirrors and glass, rather than traditional granite or marble.
- * Diversion of 1100 tons of building waste from the landfill.
- * Low-VOC adhesives, sealants, carpets, and paints to reduce toxic emissions.

This Interstate facility is one of three recent safety rest area reconstruction projects in the Commonwealth, with all three projects designed to meet the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standards.

2.11 Authority and responsibility for GHG reduction strategies are dispersed and shared among state DOTs and others.

State DOTs can influence virtually all of the strategies described in this report to varying degrees, but they have full control of almost none of them. For example:

- Carpool/vanpool programs, LED lights, pavement policies, workzone design, fleet conversions, traffic signal synchronization, etc., are largely within the control of the DOT – but all depend on adequate funding for implementation.
- Public education programs about eco-driving and other strategies can be carried out by state DOTs alone or in partnership with state environmental and energy offices – as long as funds are available to support such public outreach efforts.
- Mileage-based fees and other transportation pricing strategies generally require legislative authorization and approval of the Governor, but DOTs can provide analysis and information in support of these strategies.
- Speed limits and enforcement of speed limits are controlled by legislatures, Governors, and the police, but state DOTs can provide information and analysis in support of effective speed management, can highlight safety benefits, and can incorporate design features that discourage high speeds.
- Technology and fuels improvements require actions by the private sector, or can be spurred on by legislatures, Governors, and the Federal government, but state DOTs can provide information and analysis in support of them, and they can also play a supportive role in ensuring appropriate infrastructure changes are made to accommodate new technologies and new fuels.
- Land use changes are within the domain of local elected officials, and are heavily influenced by state and Federal policies (such as mortgage interest deductions), but state DOTs can support and reward good land use policies through transportation investments, public outreach, and planning activities.

Most of all, state DOTs and their CEOs can be a strong voice with their Governors and executives at other state agencies, to advocate sound GHG-reduction policies, based on a comprehensive and cost-effective approach to reducing transportation GHG.

CHAPTER 3: SCENARIOS

The scenario analysis is a high level overview of how different combinations of strategies could reduce greenhouse gas emissions over the coming decades. These scenarios were developed for the 2005 to 2050 time period, and focus primarily on the LDV fleet (passenger cars and light trucks). A separate and much simpler scenario analysis was conducted for medium and heavy trucks.

3.1 Light Duty Vehicle Fleet Scenarios

Overview of LDV Scenario Assumptions

Because the scenario analysis extends to 2050, there is a high degree of uncertainty regarding how technological advances, energy prices, or climate change related legislation may influence GHG emissions from the LDV fleet during this time period.

Each scenario represents varying combinations of LDV fleet CO₂e emissions improvements; reductions in the growth rate in vehicle miles traveled (VMT) from a host of different strategies; and GHG emissions reductions from strategies that enhance the operational efficiency of the LDV fleet.

These scenarios are based on different assumptions of the following: LDV fleet CO₂e emissions per vehicle mile improvements; reductions in growth in VMT; and operational efficiency improvements:

LDV Fleet CO₂e Emissions Improvements

In the Annual Energy Outlook (AEO) 2008, the U.S. DOE Energy Information Administration (EIA) is forecasting the LDV fleet average on road fuel economy to increase from 20.3 mpg in 2008 to 27.9 mpg in 2030. This forecast reflects the most recent requirements proposed in the Energy Independence and Security Act (EISA) of 2007, which requires new LDVs to reach a combined average fuel economy of 35 mpg by 2020, based on the U.S. EPA test value used to measure compliance with the CAFÉ standard. According to the EIA Annual Energy Outlook 2008, the EPA CAFÉ test value generally differs from the estimated mpg value on the fuel economy label and, typically, exceeds the actual on-the-road fuel economy of a new vehicle by a significant margin. The EIA forecast fleet fuel economy reflects on-the-road fuel economy of vehicles, which is lower than the EPA CAFÉ value and the new proposed CAFÉ standard. If these fuel efficiency improvements are extended to 2050 using the AEO 2008 outlook average annual improvement rate of 1.34%, the LDV fleet fuel economy would be 36.4 mpg in 2050.

In addition, EISA includes a renewable fuel standard, which requires an increase in the use of ethanol (by 2030, ethanol is forecast to represent almost 7.7% of the LDV fleet energy consumption btu), and biodiesel.

There is a great deal of uncertainty over several issues that could result in a much more efficient LDV fleet by 2050. These include the following:

- Whether fuel costs will continue increasing as quickly as they have over the last several years, which could increase consumer demand for more fuel efficient vehicles.
- How technological innovations will improve the energy efficiency or CO₂e efficiency of the LDV fleet.
- How climate change legislation might increase the demand for more energy efficient vehicles.

Currently, the momentum in higher energy prices and increased interest in climate change legislation supports the hypothesis that the average LDV fleet fuel economy and decarbonization of fuels in the future may be considerably higher than today and higher than the EISA mandate. Therefore, several scenarios for greatly reduced CO₂e emissions per vehicle mile from the LDV fleet were tested:

- 58% reduction in average CO₂e emissions per vehicle mile (if thought of in terms of today's miles per gallon of gasoline CO₂e, this is assumed to equal about 50 mpg equivalent CO₂e)
- 72% reduction in average CO₂e emissions per vehicle mile (about 75 mpg equivalent CO₂e)
- 79% reduction in average CO₂e emissions per vehicle mile (about 100 mpg equivalent CO₂e)

Reductions in CO₂e emissions per vehicle mile are considered rather than fleet fuel economy improvements because in the future much of the vehicle energy consumption may occur off-board (at power generating facilities and hydrogen production facilities) rather than on-board the vehicle. Using CO₂e emissions reductions on a vehicle mile basis is one way to account for the potential greenhouse gas emissions from the production of hydrogen and electricity and other alternative energy sources or fuels. Another way it is represented here is in miles per gallon gasoline equivalent (mpgge), which in this analysis is intended to represent the equivalent fuel economy on a CO₂e emissions basis.

The 58% reduction in average CO₂e emissions per mile scenario for 2050 was intended to represent a future scenario in which the entire fleet consists of the most fuel efficient conventional vehicles currently available today (about 50 mpgge).

The scenario based on the 72% reduction in average CO₂e emissions per vehicle mile (or an equivalent of about 75 mpgge) was based on a future scenario in which the fleet turnover and improvements in efficiency are much higher, possibly due to an increased

consumer demand for more energy efficient vehicles or greater technological advances in vehicles. The fleet could include a mixture of both conventional vehicles and new technology vehicles, such as plug-in hybrid vehicles (PHEVs), electric vehicles, and/or hydrogen fuel cell vehicles. This scenario is also assumed to approximately represent the vehicle efficiency scenario suggested by AASHTO. AASHTO has called for doubling [56] the energy efficiency of the LDV fleet by 2030 (assumed in this analysis to double from about 20.3 mpg in 2008 to 40.6 mpgge in 2030). If this trend in fleet energy efficiency improvements were extended to 2050, the average fleet energy efficiency in 2050 would be about 76.4 miles per gallon (or the equivalent in CO₂e intensity), which is a slightly greater reduction in CO₂e emissions per vehicle mile than the 72% reduction scenario included in this analysis.

The scenario based on the 79% reduction in average CO₂e emissions per vehicle mile (about 100 mpgge using today's fuels) was the most ambitious CO₂e emissions reduction scenario, and may be considered a "stretch" vehicle CO₂e emissions reduction scenario. This scenario was based on a future in which the fleet turnover and improvements in efficiency are significantly higher, due to consumer demand for more efficient vehicles possibly associated with much higher energy prices or carbon taxes. The fleet could include a mixture of both lighter or smaller conventional vehicles and new technology vehicles (PHEVs and/or hydrogen fuel cell), and a significant reduction in GHG emissions from electric power generation or hydrogen production would also likely be required.

It is important to point that upon introducing a new vehicle technology into the marketplace, it can take many years until the new vehicle technology represents a significant portion of the fleet. For example, researchers at MIT estimated that based on historical rates of vehicle technology change, it might be reasonable to expect that in 2050, about 25% of the fleet would consist of plug-in hybrid vehicles. [57]

The potential energy or CO₂e efficiency of PHEVs or hydrogen fuel cell vehicles also depends a great deal on the energy sources used to produce electricity or hydrogen. A 2004 National Academy of Sciences study assumed that by 2050 hydrogen fuel cell vehicles operate at an energy efficiency of about 78 mpgge, [58] and some studies indicate that depending on the fuel sources used for power generation, PHEV vehicles could achieve an efficiency of up to about 80 mpgge. [59]

Reductions in the Growth of Vehicle Miles Traveled (VMT)

Currently the U.S. DOE is forecasting annual LDV fleet total VMT to increase from 2,696 billion VMT in 2008 to 4,069 billion VMT in 2030. If these VMT increases are extended to 2050 using the AEO 2008 outlook average annual VMT increase rate of 1.74%, the LDV fleet total VMT would be 5,740 billion VMT in 2050.

Recently, VMT has been increasing at a far lower rate, possibly due to higher fuel prices, congested roads, and/or a slowing economy. Several scenarios considering lower rates of VMT growth were analyzed, with the assumed reduced rate in VMT growth due to

increases in carpooling and vanpooling, a variety of possible pricing strategies, trip chaining, alternative work arrangements, increases in transit ridership, increase in walk and bike trips, and other strategies that could reduce the rate of growth of vehicle travel. The scenarios analyzed include a 0.5% annual increase in total VMT, a 0.9% annual increase in VMT, and a 1.0% annual increase in VMT. The 1.0% increase was analyzed because AASHTO has endorsed 1% as an appropriate future growth rate. [56] The 0.5% growth rate was also analyzed to see the effects of a much lower growth rate, and the 0.9% growth rate corresponded roughly to census population forecast growth rates, especially in the near term. (Census forecasts show annual population growth rates gradually declining from 0.92% in 2005 to 0.68% in 2050). In the near-term forecasts, it would represent no change in VMT per capita.

Because of a rebound effect, it may be particularly challenging to achieve reductions in VMT growth if vehicles become more energy efficient, as envisioned in this scenario analysis. The rebound effect is an economic principle in which improvements in the fuel efficiency of vehicles tend to result in additional use of the vehicle (i.e., as per mile operating costs decrease, use of a vehicle may increase). In most studies, the rebound effect has historically ranged from about 5 to 30% (i.e. a 100% improvement in vehicle efficiency would tend result in a 5 to 30% increase in vehicle use). More recent analysis suggests a declining rebound effect of vehicle efficiency improvements. [61]

Table 3.1 below summarizes the VMT assumptions (both total VMT growth and average annual U.S. per capita VMT growth for the various scenarios). VMT per capita may be most relevant for specific states or regions since different areas of the country are expected to have different rates of population change. As indicated in Table 3.1, the assumptions for changes in VMT per capita range from +0.16% per capita per year (for the 1% total VMT growth per year scenarios), to -0.31% per capita per year (for the 0.5% total VMT growth per year scenario).

Operational Efficiency Improvements

Two different scenarios for GHG emissions reductions from improvements in the operational efficiency of the transportation system were analyzed. These system or vehicle operational efficiency improvements include speed limit reductions/enforcement, ecodriving, smoothing out traffic flow, proper tires and inflation, removing bottlenecks, etc. One scenario assumed that the operational efficiency improvements gradually increase to reduce LDV fleet emissions by 10% by the year 2050, while a more ambitious scenario assumed reductions of 15%.

The 10% scenario seems plausible, based on analysis that indicates that speed limit reductions with enforcement could reduce fuel consumption by about 3.2%, [45] with an additional 6.8% reduction assumed from smoothing out the traffic flow, properly inflated tires, removing bottlenecks, etc. For comparison, one recent analysis using traffic conditions in Southern California found that CO₂ emissions can be reduced by up to almost 20% through congestion mitigation strategies, speed management, and shock wave suppression techniques that eliminate the acceleration/deceleration events

associated with stop-and-go traffic. [50] The more aggressive 15% reduction scenario assumption would require more comprehensive and innovative strategies to more dramatically improve the operational efficiency of the transportation system.

Year 2050 CO₂e Emissions Reduction Goal

Various GHG reduction goals have been either adopted or proposed in the U.S. Many states have set their own GHG reduction goals, and legislation has been proposed at the federal level. See Table 4.1 for GHG reduction goals in state climate action plans.

Examples of the goals set for GHG reduction at the national level have included:

- 70% below 1990 levels in 2050, from the proposed Climate Stewardship Act;
- 80% below 1990 levels by 2050, from the proposed Safe Climate Act of 2007;
- 60 and 62% below 1990 levels by 2050 from the proposed Climate Stewardship and Innovation Act and Global Warming Reduction Act, respectively; and
- 71% below 2005 levels from the proposed Lieberman-Warner Climate Security Act.

For this analysis, the goal of 70% below 2005 levels was somewhat arbitrarily selected for consideration, but the arbitrary “goal line” could have been ranged from 60% below 2005 levels by 2050, to 80% below 1990 levels.

Methodology for Estimating CO₂e Emissions Reductions

The baseline forecast of CO₂e (CO₂ equivalent) emissions from LDVs was based on the U.S. Department of Energy, Energy Information Administration’s 2008 Annual Energy Outlook forecasts. [61] These forecasts were released March 2008, and revised to include the impact of the Energy Independence and Security Act of 2007, which was enacted in December 2007.

Forecasts to the year 2030 for LDV energy consumption by fuel type were used to develop the baseline estimates of CO₂e emissions. For the baseline estimate, trends to 2030 were extended to 2050 using the AEO 2008 average annual change in LDV btu from 2006 to 2030 (annual increase in LDV btu of 0.31%).

For each alternative scenario evaluated, different combinations of annual increases in VMT (e.g., 0.5%, 0.9%, or 1.0%) and LDV fleet CO₂e efficiency were assumed. From this analysis, the portion of CO₂e emissions reduction from changes in VMT versus changes in LDV fleet CO₂e efficiency was estimated. The reductions in CO₂e emissions due to operational efficiency improvements were estimated based on the expected CO₂e emissions from the LDV fleet after CO₂e emissions savings from a reduced rate in growth in VMT was assumed, and increased gradually from 0% to 10% (or 15% for the optimistic operational improvements scenario) to the year 2050. These can be compared to the baseline forecast increase in per capita VMT of +0.91% per year (for the baseline annual increase in VMT of 1.74% per year).

Estimated CO₂e Emissions Reductions from Various Scenarios

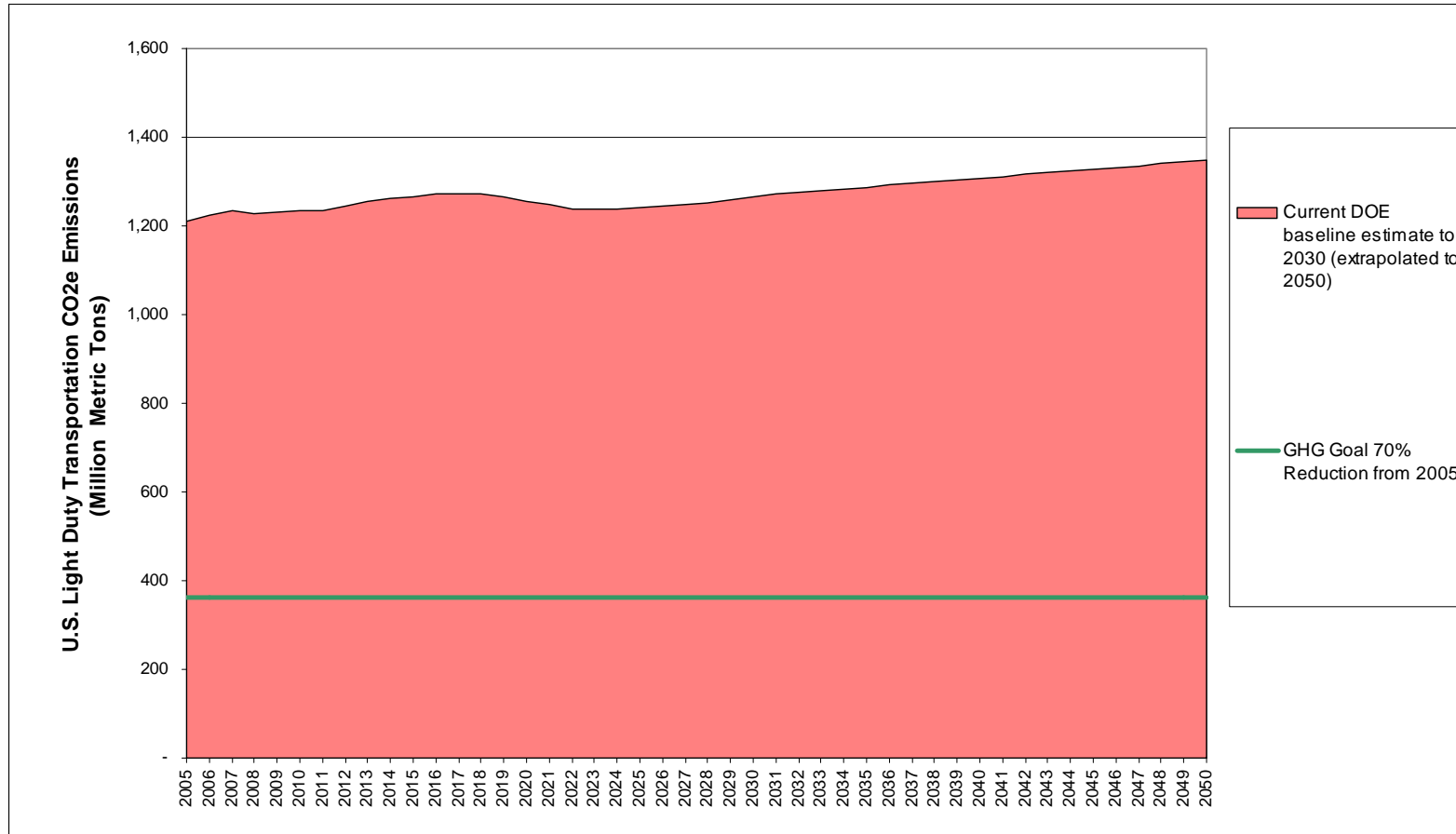
Table 3.1 below shows the different assumptions for each scenario evaluated, and CO₂e emissions reductions results, and Figures 3.1 through 3.7 present the CO₂e emissions reductions from these scenarios. As described previously, for this analysis, the goal of 70% below 2005 levels was somewhat arbitrarily selected for consideration, but the arbitrary “goal line” could have been ranged from 60% below 2005 levels by 2050, to 80% below 1990 levels.

Table 3.1 Year 2050 Scenarios Evaluated and Change in CO₂e Emissions Compared to 2005

Figure Number and Scenario	Scenario Concept Description	CO ₂ e Emissions Reduction Per Vehicle Mile in 2050	Annual Change Total VMT	Per Capita Annual Average VMT Change (2005 to 2050)	Op. Efficiency Improvements by 2050	2050 CO ₂ e% Change Compared to 2005 Baseline
Fig. 3.1 Baseline	Baseline Forecast from DOE Annual Energy Outlook 2008, with fleet fuel economy and VMT in 2050 extrapolated from 2006 to 2030 forecast.	41% (~36.4 mpg CO ₂ e equivalent)	+1.74%	+0.91%	None	+11%
Fig. 3.2 Scenario 1	“Stretch” fleet CO ₂ e efficiency (79% reduction CO ₂ e emissions/vehicle mile from 2005), and 1% annual VMT growth.	79% (~100 mpg CO ₂ e equivalent)	+1.0%	+0.16%	10%	-76%
Fig. 3.3 Scenario 2	AASHTO Approximated Scenario* (with more aggressive operational efficiency improvements): Improved fleet CO ₂ e efficiency (72% reduction CO ₂ e emissions/vehicle mile in 2050 from 2005); 1.0% increase in VMT per year.	72% (~75 mpg CO ₂ e equivalent)	+1.0%	+0.16%	15%	-69%
Fig. 3.4 Scenario 3	AASHTO Approximated Scenario* ^D : Improved fleet CO ₂ e efficiency (72% reduction CO ₂ e emissions/vehicle mile in 2050 from 2005); 1.0% increase in VMT per year.	72% (~75 mpg CO ₂ e equivalent)	+1.0%	+0.16%	10%	-64%
Fig. 3.5 Scenario 4	Improved fleet CO ₂ e efficiency (72% reduction CO ₂ e emissions/vehicle mile in 2050 from 2005); 0.9% increase in VMT per year.	72% (~75 mpg CO ₂ e equivalent)	+0.9%	+0.06%	10%	-66%
Fig. 3.6 Scenario 5	Fleet CO ₂ e efficiency (58% reduction CO ₂ e emissions/vehicle mile in 2050 from 2005); 0.9% increase in VMT per year.	58% (~50 mpg CO ₂ e equivalent)	+0.9%	+0.06%	10%	-44%
Fig. 3.7 Scenario 6	Improved fleet CO ₂ e efficiency (58% reduction CO ₂ e emissions/vehicle mile from 2005), more aggressive operational efficiency improvements, and 0.5% annual VMT growth.	58% (~50 mpg CO ₂ e equivalent)	+0.5%	-0.31%	15%	-56%

* This is not a scenario that has been specifically endorsed by AASHTO. Instead, this is an attempt to approximate an assumed 2050 scenario based on AASHTO’s proposal of reducing VMT growth to 1% a year and doubling LDV fleet fuel efficiency by 2030 (which this analysis extrapolates to 2050). However, the extrapolation to 2050 would actually result in slightly more efficient vehicles than in the 72% CO₂e emissions reduction per vehicle mile in 2050 scenarios (the CO₂e per vehicle mile equivalent of 76.4 mpg rather than the 75 mpg equivalent shown here). Therefore, 2050 CO₂e reductions from 2005 would actually be slightly higher for an assumed AASHTO scenario.

FIGURE 3.1 Baseline Scenario: 1.74% Annual VMT Growth and 36.4 mpgge LDV Fleet in 2050*



* Estimate based on U.S. Energy Information Administration Annual Energy Outlook 2008 light duty vehicle energy consumption by fuel type forecast to 2030. Forecast extrapolated from 2031 to 2050 using average annual increases in light duty btu from 2005 to 2030. These forecasts include new proposed fuel economy standards from the 2007 Energy Independence and Security Act, and the renewable fuel standard. For this analysis, fuels included in analysis were gasoline, diesel, biodiesel, and ethanol (for ethanol, this analysis assumed the use of corn ethanol in the near-term, with the ethanol transitioning to 32% cellulosic ethanol in the year 2030 and beyond). The percentage of fuels by fuel type from 2031 to 2050 were assumed to be the same as percentages of fuel by fuel type in 2030.

FIGURE 3.2 Scenario 1: 1% Annual VMT Growth, 100 mpgge LDV Fleet in 2050, Improving Operational Efficiency

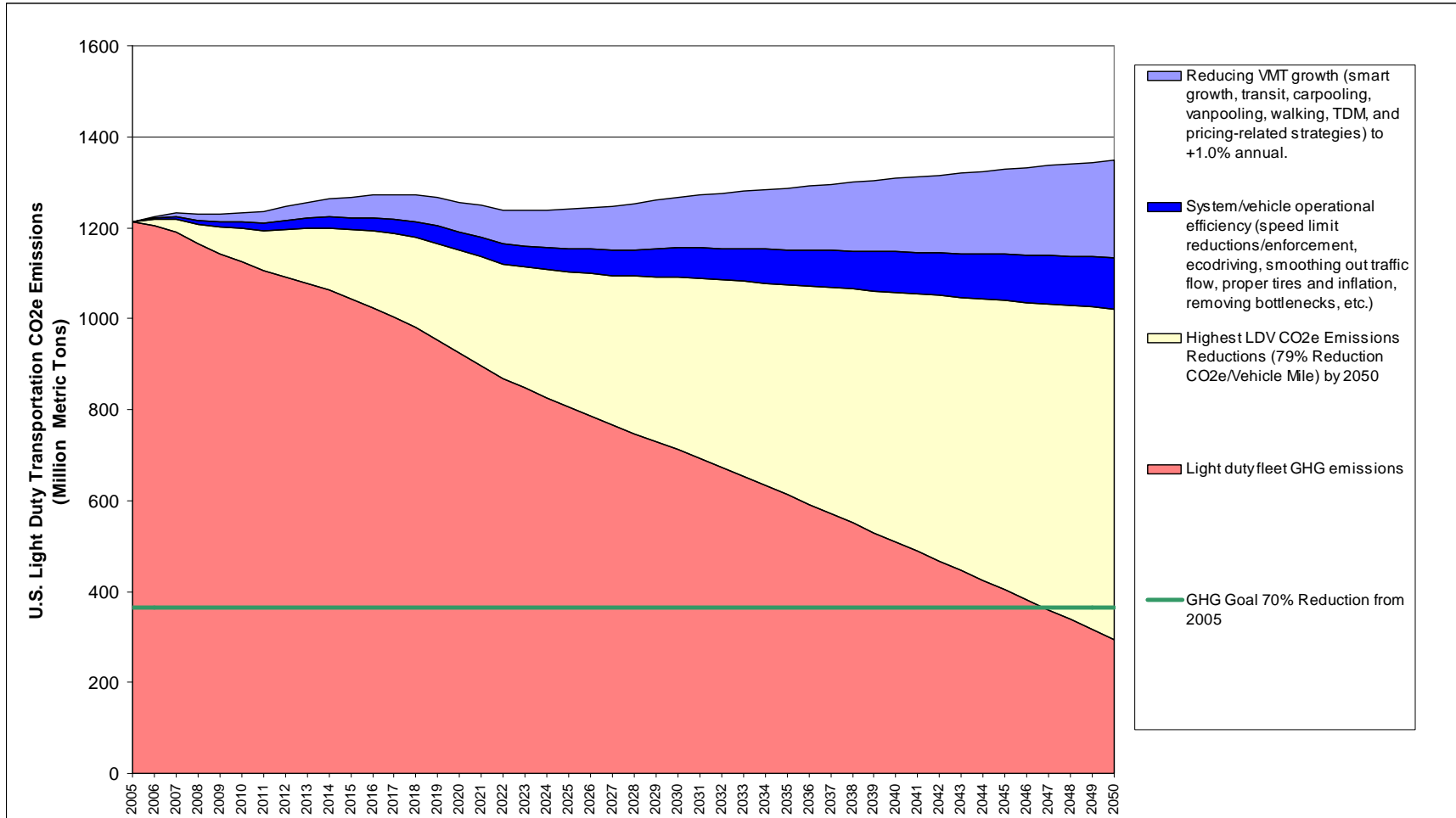


FIGURE 3.3 Scenario 2: 1% Annual VMT Growth, 75 mpgge LDV Fleet in 2050 (AASHTO Approximated Scenario), More Aggressive Operational Efficiency Improvements

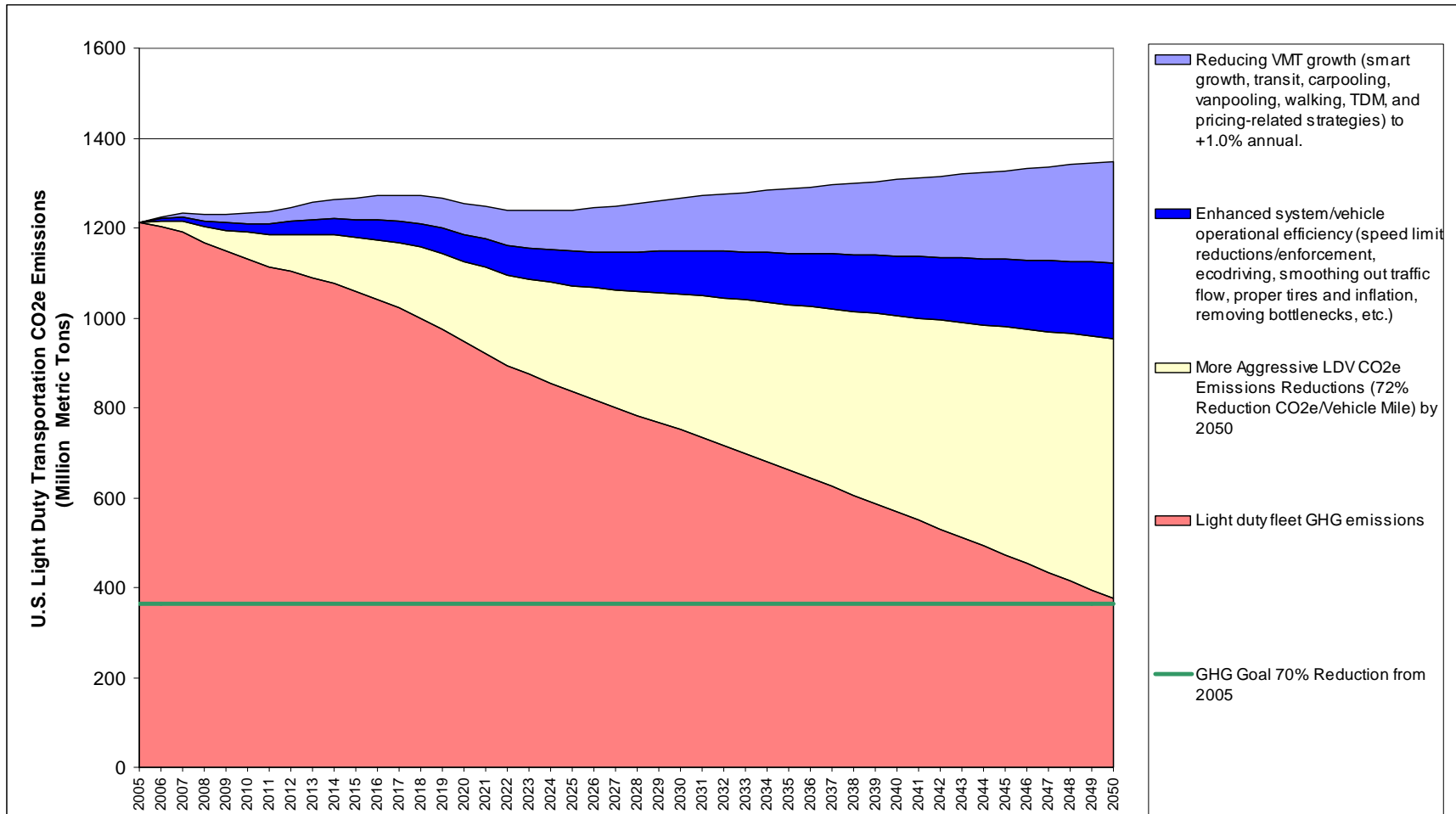


FIGURE 3.4 Scenario 3: 1% Annual VMT Growth, 75 mpgge for LDV Fleet in 2050, Improving Operational Efficiency

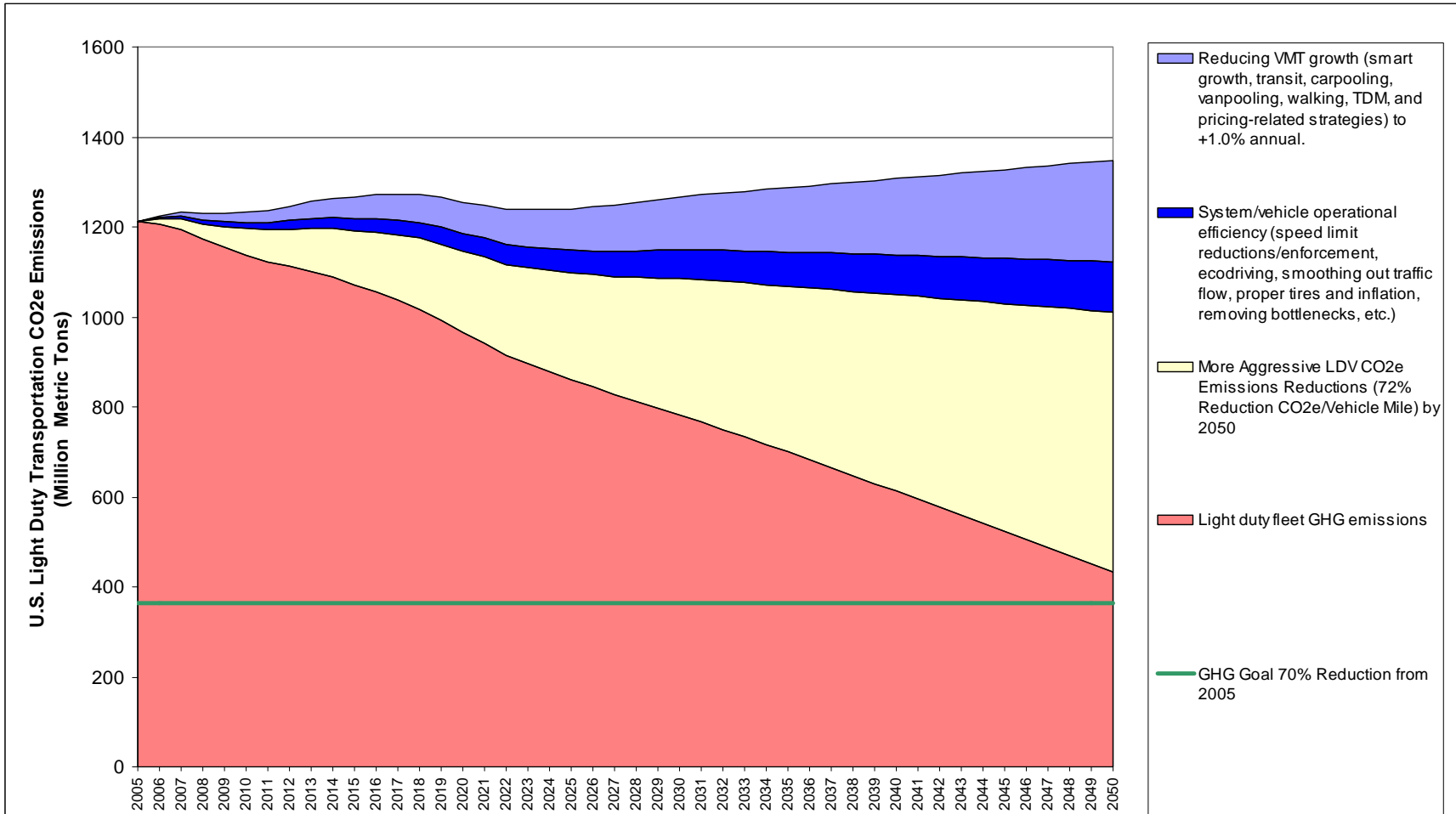
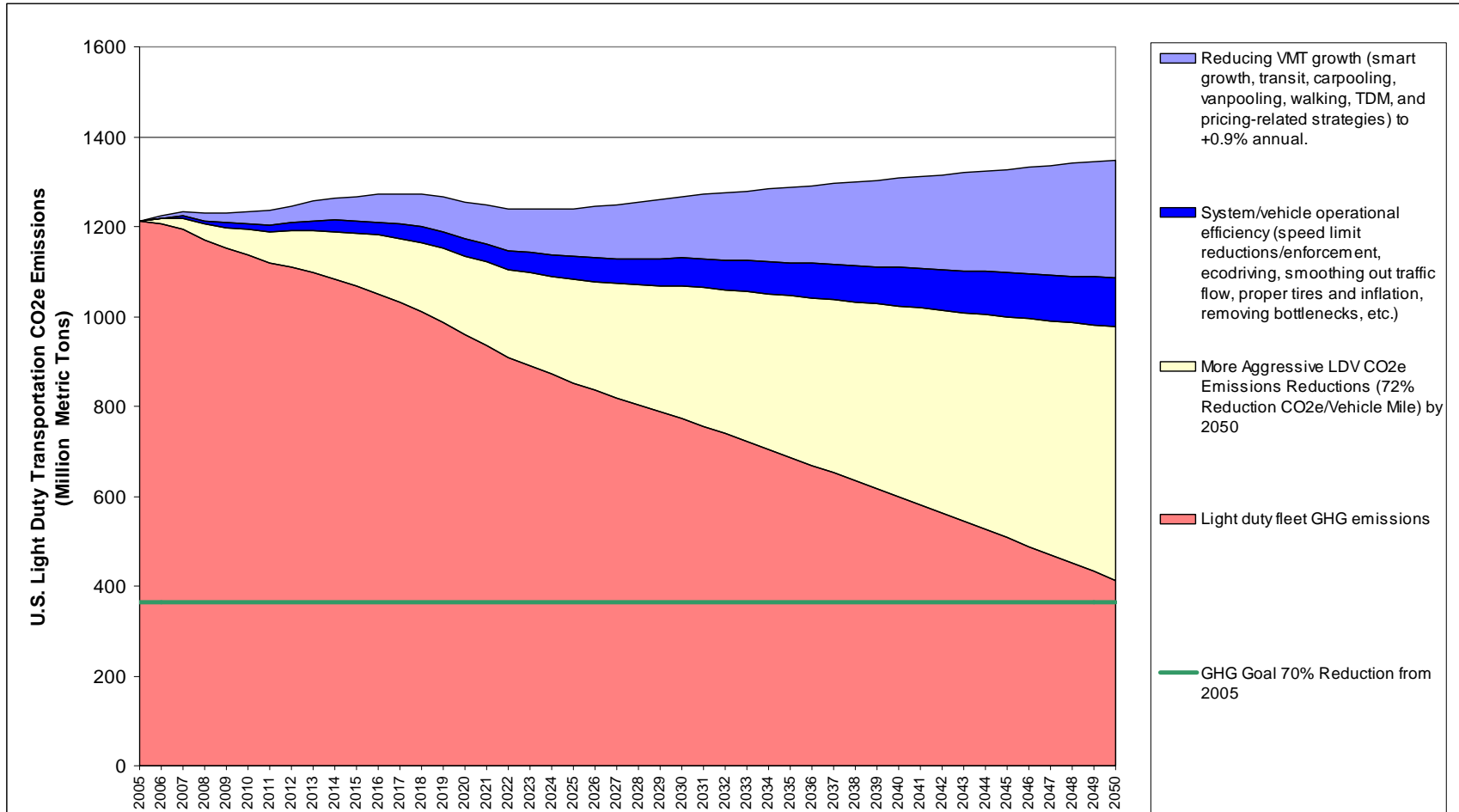


FIGURE 3.5 Scenario 4: 0.9% Annual VMT Growth, 75 mpgge LDV Fleet in 2050, Improving Operational Efficiency*



* The GHG emissions profile for Scenario 4 is almost the same as the GHG emissions profile for Scenario 3 (these scenarios are identical other than the annual VMT growth assumption of 0.9% for Scenario 4 compared to 1.0% for Scenario 3). The reduction in VMT growth from Scenario 3 to 4 results in a very small reduction in CO₂e emissions (from a 64% reduction compared to 2005 for Scenario 3 to a 66% reduction for Scenario 4).

FIGURE 3.6 Scenario 5: 0.9% Annual VMT Growth, 50 mpgge LDV fleet in 2050, Improving Operational Efficiency

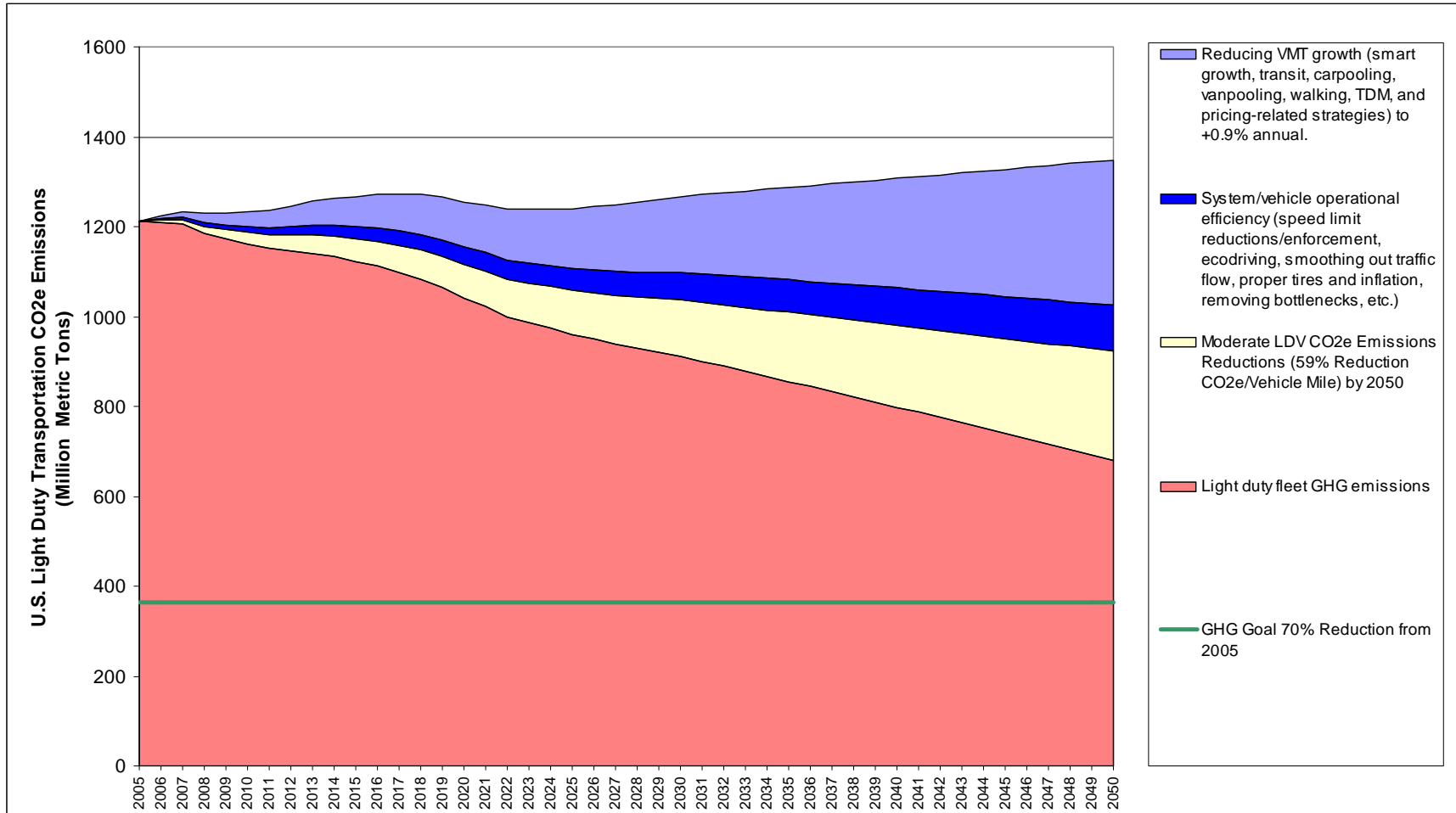
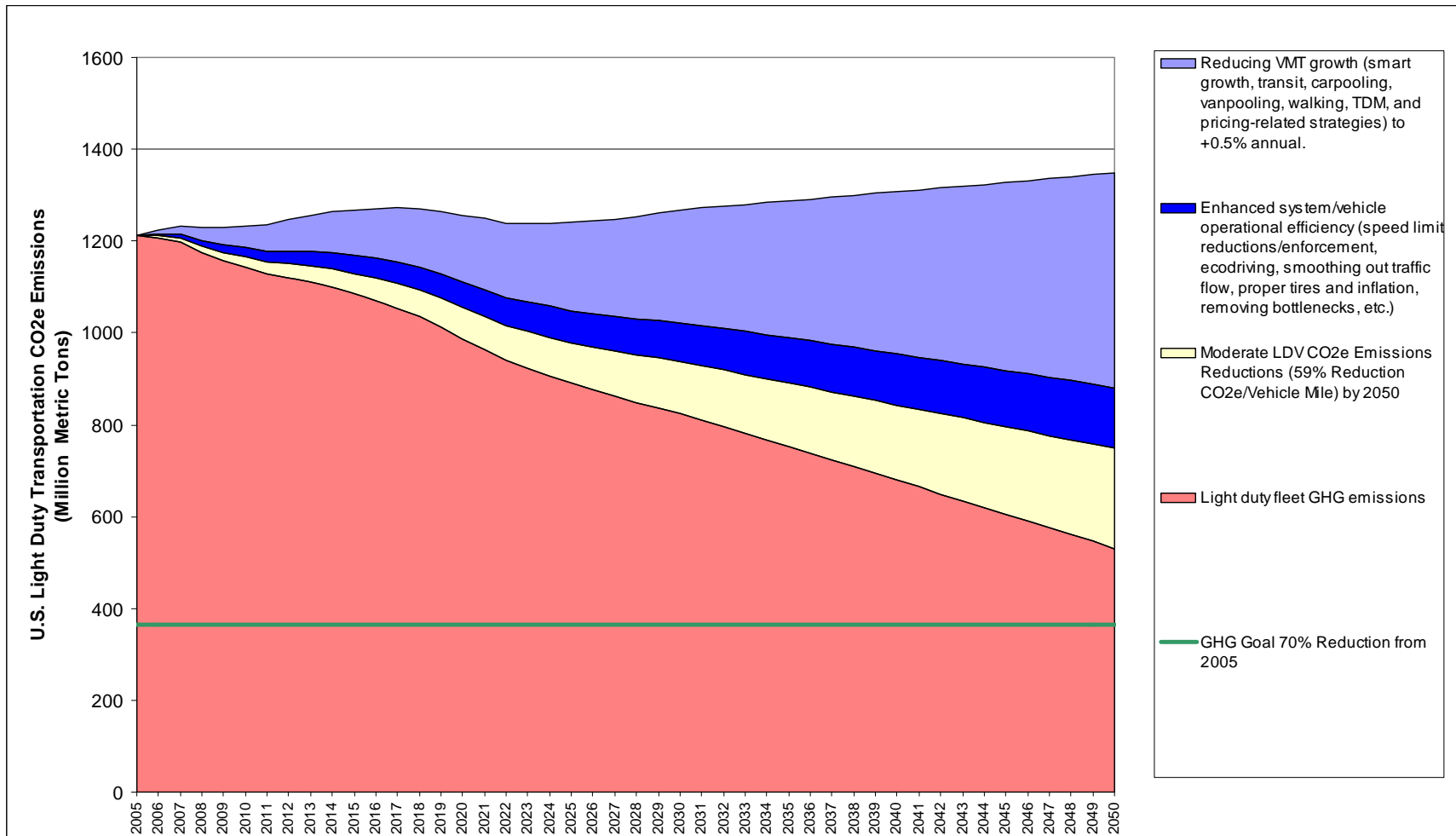


FIGURE 3.7 Scenario 6: 0.5% Annual VMT Growth, 50 mpgge LDV fleet in 2050, More Aggressive Operational Efficiency Improvements



3.2 Medium and Heavy Truck Scenarios

Overview of Medium and Heavy Truck Scenario Analysis

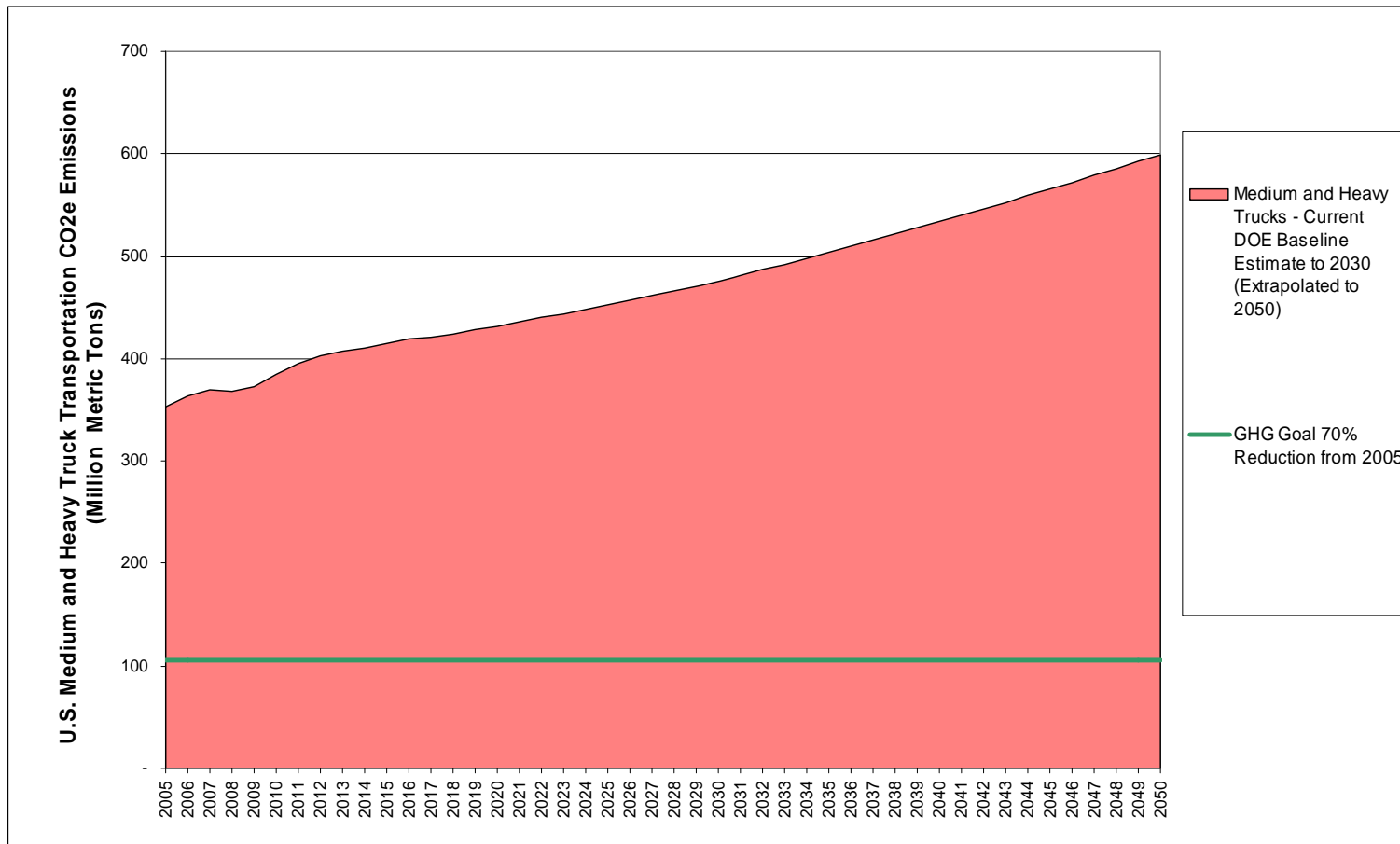
A much simpler scenario analysis was conducted for the medium and heavy truck fleet. The baseline CO₂e emissions estimate was developed based on energy consumption by fuel type for medium and heavy trucks for the years 2005 to 2030, as forecast in EIA's Annual Energy Outlook 2008, which is based on the assumption of an average annual increase in VMT of about 1.68%. The average annual increase in btu for the 2005 to 2030 period was then extrapolated to 2050 to estimate btu consumption by medium and heavy trucks to the year 2050. The btu was converted into CO₂e emissions by using estimates of CO₂e per btu for the various fuel types.

For the scenario with improved medium and heavy truck fleet CO₂e emissions improvements, it was assumed that the CO₂e emissions per vehicle mile improved by about 60% by 2030. This assumption is based on the 21st Century Truck Program¹ which includes the goal of developing and demonstrating a heavy hybrid propulsion technology that achieves a 60% improvement in fuel economy by 2012 (in this scenario a rapid fleetwide transition is assumed so the entire medium and heavy truck fleet is 60% more efficient by 2030). Based on this rate of truck efficiency improvements between 2005 and 2030, the trend is then simply continued to 2050 (with the 2050 truck efficiency improved by 133% compared to 2005).

CO₂e emissions for medium and heavy trucks are forecast to grow much more quickly than the baseline LDV fleet. This is primarily because the LDV fleet forecast assumes fairly modest improvements in average fleet fuel efficiency (about 0.5% per year, from 6.62 gasoline equivalent MPG in 2005 to 6.81 gasoline equivalent MPG in 2030.) The LDV fleet assumes greater average annual improvements in fleet fuel efficiency (about 1.34% per year). For the scenario analysis of improved efficiency of medium and heavy trucks, the average annual improvement in fleet fuel efficiency is about 1.9% per year (this can be compared to the LDV scenarios that assume annual improvements in LDV fleet efficiency ranging from 2.17 to 3.87% per year).

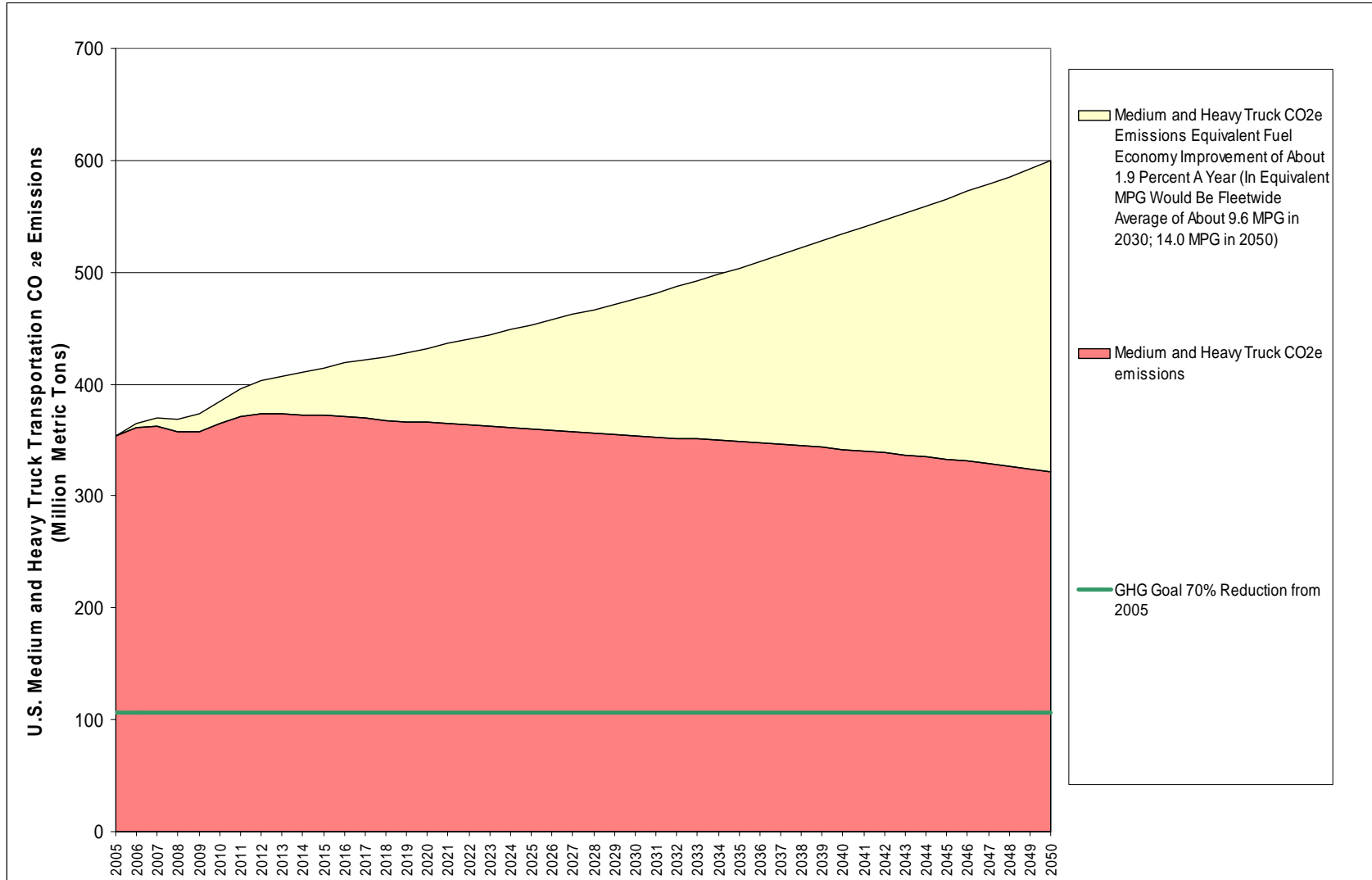
Future research could consider potential GHG emissions changes from shifting freight from trucks to rail or waterborne travel.

FIGURE 3.8 Medium and Heavy Truck Baseline Scenario: Annual VMT Growth of 1.68% and Truck Efficiency to 7.5 mpgge in 2050*



* Estimate based on U.S. Energy Information Administration Annual Energy Outlook 2008 medium and heavy truck energy consumption by fuel type forecast to 2030. Forecast extrapolated from 2031 to 2050 using average annual increases in medium and heavy truck btu from 2005 to 2030. These forecasts include new proposed fuel economy standards from the 2007 Energy Independence and Security Act, and the renewable fuel standard. For this analysis, fuels included in analysis were gasoline, diesel, biodiesel, CNG, and LPG. The percentage of fuels by fuel type from 2031 to 2050 was assumed to be the same as percentages of fuel by fuel type in 2030.

FIGURE 3.9 Medium and Heavy Truck Fleet Efficiency Improvement Scenario: Annual VMT Growth of 1.68% and Truck Efficiency to 14 mpgge in 2050

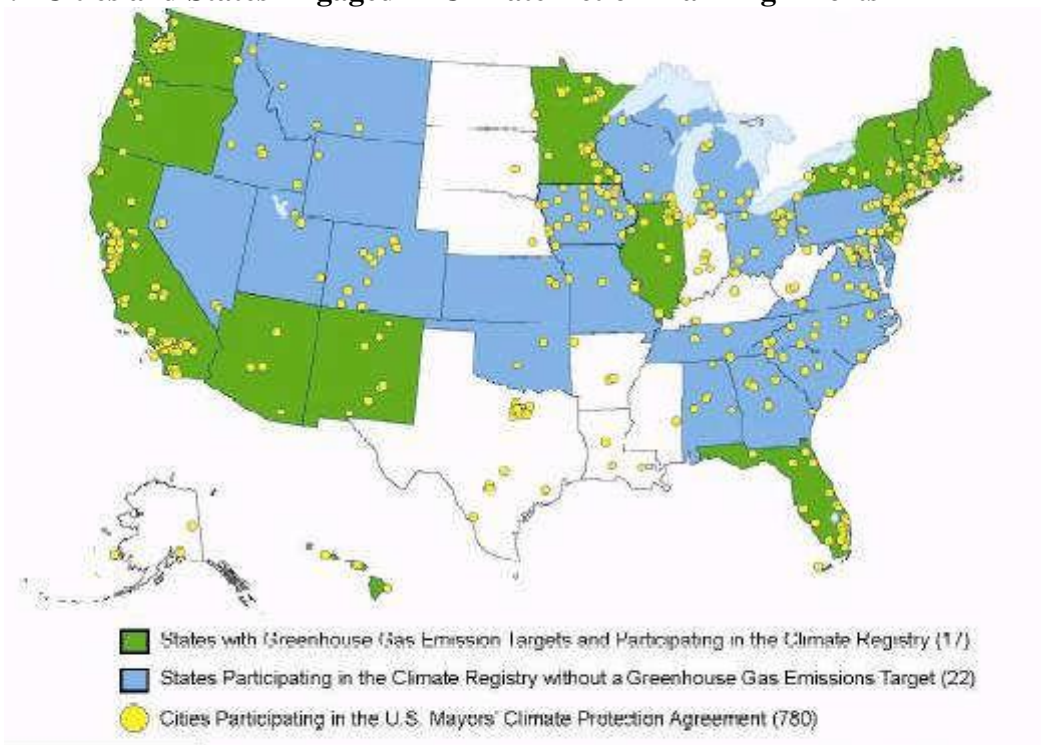


CHAPTER 4: STATE, LOCAL, REGIONAL, AND INTERNATIONAL CLIMATE ACTION PLANS

4.1 States: Over 30 states have developed or are in the process of developing climate action plans (CAPs). The surface transportation elements of these plans were often developed with limited state DOT input, are highly “aspirational,” vary erratically from state to state, and lack cost and specifics as to their implementation.

Figure 4.1 below illustrates these states and local governments that have engaged in climate action planning efforts:

Figure 4.1 Cities and States Engaged in Climate Action Planning Efforts



Source: Prepared by the Committee on Energy and Commerce Staff, February 2008

The following table presents GHG reduction goals or targets set by various states:

Table 4.1 Statewide Climate Action Plans, Overall Goals / Targets

State	2020 or Other Near Term Goal	2050 or Other Long Term Goal
Western		
Arizona	2000 level by 2020	50% below 2000
California	1990 level by 2020	80% below 1990 by 2050
Colorado	20% below 2005 by 2020	80% below 2005 by 2050
Hawaii	1990 level by 2020	
Montana	1990 level by 2020	80% below 1990 level by 2050
New Mexico	10% below 2000 by 2020	75% below 2000
Oregon	10% below 1990 by 2020	75% below 1990 by 2050
Utah	2005 levels by 2020	
Washington	1990 levels by 2020, 25% below 1990 levels by 2035	50% below 1990 levels by 2050
Midwestern		
Illinois	1990 level by 2020	60% below 1990 level by 2050
Iowa		50% below 2005 level by 2050; additional scenario recommended at 90% below 2005 level by 2050
Kentucky	7% below 1990 levels by 2012(per Kyoto Proposal)	
Michigan	10-20% below 2002 levels by 2015; 25-35% below 2002 levels by 2025	80% below 2002 levels by 2050
Minnesota	15% below 2005 levels by 2015, 30% below 2005 levels by 2025	80% below 2005 levels by 2050
Wisconsin	1990 level by 2020	60 - 80% below 1990 levels by 2050
Southeastern		
Florida	2000 levels by 2017, 1990 levels by 2025	80% below 1990 levels by 2050
North Carolina	<i>Targets in Progress</i>	
South Carolina	5% below 1990 levels by 2020	
Tennessee	7% below 1990 levels by 2008-2012 time frame	
Northeastern		
Connecticut	1990 levels by 2010, 10% below 1990 by 2020	75 - 85% below 2001 levels
Delaware	7% below 1990 by 2010	N/A
Maine	1990 levels by 2010, 10% below 1990 by 2020	75% below 1990
Maryland	10% below 2006 by 2012, 15% below 2006 by 2015, 25-50% below 2006 by 2020	90% below 2006 by 2050
Massachusetts	1990 levels by 2010, 10% below 1990 by 2020	75 - 85% below 2001 levels
New Hampshire	1990 levels by 2010, 10% below 1990 by 2020	75 - 85% below 2001 levels
New Jersey	1990 levels by 2020	80% below 2006 levels by 2050
New York	5% below 1990 by 2010, 10% below 1990 levels by 2020	
Pennsylvania		80% reductions from current levels by 2050
Rhode Island	1990 levels by 2010, 10% below 1990 by 2020	75 - 85% below 2001 levels
Vermont	1990 levels by 2010, 10% below 1990 by 2020	75 - 85% below 2001 levels

The next table focuses on surface transportation GHG reductions, showing them as (a) a percent of all surface transportation GHG in the reference year; and (b) a percent of net reductions from all sectors (including carbon sinks). Note the extremely wide variations among states in both sets of percentages.

Table 4.2 Statewide Climate Action Plans, Surface Transportation Shares of GHG Reduction

STATE	YEAR	SURFACE TRANSPORTATION REDUCTION AS % OF SURFACE TRANSPORTATION GHG IN REFERENCE YEAR	TOTAL SURFACE TRANSPORTATION REDUCTION AS % OF REDUCTION FROM ALL SECTORS (INCLUDING CARBON SINKS)
Western			
Arizona	2020	25%	9%
California	2020	28%	10%
Colorado	2020	22%	6%
Montana	2020	9%	6%
New Mexico	2020	30%	8%
Oregon	2025	25%	8%
Washington	2020	26%	16%
Midwestern			
Minnesota	2025	27%	5%
Southeastern			
North Carolina	2020	31%	11%
South Carolina	2020	19%	9%
Northeastern			
Connecticut	2020	N/A	7%
Maine	2020	23%	27%
Maryland	2020	31%	10%
New York	2020	18%	7%
Pennsylvania	2025	30%	8%
Rhode Island	2020	N/A	20%
Vermont	2028	84%	214%*

Notes:

Table accounts for climate action plans developed after year 2000 and with available ton reduction estimates. Surface transportation includes highway, freight, rail, port-related strategies, and smart growth strategies. Some plans may also cover off-road strategies (i.e. construction equipment, ATVs, snowmobiles, etc.), although most have produced negligible results to make a large enough impact on overall ton reductions.

Climate Plan for New Jersey is not available and therefore is not presented in this table.

* Surface transportation reduction in Vermont is higher than the forecast emissions baseline due to carbon sinks

Table 4.3 takes the planned GHG reductions from surface transportation and breaks them down into 4 categories: (a) vehicle improvements; (b) low carbon fuels; (c) smart growth and transit; and (d) other. Once again, there are extremely wide variations among the states as to their reliance on each of these 4 reduction categories.

Table 4.3 Statewide Climate Action Plans, Breakdown of Surface Transportation Elements

STATE	YEAR	Vehicle Improvements	Low Carbon Fuels	Smart Growth and Transit	Other*	Largest GHG Reduction from "Other" Category
Western						
Arizona	2020	40%	7%	25%	28%	Pay-As-You-Drive Insurance
California	2020	60%	24%	10%	6%	Goods Movement Efficiency Measures
Colorado	2020	40%	26%	22%	13%	Variable Priced Insurance
Montana	2020	61%	24%	8%	7%	Intermodal Freight Transportation
New Mexico	2020	31%	21%	16%	31%	Pay-As-You-Drive Insurance
Oregon	2025	80%	14%	6%	0%	N/A
Washington	2020	8%	23%	64%	5%	Transportation Pricing
Midwestern						
Minnesota	2025	15%	35%	25%	25%	Climate-Friendly Transportation Pricing/Pay-as-You-Drive
Southeastern						
North Carolina	2020	35%	12%	38%	15%	Pay-As-You-Drive Insurance
South Carolina	2020	14%	55%	29%	1%	Stricter Enforcement of Speed Limits
Northeastern						
Connecticut	2020	51%	38%	8%	2%	Multistate Intermodal Freight Initiative
Maine	2020	53%	25%	21%	1%	Freight (subtotal excludes Black Carbon)
Maryland	2020	24%	12%	45%	20%	Pay-As-You-Drive Insurance
New York	2020	59%	11%	27%	4%	Freight and Aviation Measures
Pennsylvania	2025	45%	36%	18%	<1%	Anti-Idling Program
Rhode Island**	2020	46%	10%	31%	14%	Vehicle Miles Traveled (VMT) Based Insurance Premium Structures
Vermont	2028	21%	14%	49%	17%	Pay-As-You-Drive Insurance
Median		40%	23%	25%	7%	

Notes:

Table accounts for climate action plans developed after year 2000 and with available ton reduction estimates. Surface transportation includes highway, freight, rail, port-related strategies, and smart growth strategies. Some plans may also cover off-road strategies (i.e. construction equipment, ATVs, snowmobiles, etc.), although most have produced negligible results to make a large enough impact on overall ton reductions.

Climate Plan for New Jersey is not available and therefore unable to present in this table.

* Includes management and operational improvements to surface transportation systems and fleets (i.e. anti-idling, truck stop electrification, Pay-As-You-Drive insurance, traffic signalization, intermodal freight initiatives, etc.).

**Includes non-consensus options.

The four categories of transportation GHG reductions described in Table 4.3 may include the following strategies:

- **Vehicle Improvements**: Vehicle technology improvements include strategies that increase the energy efficiency and fuel economy of light duty and heavy duty vehicle fleets. These strategies may include GHG tailpipe standards, feebate programs (incentives for new lower-emitting passenger vehicles), add-on technologies (i.e. fuel efficient replacement tires, low friction oil, automatic tire inflation for heavy duty vehicles), black carbon control technologies, facilitated adoption of new clean engines for rail and marine, incentives for accelerated replacement of high-emitting fleets.
- **Low Carbon Fuels**: Mitigation measures that fall under this category, encourage energy independence, and increase the diversity and usage of transportation energy sources with lower carbon content measured on a lifecycle basis. Such alternatives include a low carbon fuel standard (requiring a 10% reduction in carbon content of all passenger vehicle fuels), low-GHG fuel for state fleets, alternative fuel infrastructure development (cellulosic ethanol, E10, E85, biodiesel, B100, CNG, LPG, electric, hydrogen fuel cell, etc.), incentives for low carbon fuel providers and biodiesel engine vendors.
- **Smart Growth and Transit**: Strategies under this category involve efficient location and land use of residential, commercial, industrial and open spaces and the planning of transportation systems to effectively connect destinations in the most energy and resource efficient manner. Smart growth planning includes infill and brownfield redevelopment, targeted open space protection, mixed land uses, transit-oriented developments, downtown revitalization, land use-zoning-building code reforms, GHG evaluations in state policies, statewide growth management plan, and providing technical and financial support to local agencies for GHG-reducing efforts.
- **Other**: This category involves improved management of the transportation system through pricing, operational and transportation system efficiency measures. Mitigation measures that improve the efficiency of the State’s overall transportation system generally improve the connectivity between intermodal systems, increase modal shifts from single occupancy vehicles (SOVs) to high occupancy vehicles (HOVs) or transit, improve traffic flow and often result in reduced vehicle miles traveled (VMT). Transportation system efficiency strategies include variable priced insurance (i.e. Pay-As-You-Drive Insurance (PAYD)), Intelligent Transportation Systems (ITS), or pricing applications (i.e. electronic toll collection, toll roads, congestion pricing, etc.). Operational improvements may include truck stop electrification, anti-idling regulations, speed limit enforcements, or maintenance and driver training. Other miscellaneous strategies related to off-road vehicles and construction equipment are also included in this category.

Overview of the State Climate Plans: All the state climate action plans are multi-sector plans, including sector-specific policy recommendations and their GHG reduction potential, estimated cost effectiveness and savings to the economy. Final reports run about 100 pages or more in length. Although the plans are fairly comprehensive in coverage, a key area of uncertainty lies in

the effectiveness of different GHG reduction strategies including effects of individual travel behavior, economic forces and technological breakthroughs over a 20-40 year time horizon.

Highly Aspirational Transportation Strategies: Within these state climate plans, it may be fair to characterize some of the types of transportation strategies as more “aspirational” or “aggressive” than other types of transportation strategies. For example, many of the state climate action plans estimate that there will be a relatively large GHG reduction from compact development and transit oriented development, even in relatively rural states such as Vermont and New Mexico. In Washington State, for example, the VMT reduction measures that fall under the smart growth and transit category are estimated to account for up to 64% of the transportation emission reductions. Changes in land use of this magnitude would require further analysis of the associated policies, trade-offs, costs, and benefits. On the other hand, many of the state climate action plans appear to rely on relatively incremental changes in current vehicle technology and fuels (such as the Clean Car Standards), as opposed to more aggressive and transformational technological and fuel changes for which states like California, Iowa and Florida to name a few, are looking more seriously into plug-in technologies.

Areas of Uncertainty in the Climate Plans: Because these state climate plans are intended to lay out the long term vision for the state, some as far as 2020 and others as far as 2050, uncertainty lies in the ability to change land use patterns in a way that meets both GHG reduction goals and promotes the local transit system to encourage or incentivize modal shifts that maximize transit ridership.

In addition to changing travel behavior, whether through pricing incentives or changes in land use patterns, evolving technologies that enhance vehicle fuel efficiency, low carbon fuel alternatives and infrastructure also pose questions with regard to feasibility of implementation within a specified time frame. For some state DOTs, financial feasibility for some strategies was an issue (e.g., new alternative fueling stations and distribution centers, and aggressive changes in land use patterns to obtain GHG emission reductions).

Strategies related to both smart growth and vehicle technology improvements warrant deeper analysis of the associated policies, trade-offs, costs and benefits within each individual state and region to determine the effectiveness of the mitigation strategies proposed and possible impacts or changes to occur in future travel behavior.

State DOT Concerns about Climate Planning Process: DOT staff in a significant number of states that developed climate action plans have expressed several concerns about the process used to develop these plans:

- In some cases, state DOTs and other major transportation interests were not invited (and in one state not allowed) to serve on the overall steering committees for climate action plans. In other cases, state DOTs may not have designated appropriate or adequate staff to the effort, either because they did not appreciate the significance of the state climate action planning process or because the process was very time-consuming and DOT staff were coping with a large array of other pressing responsibilities.

- In many cases, state DOTs felt that the representation on the steering committee was unbalanced, with multiple representatives of environmental advocacy organizations outnumbering a single representative of a state DOT.
- Several state DOTs felt that key analysts brought in to support the process had a pre-ordained agenda and relied on unsound data or perceptions that were not supported by any data.
- Most budgets and timetables for the climate plans were constrained, which appears to have compromised the quality of analysis and time needed for the development of analytically sound climate action plans.
- The costs for implementing transportation strategies were not adequately considered, and some cost estimates appear to be unrealistic.

The Vermont climate action plan illustrates some of these concerns. The Vermont plan would reduce Vermont's transportation GHG by **84%** by 2028, predominantly through transit and smart growth strategies. By comparison, **31%** was the next highest transportation GHG reduction among 17 states whose plans were analyzed for this study. Moreover, the GHG reductions associated with Vermont's transit and land use strategies **would entail a reduction of 6,681 million VMT in 2030, compared to a projected reference case of 10,475 million VMT in 2030.** Needless to say, a reduction of almost 7 billion VMT from a projected VMT of 10.5 billion is open to question, both as to feasibility and the implications for Vermont's rural, tourist-based economy.

Assumptions and Methodologies: A variety of assumptions and methodologies were used for analyzing each mitigation strategy in State Climate Action Plans. Some plans utilize computer software programs to quantify the potential GHG emission reductions and costs, while other plans may develop customized spreadsheet analyses using unique factors and data within the particular state.

Some plans, as analyzed by RAAB Associates and Tellus Institute, use modeling software known as LEAP 2000 (See Figures 4.2 and 4.3). This program is capable of detailed analysis and tracking of all costs associated with a GHG mitigation action plan, including capital, operating and maintenance, and fuel costs, and any indirect costs such as taxes or tradable permits associated with emissions. LEAP 2000 can also track the externality co-benefits arising from the avoided emissions of criteria pollutants. Some of the benefits of using this software include: easy-to-use and follow display of information, flexible modeling structure, powerful scenario management system, highly transparent, powerful simulation capabilities, and reporting. For more details, including a downloadable evaluation version of LEAP 2000, visit: www.tellus.org/seib/leap.

Figure 4.2 Main Screen of LEAP 2000

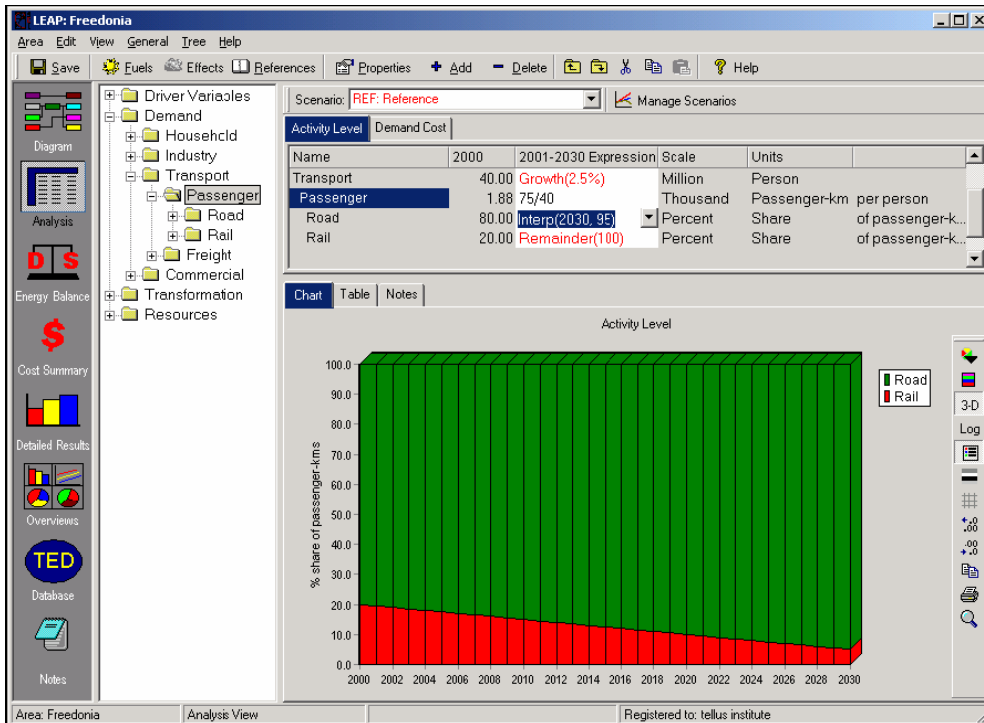
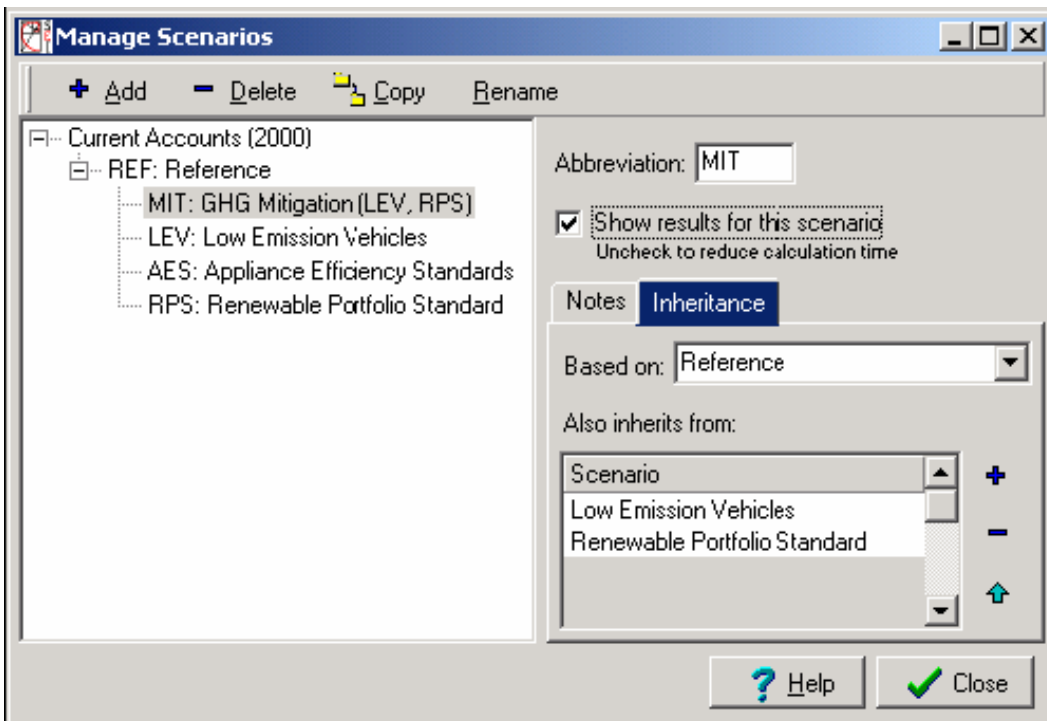


Figure 4.3 LEAP 2000 Scenario Management



Source: RAAB Associates, Ltd.

The Center for Climate Strategies (CCS), on the other hand, uses what is typically characterized as a “bottom up” approach, involving aggregate or integrative analysis of policies across all sectors. CCS has described a framework and general methodology they use in quantifying the GHG impacts and costs or cost savings through a quantification memo. The following was derived from a quantification memo used to develop the quantification framework for the state of Iowa (Quantification Methods Memo to the Iowa Climate Change Advisory Council (ICCAC): <http://www.iaclimatechange.us/ewebeditpro/items/O90F16629.pdf>).

CCS uses the following general methods, customizing the analysis of each policy option to the policy design features and specifications for analysis resulting from facilitated agreement. The quantification process is intended to provide both consistency and flexibility. Figure 4.4 illustrates key CCS guidelines:

Table 4.4 Guidelines for Quantification Approach, Center for Climate Strategies

<p>(a) Focus of Analysis: Net GHG reduction potential uses physical units of million metric tons (MMt) of carbon dioxide equivalent (CO_{2e}) and net cost per metric ton reduced uses units of dollars per metric ton of carbon dioxide equivalent (\$/tCO_{2e}). Where possible, full life cycle analysis is used to evaluate the net energy (and emissions) performance of actions (taking into account all energy inputs and outputs to production). Net analysis of the effects of carbon sequestration is conducted where applicable.</p> <p>(b) Geographic Inclusion: Measure GHG impacts of activities that occur within the state, regardless of the actual location of emissions reductions.</p> <p>(c) Direct vs. Indirect Effects: Define “direct effects” as those borne by the entities implementing the policy recommendation. For example, direct costs are net of any financial benefits or savings to the entity. Define “indirect effects” as those borne by the entities other than those implementing the policy recommendation. Quantify these indirect effects on a case-by-case basis, depending on magnitude, importance, time available, need, and availability of data. (See additional discussion and list of examples below.)</p> <p>(d) Non-GHG (External) Impacts and Costs: Include in qualitative terms where deemed important. Quantify on a case-by-case basis as needed, depending on need and where data are readily available.</p> <p>(e) Discounted and “Levelized” Costs: Discount a multi-year stream of net costs (or savings) to arrive at the “net present value cost” of implementing a policy option. Discount costs in constant 2005 dollars using a 5% annual real discount rate for the project period of 2009 through 2020 (unless otherwise specified for the particular policy option). Capital investments are represented in terms of levelized or amortized costs through 2020. Create a “levelized” cost per ton by dividing the “present value cost or savings” by the cumulative reduction in tons of GHG emissions. This is a widely used method to estimate the “dollars per ton” cost or cost savings of reducing GHG emission (all in CO_{2e}). A “levelized” cost is a “present value average” used in a variety of financial cost applications.</p>
--

(f) Time Period of Analysis: Count the impacts of actions that occur during the project time period and, using levelized emissions reduction and cost analysis, report emissions reductions and costs for specific target years such as 2012 and 2020. Where additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, show these for comparison and potential inclusion.

(g) Aggregation of Cumulative Impacts of Policy Options: In addition to “stand-alone” results for individual options, CCS will estimate cumulative impacts of all options combined. In this process, we avoid simple double counting of GHG reduction potential and cost when adding emission reductions and costs associated with all of the policy recommendations. To do so, CCS notes and/or estimates interactive effects between policy recommendations using analytical methods where significant overlap or equilibrium effects are likely.

(h) Policy Design Specifications and Other Key Assumptions: Include explicit notation of timing, goal levels, implementing parties, the type of implementation mechanism, and other key assumptions as determined by the ICCAC.

(i) Transparency: Include policy design choices (above) as well as data sources, methods, key assumptions, and key uncertainties. Use data and comments provided by ICCAC to ensure best available data sources, methods, and key assumptions that use their expertise and knowledge to address specific issues in Iowa. Modifications will be made through facilitated decisions, as needed, to improve analysis.

(j) Cost-Effectiveness: Because monetized dollar value of GHG reduction benefits are not available, physical benefits are used instead, measured as dollars per MMtCO₂e (cost or savings per ton) or “cost effectiveness” evaluation. Both positive costs and cost savings (negative costs) are estimated as part of compliance cost. For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the U.S. Environmental Protection Agency (US EPA) available at: <http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html>.

Examples of direct vs. indirect impacts for the Transportation and Land Use sector may include:

Direct Costs and/or Savings

- Incremental cost of more efficient vehicles net of fuel savings
- Incremental cost of implementing Smart Growth programs, net of saved infrastructure costs
- Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure costs
- Incremental cost of alternative fuel, net of any change in maintenance costs

Indirect Costs and/or Savings

- Health benefits of reduced air and water pollution
 - Ecosystem benefits of reduced air and water pollution
 - Value of quality-of-life improvements
 - Value of improved road safety
 - Energy security
 - Net value of employment impacts
-

The “Notional Rating” Process: In the early development stages of many of the state climate action plans, a “notional rating” was given to all policy options considered. A notional rating is a High (H), Medium (M), or Low (L) rating that is made to characterize 1) the potential GHG reduction and 2) potential cost effectiveness of a particular mitigation strategy based on the opinions of the participants. Notional ratings are gathered and discussed among participants involved in developing the plans, most of whom have little or no knowledge or experience with transportation costs. For an example of a notional rating, see <http://www.flclimatechange.us/ewebeditpro/items/O12F16861.pdf>.]

Comparisons to Other States: In some climate action plans, where preliminary policies considered overlapped with those of neighboring states that were already quantified and/or adopted, a comparative assessment of ton reductions among those states with the a climate action plan in place was taken. For example, the Utah Governor’s Blue Ribbon Advisory Council on Climate Change compared the costs and benefits of each recommended mitigation strategy in the states that have quantified and/or adopted the policy. Utah accompanied each mitigation recommendation with a list of other states that have adopted the policy, the cumulative tons that are reduced (most commonly through year 2020), the percent reduction of the respective state’s 2020 emissions, and any relevant cost or savings information (Utah Final Blue Ribbon Advisory Council on Climate Change Report, “Transportation and Land Use Options,” 2007. http://www.deq.utah.gov/BRAC_Climate/docs/Final_Report/Sec-8-BRAC_TRANSPORTATION_LAND_USE.pdf

Table 4.5 below provides web links to most of the state climate action plans, as well as current status, year completed, and the lead agency or contractor involved in preparation of the plans.

Table 4.5 State Climate Action Plan Resources

Western					
Alaska	http://www.climatechange.alaska.gov/	In Progress	TBA	Center for Climate Strategies	
Arizona	http://www.azclimatechange.gov/	Completed	2006	Center for Climate Strategies	
California	http://www.arb.ca.gov/cc/scopingplan/document/scopingplan.document.htm	Completed	2008	California Air Resources Board (CARB)	
Colorado	http://www.coloradoclimate.org/	Completed	2007	Center for Climate Strategies	
Hawaii	http://hawaii.gov/dbedt/info/energy/publications/ccap.pdf	Completed	1998	State of Hawaii Department of Business, Economic Development & Tourism, Energy, Resources, & Technology Division, and Department of Health Clean Air Branch	
Idaho	http://www.deq.idaho.gov/air/prog_issues/climate_change/ghg_state_government.cfm	Completed	FY08-09	Plan	
Montana	http://www.mtclimatechange.us/	Completed	2008	Department of Environmental Quality	
Nevada	http://gov.state.nv.us/climate/	Completed	2007	Center for Climate Strategies	
New Mexico	http://www.nmclimatechange.us/	Completed	2008	Nevada State Energy Office	
Oregon	http://www.oregon.gov/ENERGY/GBLWRM/docs/GWReport-FInal.pdf	Completed	2006	Center for Climate Strategies	
Utah	http://www.deq.utah.gov/BRAC_Climate/index.htm	Completed	2004	National Policy Consensus Center and Oregon Consensus Program at Portland State University	
Washington	http://www.ecy.wa.gov/climatechange/cat_overview.htm	Completed	2007	Blue Ribbon Advisory Council (BRAC) on Climate Change	
Midwestern					
Illinois	http://dnr.state.il.us/orep/nrrc/iccp/toc.htm	Completed	2007	Center for Climate Strategies	
Iowa	www.iaclimatechange.us	In Progress	2008	Center for Climate Strategies	
Kansas	http://www.ksclimatechange.us/	In Progress	2010	Center for Climate Strategies	
Kentucky	http://www.epa.gov/climatechange/wycd/stateandlocalgov/downloads/ky_2_fin.pdf	Completed	1998	The Kentucky Natural Resources and Environmental Protection Cabinet	
Michigan	http://www.miclimatechange.us/	Completed	2008	Center for Climate Strategies	
Minnesota	http://www.mnclimatechange.us/	Completed	2008	Center for Climate Strategies	

Missouri	http://www.dnr.mo.gov/pubs/pub1447.pdf	Completed	2002	Missouri Department of Natural Resources
North Dakota		NA		
Ohio	http://www.cmnh.org/site/sustainability/climateactionplan.aspx http://dnr.wi.gov/environmentprotect/gfgw/documents/interim_report.pdf	In Progress	NA	Cleveland Museum of Natural History
Wisconsin		Interim Report	2008	Wisconsin Department of Natural Resources
Southeastern				
Arkansas	http://www.arclimatechange.us/	Completed	2008	Center for Climate Strategies
Florida	http://www.flclimatechange.us/	Completed	2008	Center for Climate Strategies
North Carolina	http://www.ncclimatechange.us/	Completed	2007	Center for Climate Strategies
South Carolina	http://sclimatechange.us/	Completed	2008	Center for Climate Strategies
Tennessee	http://www.state.tn.us/ecl/pdf/greenhouse/entiredocument.pdf	Completed	1999	Center for Electric Power, Tennessee Technological University
Northeastern				
Connecticut	http://www.ctclimatechange.com/StateActionPlan.html	Completed	2005	Governor's Steering Committee on Climate Change and Climate Change Coordinating Committee
Delaware	http://ceep.udel.edu/publications/globalenvironments/reports/deccap/fullreport.pdf http://mainegov-images.informe.org/dep/air/greenhouse/Report%20to%20NRC%201-18-08_FINAL.pdf	Completed	2000	Center for Energy and Environmental Policy (University of Delaware)
Maine		Completed	2004	Muskie School of Public Service at University of Southern Maine, and RAAB Associates
Maryland	http://www.mdclimatechange.us/ http://masstech.org/renewableenergy/public_policy/DG/resources/2004_MA_Climate_Protection_Plan.pdf	Completed	2008	Center for Climate Strategies
Massachusetts		Completed	2004	Commonwealth Development
New Hampshire	http://www.des.state.nh.us/ard/climatechange/challenge.pdf	Completed	2001	New Hampshire Department of Environmental Services
New Jersey	http://www.state.nj.us/globalwarming/public/ http://www.ccap.org/pdf/04-2003_NYGHG_Recommendations.pdf	Completed	2007	Center for Climate Strategies
New York		Completed	2003	The Center for Clean Air Policy
Pennsylvania	http://www.pecpa.org/roadmap.htm http://www.dem.ri.gov/programs/bpoladm/stratpp/greenhos.htm	Completed	2007	Pennsylvania Environmental Council, Inc.
Rhode Island		Completed	2002	RAAB Associates (PM/Facilitator), Tellus Institute (Technical/Policy Consultant)
Vermont	http://www.vtclimatechange.us/	Completed	2007	Center for Climate Strategies

Notes:

* Completed Energy Plan Available, but no Climate Action Plan yet available. For Virginia, greenhouse gas (GHG) reduction targets are included in the State's Energy Plan (2007) - See Table 1 for details.

4.2 State DOTs: State DOTs have begun to focus on climate change and are developing GHG reduction strategies.

Several State DOTs are in the forefront of efforts to address Global Climate Change in the planning, implementation, and operation of their transportation networks. Specific examples include:

- The **California Transportation Plan** identifies three key strategies to commit to a clean and efficient transportation system: (1) Expand the market share of cleaner vehicles and the necessary fuel infrastructure; (2) Enhance education, planning tools, and performance standards on energy efficiency, air quality, and climate change implications of transportation decision making; and (3) Implement measures to lower emissions of greenhouse gases and air pollutants in transportation options.
- **New York State's Department of Transportation** has developed draft methodology templates for MPOs to follow in conducting greenhouse gas/energy analyses as part of the transportation planning process for regionally significant projects. Two templates were developed; one for the planning level and one for the project level.
- **Oregon's Strategy for Greenhouse Gas Reductions** recommends a GHG analysis of regional transportation plans. Specific recommendations include: (1) "When transportation plans are updated and air quality conformity determinations are required, calculate estimates of GHG emissions from transportation sources using EPA approved methods. Comparisons with earlier greenhouse gas emission forecasts should be made available to document change over time."; and (2) "Develop a method to account for GHG emissions and use it as a ranking criterion in transportation planning decisions." In addition, Oregon has begun installing solar panels in highway rights of way, with the goal of supplying all the state DOT electricity needs through solar panels.

In addition to these examples, many State DOTs are undertaking strategies such as:

- Adding new bicycle and pedestrian paths to encourage non-motorized vehicular travel.
- Adopting no-idle policies for public fleet vehicles.
- Replacing arrow boards and warning beacons used to direct and warn motorists in construction zones with low-energy LED lights that do not require the vehicle's engine to be running in order to operate. Washington has outfitted more than 200 vehicles with LED lights, saving an estimated 121,000 gallons of fuel per year.

- Giving priority to hybrid, fuel-efficient, or low-emission vehicles when replacing fleet vehicles.
- Establishing Incident Response Programs, which consist of vehicles that patrol highways to clear blocking incidents quickly, reducing the amount of time motorists spend sitting and idling in traffic.
- Adopting the California GHG automobile standards. Currently 15 states have adopted GHG auto standards, and are seeking EPA approval of a waiver to allow them to take effect.
- Controlling traffic congestion using such tools as metered on-ramps, traffic cameras, park and ride lots, tolling, and variable-direction express lanes.
- Creating Transportation Demand Management Plans, like New Hampshire's interagency consortium, to reduce single occupancy vehicles driven by state employees either on the job or to and from work.
- Installing Intelligent Transportation Systems which improve traffic flow and decrease congestion.
- Designating High Occupancy Vehicle lanes (HOV) to provide incentives for carpools and vanpools.

4.3 Regions: Three major multi-state/regional climate initiatives are underway in the United States.

There are currently three major regional climate plans underway in the U.S.: The Western Climate Initiative (WCI), The Midwestern Regional Greenhouse Gas Reduction Accord (MRGHGRA), and the Regional Greenhouse Gas Initiative (RGGI).

Western Climate Initiative (WCI): The Western Climate Initiative (WCI) began in February 2007 as a joint effort to reduce GHG emissions and address climate change amongst the governors of Arizona, California, Montana, New Mexico, Oregon, Washington and Utah. In addition to these seven states, the Canadian provinces of British Columbia, Quebec and Manitoba have also joined as the first participating jurisdictions outside the U.S. WCI includes “member” states (listed above) and “observer” states. Member states in the WCI are required to have: (1) an economy-wide GHG reduction goal; (2) has developed a comprehensive multisector state climate change action plan to achieve that goal; (3) committed to adopt GHG tailpipe standards for passenger vehicles; and (4) participated in the climate registry. Observer states, on the other hand, may be in the process of developing a state climate change action plan and are monitoring the process prior to considering full membership. Together, the WCI member states work together to achieve a regional goal of 15% below 2005 levels by 2020 (or approximately 33% below business-as-usual levels) with the development of a multi-state cap and trade program.

The WCI builds on work already undertaken individually by the participating states and provinces, as well as two existing regional agreements: the Southwest Climate Change Initiative of 2006 and the West Coast Governors' Global Warming Initiative of 2003.

Midwestern Regional Greenhouse Gas Reduction Accord (MRGHGRA): On November 15, 2007, the Midwestern Regional Greenhouse Gas Reduction Accord (MRGHGRA) was established. Six states – Illinois, Iowa, Kansas, Michigan, Minnesota, Wisconsin and the Premier of the Canadian Province of Manitoba signed the agreement, and in addition, the governors of Indiana, Ohio, and South Dakota joined the agreement as observers to participate in the development of the cap and trade system. Under the Accord, members agree to establish greenhouse gas reduction targets, including a long-term target of 60-80% below current emission levels, and develop a multi-sector cap and trade system to help meet the targets. Participants will also establish a greenhouse gas emissions reductions tracking system and implement other policies, such as low-carbon fuel standards.

Regional Greenhouse Gas Initiative (RGGI): In the Northeastern region of the U.S., the Regional Greenhouse Gas Initiative (RGGI) was the first of the three regional initiatives, established on December 20, 2005. RGGI sets a cap on emissions of carbon dioxide from power plants, and allows sources to trade emissions allowances. The program will begin by capping emissions at current levels in 2009, and then reducing emissions 10% by 2019. The governors of Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont signed a Memorandum of Understanding agreeing to implement the first mandatory U.S. cap-and-trade program for carbon dioxide. In 2007, Massachusetts and Maryland also joined the agreement. Observers include Pennsylvania and the District of Columbia.

Other multi-state efforts include the Southwest Climate Change Initiative, the West Coast Governors' Global Warming Initiative, Western Governors' Association: Clean and Diversified Energy Initiative, Powering the Plains, Energy Security and Climate Stewardship Platform for the Midwest, and the New England Governors and Eastern Canadian Premiers (NEG-ECP).

4.4 Cities: Nearly 800 mayors have signed the U.S. Conference of Mayors Climate Protection Agreement, agreeing to reduce community-wide GHG by 2012 to at least 7% below 1990 levels.

According to a white paper authored by the Committee on Energy and Commerce Staff, nearly 800 mayors in communities representing more than 77 million Americans from all 50 States have signed the U.S. Conference of Mayors Climate Protection Agreement, whereby they agree to reduce community-wide greenhouse gas emissions by 2012 to at least 7% below 1990 levels. A report last year found that many cities will not be able to meet this goal absent complementary State and Federal policies to reduce greenhouse gas emissions. In mid-2007 a multi-state Climate Registry was launched to establish a

common protocol for greenhouse gas emissions reporting due to the lack of such a protocol at the Federal level. The Registry now has 39 member States plus the District of Columbia.

State and local governments can reduce greenhouse gas emissions by reducing the carbon footprint of their buildings and operations (including schools, hospitals, sewage treatment plants, municipal landfills, airports, bus fleets and terminals, street lighting and stop lights). For example, King County, Washington, recently announced plans to purchase 500 new hybrid buses over the next 5 years as part of its effort to convert the County's entire transit and vehicle fleet to low-emission vehicles. In addition to the adoption of low-emission vehicle fleets, states and local governments can also significantly reduce greenhouse gas emissions through land use and transportation decisions at all levels of governments.

Below is a summary of the VMT and GHG reduction strategies most commonly contained in local climate change action plans

<http://yosemite.epa.gov/gw/StatePolicyActions.nsf/matrices/local>

Transportation System Efficiency

- *Commuter Incentives* – Programs that promote alternatives to single-occupancy automobiles for commuter travel. This typically includes car pool programs, ridesharing, park-and-ride, auto restriction zones, employer transit subsidies, telecommuting, shuttle systems, high occupancy vehicle lanes, walk to school programs, compressed work week, parking management, and traffic management organizations.
- *Intelligent Transportation Systems* – Programs that use computerized systems to increase the flow of traffic on local streets and highways.
- *Land Use/Transit-Oriented Development* – Programs that minimize transportation GHG emissions by facilitating alternatives to automobile travel through land use planning.
- *Non-motorized Travel* – Programs that promote walking, bicycles, and other non-motorized alternatives to automobile travel.
- *Traffic Calming* – Programs that reduce the speed of automobile traffic, thereby reducing GHG emissions and encouraging alternate, non-motorized forms of travel such as bicycles and walking.

Alternative Fuel Vehicles

- *Refueling Infrastructure Development* – Policies that encourage the development of alternative fuel refueling stations to encourage the use of alternative fuel vehicles.
- *Alternative Fuel Vehicle Fleet Requirements* – Policies that require an agency's fleet to contain a certain percentage of alternative fuel vehicles, and that require agencies to purchase smaller and more fuel-efficient vehicles and eliminate older, less fuel-efficient vehicles.

Public Transportation

- *Promotion of Mass Transit* – Programs that promote the use of rail, bus, and other forms of mass transit, including improving and expanding the system, and public outreach.

Pricing Strategies

- *Road or VMT Pricing* – Programs in which charges are levied to individuals traveling on certain segments of roads or during peak hours, or upon a VMT (Vehicular Miles Traveled) basis.
- *Increase Driving Costs* – Policies that promote increasing driving costs in order to encourage alternate forms of transportation or carpooling, such as higher parking costs.

4.5 International: Other developed countries are adopting a wide variety of transportation GHG strategies

Asia-Pacific Region

Since the Asia-Pacific region is home to both some of the poorest and wealthiest countries in the world, energy efficiency benchmarks and GHG reducing strategies are not yet coordinated among the different countries. There are a number of regional organizations and programs, however, which have been established to encourage energy-efficiency through collaboration, education, grant funding, soft loans, and data provision. For example, the Asia-Pacific Economic Cooperation (APEC) is currently establishing guidelines for the development of bio-diesel standards for the APEC region, surveying transportation efficiency policies in APEC economies, and developing alternative fuels implementation guidelines. Other multi-lateral efforts include the Asian Environmental Compliance and Enforcement Network (ASCEN), which promotes improved compliance with environmental legal requirements in Asia; the World Bank Asia Alternative Energy Program (ASTAE), which provides financing for alternative energy projects; and the Clean Air Initiative (CAI-Asia), which promotes and demonstrates innovative ways to improve air quality throughout Asia.

In recent years, Singapore and Japan have been especially active in promoting energy efficiency and GHG mitigation in the transportation and land use sector.

Singapore

Singapore is an environmentally-conscious island economy, with limited space to grow and relatively high fuel costs. Since the mid-nineties, the Singaporeans have initiated a series of programs and regulations intended to integrate land use and transport planning, encourage transit use, improve fleet efficiency, and reduce car ownership.

Singapore has led the region for many years with its innovative strategies for reducing VMT. The most well-known strategies are:

- **The national car registration quota:** restricts the number of cars that may be purchased each year and substantially increases the cost of ownership, and electronic, dynamic congestion charging, which discourages car travel in central parts of the city during select times of the day.
- **Park and ride program:** includes the sale of convenient combined parking and transit monthly passes.
- **Personalized fare cards:** can be used for all transit and taxi fares, as well as downloading coupons and making store purchases.
- **Competitive car sharing program** and a new, high-tech **bicycle sharing program**, similar to the program recently rolled out in Paris.
- **Fuel Economy Labeling Program** for passenger vehicles, which helps consumers easily recognize and compare the fuel economy of different vehicles.
- **Green Vehicle Rebate Program:** reimburses consumers for purchasing vehicles that use energy sources other than petroleum and diesel, such as compressed natural gas (CNG), electricity, methanol, hydrogen, or solar energy.
- **Land Transportation Authority (LTA):** In an attempt to better integrate land use and transportation planning, the Singaporean government created the LTA in 1995, merging four previously separate public entities: Registry of Vehicles, Mass Rapid Transit Corporation, Roads and Transportation Division of the Public Works Department, and Land Transport Division of the then-Ministry of Communications. The LTA oversees both public and private surface transportation, and is permitted to manage real estate and urban development activities in areas adjacent to transit hubs and stations with the ultimate goal of encouraging transit use.

Japan

Japan has virtually no domestic oil or natural gas reserves, and in 2005, Japan was the second largest net importer of crude oil in the world. In the past few decades, Japan has significantly improved energy conservation and is widely considered a global leader in the development and implementation of energy efficiency and GHG reducing innovations. Between 1995 and 2004, average vehicle fuel efficiency in Japan has improved by 22%. Some of the most successful strategies used to reduce GHG emissions include:

- **Promotion of transit use** through road-based transit services, suburban residential development near stations, and retail services and “leisure centers” near train stations.

- **“Top Runner” program:** applies to multiple goods, including passenger and freight vehicles. The scheme sets future fuel efficiency standards higher than the performance of the best product among those currently commercially available in the same product category. Manufacturers which have not achieved the standards by the set deadline are given technical advice, publicly announced, and/or fined a sum less than or equal to US\$8,700.
- **“Green Tax” program:** includes a combination of tax incentives and penalties for fuel and energy efficient passenger and commercial vehicles. Sales tax reductions for hybrid passenger cars are about 2.2%, and reductions for electric, CNG, and hybrid trucks are about 2.7%. Tax penalties for Diesel, gasoline, and LPG vehicles older than 10 years are about 10%. As of 2006, hybrids, such as the Toyota Prius, accounted for almost 11 million, or 21%, of all autos on Japanese roads.
- **“Eco-Drive” program:** includes a public awareness campaign and partial government subsidies for purchasing cars equipped with a system for tracking fuel efficiency.

Similar to Singapore, the Japanese government, in 2001, consolidated the former Ministry of Construction, Ministry of Transport, National Land Agency, and the Hokkaido Development Agency to form the Ministry of Land, Infrastructure and Transport (MLIT). MLIT is responsible for coordinating the physical, economic, and social infrastructures of Japan, with transportation viewed as a “lifeline that brings all of these elements together.” In the MLIT, road transport and railway planning is conducted at the same organization level as housing and city development planning, all reporting to a single umbrella entity.

European Union (EU)

The EU, together with its Member States, is working to improve energy efficiency in all sectors, while increasing the use of renewable energy. The EU is committed under the Kyoto Protocol to reduce total GHG emissions by 8% below 1990 levels between 2008 and 2012. In March 2007 EU leaders committed to a 20 to 30% reduction in overall GHG emissions by 2020. Figure 4.4 below summarizes EU and UK targets.

Figure 4.4 EU and UK GHG Reduction Targets

Legislation / Regulation	GHG Reduction Target
EU Climate Change Policy	
Kyoto Protocol	The European Union (EU) is committed to reduce total GHG emissions by 8% by 2008-12 below 1990 levels. In 2007 this was increased to 20-30% reduction by 2020.
EU Legislation	European Automobile Association committed to reducing CO ₂ emissions to 140g/km for all new cars sold in the EU, by 2008/9.
New EC Draft legislative proposal to be developed later this year.	Target of 130 g CO ₂ /km for all new cars sold in EU to be delivered by 2012 from fuel efficiency alone; and an additional 10 g CO ₂ /km coming from other measures e.g. more efficient air conditioning, low rolling resistance tyres etc.
UK General GHG Reduction Target	
UK Climate Change Bill (due to receive Royal Assent in Summer 2008).	Reduce CO ₂ by 60% of 1990 levels by 2050, and 26 – 32% by 2020 (currently under review).
UK Transport Sector (excluding aviation)	
Kyoto Target	Reduce GHG emissions by 12.5% by 2008 – 12 over 1990 levels.
UK Domestic Target	Reduce CO ₂ emissions by 20% by 2010 over 1990 levels.
Powering Future Vehicles Strategy (2002)	By 2012 10% of new cars in UK will be "low carbon" vehicles (i.e. tailpipe emissions <100g/km in CO ₂).
Road Tax	Vehicles taxed according to emissions output.
Renewable Transport Fuel Obligation (2005)	5% all fuel sold on UK forecourts to come from renewable source by 2010. Coming into force 2008 / 09.
UK Rail Sector	
The Rail Sector is due to set targets for reducing CO ₂ emissions per passenger-km and per tonne-km in 2009.	
Shipping	
No 'serious' environmental measures in place at European or international level.	

Source: PB Ltd.

In the EU, transportation CO₂ emissions grew by 32% between 1990 and 2005. Other sectors reduced their emissions by 9.5% on average over the same period. The share of transport in CO₂ emissions was 21% in 1990, but by 2005 this had grown to 27%. Emissions from 'light duty vehicles' (passenger cars and vans) are responsible for approximately half of this (T & E (2008) European Federation for Transport and Environment, April 2008).

<http://www.transportenvironment.org/News/2008/4/2020-car-targets>, accessed 20 May 2008).

As a result, two major EU-wide GHG mitigation strategies in the transportation sector are:

- Fuel economy standards (which, unlike other countries, are voluntary and are based on CO₂ emissions), and

- Emissions-based toll-charging

Since the Kyoto Protocol entered into force in February 2005, the UK Government has set plans to deliver its target to cut GHG emissions by 12.5%, and increased its domestic goal to cut CO₂ emissions by 20% below 1990 levels by 2010. The UK Government estimates that the proposals in the 2006 UK Climate Change Programme could reduce the UK's GHG emissions to approximately 23 to 25% below 1990 levels by 2010, and comfortably beyond the UK's Kyoto target. The Government has since introduced a Climate Change Bill, which puts into statute the UK's targets to reduce CO₂ emissions by at least 60% by 2050, and by 26 to 32% by 2020, relative to a 1990 baseline. The Bill was introduced into the House of Lords in November 2007, with the aim to receive Royal Assent by early summer 2008. An independent Committee on Climate Change is currently reviewing the target, with a view to tightening reduction targets to 80% by 2050. A decision is expected by December 1, 2008.

To address the predicted domestic shortfalls in oil, the UK government has begun a multi-pronged strategy, including a series of programs and regulations targeted at the transportation sector:

- One of the most internationally visible examples of VMT reduction strategies in Europe is **London's Congestion Charge**. Drivers entering central London between 0700 - 1800 hours Monday - Friday must pay an £8 entry fee. Failure to pay will result in a fine. The scheme has led to many benefits including a 21% decline in road transport, decline in key pollutants and an increase in cycling of 43% in the charging zone (TfL (2008) Congestion Charging, Transport for London. (<http://www.tfl.gov.uk/roadusers/congestioncharging> , accessed 29 May 2008))
- **Pay-as-You-Drive (PAYD) Insurance** programs, where a portion of auto insurance premiums are linked to miles driven (while the remaining portion is a "fixed cost" as under current practice). Active schemes may be found in the UK, Italy, and the Netherlands.
- **Transit-oriented Development:** In addition to the UK, Denmark and Sweden are often credited for having the most visible, successful transit-oriented development strategies, which focus pedestrian-friendly town and neighborhood development around light and heavy rail stations. The UK Planning System is also playing a greater part in creating a modal shift away from dependency on private vehicles. New developments are being given restricted car parking allowances, while larger developments are increasingly required to submit Travel Plans for commuting staff.
- Similar to the **fuel economy labeling programs** in Singapore and Japan, in the UK, new cars feature labels that highlight the fuel efficiency. In addition, labels also feature information on how much drivers can expect to pay in fuel bills in a typical year for a particular car, and whether the car qualifies for a reduction in Vehicle Excise Duty.

- **Fuel Duty and Promotion of cleaner, more fuel efficient vehicles** (e.g. tax on vehicle use to discourage motorists driving less fuel efficient vehicles, Transportation for London offers discounts for alternative fuel vehicles applicable to the congestion charge system).
- **New vehicle excise duties and company car taxes** introduced by the UK Department for Transport. Fees are graduated according to CO₂ emissions.
- The UK Energy Savings Trust, partially funded by the Department for Transport also offers **Free “green fleet reviews”** to provide organizations with tailored fleet management advice to help lower running costs, reduce environmental impact and enhance corporate social responsibility.
- The UK Department for Transport actively promotes **anti-idling** (e.g., the “Switch it Off” campaign), and other countries, such as Sweden and Germany may enforce anti-idling in commercial vehicles.
- The UK Energy Savings Trust has recently established **“Alternative Fueling Station” grants** to help organizations install refueling or recharging stations for alternative, cleaner fuels.
- On November 10, 2005 new measures were announced to make transportation fuels less carbon intensive by requiring 5% of all UK fuel sold on UK forecourts to come from a renewable source by 2010. The **‘Renewable Transport Fuel Obligation’** will be introduced in 2008-09. This measure aims to ensure a cost effective transition to a renewably fuelled transport system over the long term, saving around 1 million tones of carbon emissions a year by 2010, predicted to be equivalent to taking 1 million cars from U.K. roads.
- Many local authorities across the UK have also implemented the use of **‘car share lanes’** which give priority to vehicles carrying a minimum of two people during rush hour. The aim is to encourage higher occupancy of vehicles traveling to the same destination and thus reduce road traffic congestion. A number of activities to increase occupancy rates are being considered.

CHAPTER 5: ADAPTING SURFACE TRANSPORTATION SYSTEMS TO CLIMATE CHANGE

5.1 Climate changes are occurring, will intensify, and pose significant risks to transportation systems.

Climate change is already occurring – at a rate faster than climate models had predicted. Over the next 50 to 100 years the warming climate will cause unprecedented levels of weather and climate extremes, including direct threats to the U.S. transportation infrastructure. The impacts will vary by mode of transportation and geographic region, but they will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems.

The potential effects on transportation fall into three main categories:

- **Sea level effects:** Rising sea levels will cause flooding of transportation infrastructure in coastal regions, which may be permanent, frequent, or intermittent. Flooding will be exacerbated in coastal regions that experience land subsidence, as in parts of the Gulf Coast. Some transportation facilities may need to be relocated or retrofitted. More frequent emergency evacuations may be needed, along with alternative transportation routings for periods when some routes are out of service.
- **Storm effects:** More intense storms, storm surges, and precipitation will cause temporary interruptions to transportation systems and operations and will have significant potential to damage bridges, pavements, traffic signs and signals, railroads, and transit systems. Bridges and other structures will be particularly vulnerable to high winds, storm surges, and scour.
- **Temperature effects:** Higher temperatures will cause greater wear on pavement and rail systems and influence design and material decisions. Pavements and rails will be more prone to buckling. During extreme high temperatures, maintenance and construction activities may have to be suspended or limited to protect transport workers.

Local populations and service will suffer direct effects of flooding, storms, and higher temperatures, and these effects are likely to be worsened by limitations on their access to transportation.

5.2 Transportation agencies need to consider adjustments to planning, design, operation, and maintenance of transportation systems.

The most important first step in adapting to global climate change threats is accurately assessing the vulnerability of existing transportation infrastructure. State DOTs, in collaboration with local governments, MPOs, transit operators, and owners and operators of ports, airports, railroads, and pipelines can conduct inventories and risk assessments for their transportation facilities and systems. Based on risk assessments, state DOTs can lead collaborative efforts to reduce risks, including:

- retrofitting vulnerable facilities;
- developing contingency plans in case of the interruption of transportation services;
- ensuring emergency evacuation plans are in place and take climate risks into account;
- identifying/protecting open space and wetlands to act as a buffer during severe precipitation;
- ensuring future transportation facilities are designed and sited to minimize climate risks; and, of course,
- maximizing efforts to reduce GHG emissions that contribute to climate change.

Ongoing monitoring and adaptation are key elements in reducing risks. The information acquired by monitoring can be incorporated into both short-term and long-term investment and design decisions. The use of sensors and other “smart” technologies such as those used in the California Seismic Retrofit Program, which analyzes the vulnerability of highway bridges to earthquakes, would enable infrastructure providers to receive advance warning that the monitored infrastructures are being subjected to stresses beyond those they were designed to withstand. They would also provide valuable information for infrastructure adaptation decision-making.

Historical regional climate patterns commonly used by transportation planners to guide their operations and investments may no longer be reliable enough to guide future plans and designs. This uncertainty indicates that state DOTs will need to incorporate climate risks into future investment priorities.

As the climate changes, many U.S. locations will experience new climate-induced weather patterns that will affect their transportation infrastructure. As this happens, the effective communication of lessons-learned and best practices among transportation professionals will be crucial to adapting U.S. transportation infrastructure to climate changes that are already taking shape.

One of the most effective strategies for reducing the risks of climate change is to avoid placing people and infrastructure in vulnerable locations. NEPA documents and state transportation plans are key junctures for considering the appropriate location of new

transportation facilities. It is now advisable, and may soon be required, that NEPA documents consider the impacts of climate change on future transportation projects.

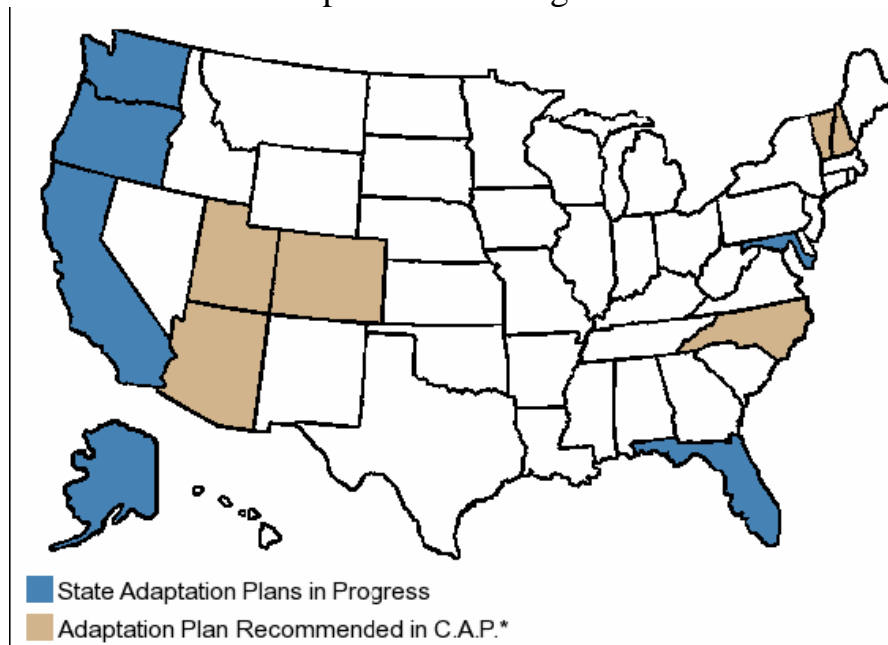
Information and best practices are now relatively limited for managing climate change risks to transportation infrastructure – both existing infrastructure and new infrastructure. This is already starting to change, as TRB, FHWA, highway agencies in other countries, and some U.S. states are tackling this issue. In 2008, two important reports on adaptation were issued:

- the TRB report “Potential Impacts of Climate Change on U.S. Transportation” and
- the FHWA report “[Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study.](#)”

Also, in 2007 the United Kingdom Highways Agency contracted for development of a risk management framework for adapting transportation facilities to climate impacts and is currently considering implementation of the framework that was developed.

Twelve states have included adaptation within the scope of their climate action plans or are in the early stages of developing a state adaptation plan, including Maryland, Alaska, California, Washington, and Florida. The states' climate action plans generally recommend that state adaptation plans be created for critical impact areas. A few other states have recognized the need for separate and comprehensive adaptation efforts to parallel their mitigation activities. In these instances, adaptation is addressed through a separate technical working group and deals with cross-cutting issues such as existing and future built environment and infrastructure, resource and resource-based industries, human health, safety and welfare.

Figure 5.1 State Climate Adaptation Planning



5.3 The costs of climate adaptation for transportation are unknown at this time, but will be significant and will need to be factored into future transportation budgets, plans, and programs.

While no one has attempted to estimate the future cost of adapting existing and new surface transportation infrastructure in the United States, the costs will clearly be extremely large. If transportation budgets are not increased to absorb these costs, state and local transportation agencies will be forced to make hard choices between taking protective measures or curtailing transportation operations, maintenance, and capital investment.

One indicator of the potential cost for adapting U.S. infrastructure to climate impacts is this estimate from the 2007 Stern Review, which encompasses transportation as well as buildings and other infrastructure:

“The additional costs of making new infrastructure and buildings resilient to climate change in OECD countries could be \$15-150 billion each year (0.05 – 0.5% of GDP).”
[2]

REFERENCES

1. Intergovernmental Panel on Climate Change (IPCC), 2007, *Summary for Policymakers of the Synthesis Report of the IPCC Fourth Assessment Report*. In *Climate Change 2007*, Cambridge University Press. New York.
2. Stern, Sir Nicholas, *The Economics of Climate Change: The Stern Review*. 2007, Cambridge, UK: Cambridge University Press. 692.
3. Summarized by the Pew Center on Climate Change, at <http://www.pewclimate.org/international>
4. Hansen, J., et al., *Target Atmospheric CO₂: Where Should Humanity Aim?* Atmospheric and Oceanic Physics, 2008.
5. U.S. Environmental Protection Agency Office of Transportation and Air Quality, *Greenhouse Gas Emissions from the U.S. Transportation Sector 1990-2003*, March 2006.
6. Hooss, G., et al., *A Nonlinear Impulse Response Model of the Coupled Carbon Cycle Climate System (NICCS)*. *Climate Dynamics*, 2001. 18: p. 189-202.
7. Pew Center on Climate Change.
8. Energy Information Administration, United States Energy Profile, as accessed at <http://www.eia.doe.gov/pub/international/iealf/tableh1cco2.xls> on May 20, 2008.
9. European Conference of Ministers of Transport, *Transport and Environment: Review of CO₂ Abatement Policies for the Transport Sector*, 2006.
10. McKinsey and Company, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*
11. Nic Lutsey, "Prioritizing Climate Change Mitigation Alternatives: Comparing Transportation Technologies to Options in Other Sectors," Ph.D dissertation at University of California, Davis.
12. "The King Review of Low Carbon Cars," for the U.K. Government, by Professor Julia King, Vice-Chancellor of Aston University, March 2008.
13. Greene, D.L., et al., *Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy*. *Energy Policy*, 2005. 33(6): p. 757-775.
14. *Honda Civic Now America's Best-Selling Vehicle*, in *U.S. News and World Report*. 2008: <http://usnews.rankingsandreviews.com/cars-trucks/daily-news/080604-Honda-Civic-Now-America-s-Best-Selling-Vehicle/>.
15. Merx, K., *GM Slashes 2008 Truck Production*, in *Detroit Free Press*. 2008: Detroit, MI.
16. Boies, A., et al., *A Smaller Carbon Footprint: Research suggests combining strategies to meet legislative goals in the transportation sector*, C.f.T. Studies, Editor. 2008, University of Minnesota: Minneapolis, MN.
17. Schipper, Lee 2008 *Fuel Economy Trends in Industrialized Countries; When the Rubber Hits the Road* Special presentation for the World Resources Institute, http://embarq.wri.org/documentupload/fuel%20economy_wri.pdf
Accessed August 6, 2008.

18. German, John 2008. *Weight Reduction and Safety Implications* Presentation to Passenger Vehicle GHG Symposium,
http://www.arb.ca.gov/cc/ccms/meetings/042108/4_21_current_tech_n_4_german.pdf
Accessed August 5, 2008.
19. Samaras, C. and K. Meisterling, *Life Cycle Assessment of Greenhouse Gas Emissions from Plug-in Hybrid Vehicles: Implications for Policy*. Environ. Sci. Technol., 2008.
20. Farrell, A. and D. Sperling, *A Low-Carbon Fuel Standard for California-Part 1 Technical Analysis*. 2007, University of California: Berkeley California.
21. National Renewable Energy Laboratory, *Research Advances: Cellulosic Ethanol*, DOE, Editor. 2007, U.S. Department of Energy Office: Golden, CO.
22. Fargione, 2008 and Searchinger, 2008.
23. Lynd, L. *Biomass Energy Systems of the Future*. 2005 [Available from:
<http://www.bioeconomyconference.org/06Sessions/lynd.html>
24. NREL. *Alternative Fuels and Advanced Vehicle Data Center: Biodiesel Production*. 2008 Available from:
http://www.eere.energy.gov/afdc/fuels/biodiesel_production.html.
25. Anderson, J., et al. *Minnesota Climate Change Advisory Group Final Report*. 2008 Available from: <http://www.mnclimatechange.us/MCCAG.cfm>.
26. Washington state legislature bill summary, at
<http://apps.leg.wa.gov/billinfo/summary.aspx?bill=2815&year=2008>
27. California High-Speed Rail Authority:
http://www.cahighspeedrail.ca.gov/images/chsr/20080529170548_Sec_3.5_Energy.pdf.
28. Kitsap Transit, Worker/Driver Program,
<http://www.kitsaptransit.org/WorkerDriverBusProgram.html>.
29. Personal Communication, Phil Duryea, Kitsap Transit, August 11, 2008.
30. Reid Ewing, et al., "Growing Cooler," Urban Land Institute, 2007.
31. Small and Van Dender, "Long-term Trends in Transport Demand, Fuel Price Elasticities, and Implications of the Oil Outlook for Transport Policy," OECD Joint Transport Research Centre Discussion Paper, December, 2007.
32. Hughes, Knittel, and Sperling, Evidence of a Shift in the Short-Run Elasticity of Gasoline Demand, NBER, September 2006.
33. http://www.stockholmsforsoket.se/upload/Sammanfattningar/English/Final%20Report_The%20Stockholm%20Trial.pdf.
34. Litman, Todd, Transportation Elasticities - How Prices and Other Factors Affect Travel Behavior, April, 2007.
35. Portland State University, "Policy Options to Attract Auto Users to Public Transportation." Volume II: Technical Report, December 1995.

36. Erin Vaca and J. Richard Kuzmyak, Parking Pricing and Fees, Chapter 13, TCRP Report 95, Transit Cooperative Research Program, 2005.
37. Erin Vaca and J. Richard Kuzmyak, Parking Pricing and Fees, Chapter 13, TCRP Report 95, Transit Cooperative Research Program, 2005.
38. Garcia, Nicholas, Washington State Energy Office, Greenhouse Gas Mitigation Options For Washington State, Prepared for: Environmental Protection Agency, April, 1996.
39. Deakin, Elizabeth, and Harvey, Greig, Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy, and Equity Impacts, University of California Transportation Center, Revised 1996.
40. Recommended for consideration by the National Surface Transportation Revenue Policy and Revenue Study Commission, "Transportation for Tomorrow," December 2007.
41. Minnesota Department of Transportation, *Potential Public Policy Implications of Pay-as-You-Drive (PAYD) Leasing and Insurance Products Mileage-Based User Fee Demonstration Project*, March, 2006.
42. Washington Department of Transportation: <http://www.wsdot.wa.gov/NR/rdonlyres/D108DA4F-7BC0-4F4F-A524-ECE2B2121612/0/ExecSummary.pdf>.
43. Washington Department of Transportation: <http://www.wsdot.wa.gov/TDM/GTEC/>.
44. Maine DOT, Rule for the Maine Sensible Transportation Policy Act (Provisionally Adopted) <http://www.maine.gov/mdot-stage/planning-documents/stpa/>
45. Oregon DOT: <http://www.oregon.gov/LCD/TGM/docs/biennialreport0507.pdf>.
46. International Energy Agency/OECD, Saving Oil in a Hurry, 2005.
47. Nancy McGuckin, Johanna Zmud, Yukiko Nakamoto, Trip Chaining Trends in the U.S., Understanding Travel Behavior for Policy Making, Presentation for the Transportation Research Board, 2005.
48. http://www.oregon.gov/ODOT/PT/PROGRAMS/TRANS_OPTIONS/about_dlsn.shtml.
49. U.S. DOT Deputy Secretary Barrett testimony to U.S. House of Representatives Subcommittee on Innovation and Technology, June 24, 2008.
50. Matthew Barth and Konok Boriboonsomsim, "Real-World CO2 Impacts of Traffic Congestion" University of California at Riverside, Nov. 2007.
51. National Academy of Sciences, Transportation Research Board. 55: A Decade of Experience. (Special report 204.) Washington, D.C. 1984.
52. Auto Alliance, "The EcoDriver's Manual: A Guide to Increasing your Mileage and Reducing Your Carbon Footprint," at www.fs.fed.us/sustainableoperations/documents/TheEcoDriversManual.pdf.
53. Office of Integrated Analysis and Forecasting, EIA, "Annual Energy Outlook 2007, with Projections to 2030." 2007, Department of Energy.
54. Virginia DOT, http://www.virginiadot.org/news/statewide/2007/vdot_receives_2007_green.asp.

55. Virginia DOT, <http://www.virginiadot.org/travel/resources/NKSRAWB-LEEDbrochure.pdf>.
56. AASHTO, A New Vision for the 21st Century, July 2007.
57. Matthew A. Kromer and John B. Heywood, Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet, May, 2007.
58. National Academy of Sciences, The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs, National Academies Press, Washington, DC, 2004.
59. Unnasch 2001, EPA Fuel Economy Guide, EPRI 2001, EPRI 2003, Unnasch 2005, Brinkman 2005 as referenced in February 2007 report "Full Fuel Cycle Assessment Tank to Wheels Emissions and Energy Consumption," prepared for the California Energy Commission by TIAX LLC.
60. Small, Kenneth, and Van Dender, Kurt, *U.S. Transportation Center Access #31*, "If Cars Were More Efficient, Would We Use Less Fuel?", Fall, 2007.
61. EIA, Annual Energy Outlook 2008, Table 35 - Transportation Sector Energy Use by Mode and Type, March 2008.

APPENDIX A: Conversion Factors

	Btu per Gallon (or per kWh for electricity)	Metric Tons CO ₂ e per Btu
Gasoline	125000	0.00000007469
Diesel fuel	138700	0.00000007706
LPG	91300	0.00000006639
Jet fuel	135000	0.00000007461
Residual Fuel Oil	149700	0.00000008303
Natural Gas	129400	0.00000005311
Electricity*	10339	0.00000005910

*National average; CO₂e per btu for electricity varies greatly by region.

Sources: Transportation Energy Data Book Edition 26, Table A.3;

<http://www.eia.doe.gov/oiaf/1605/coefficients.html>;

<http://www.epa.gov/appdstar/pdf/brochure.pdf>;

<http://www.epa.gov/otaq/climate/420f05004.htm#step4>

1 Metric Ton (tonne) = 2204.62262 pounds

1 gallon of gasoline = 50 lbs CO₂

Electric power generation: U.S. nationwide average btu per kilowatt hour 10339 (From Transportation Energy Data Book, Includes Assumption that Power Generation at 3412 btu/kilowatt hour is about 33% Efficient)

Power generation GWP factors assumed for non CO₂ GHG emissions: 21 for CH₄; 310 for N₂O

U.S. Average GWP lbs./kWh (pounds CO₂e emissions/kWh): 1.3462

Washington State Average GWP lbs/kWh (pounds CO₂e emissions/kWh): 0.25001

APPENDIX B: List of Acronyms

21CTP	21 st Century Truck Program
AASHTO	American Association of State Highway and Transportation Officials
AEO	Annual Energy Outlook
ANPR	Advanced Notice of Proposed Rulemaking
APEC	Asia-Pacific Economic Cooperation
APTA	American Public Transportation Association
ASCEN	Asian Environmental Compliance and Enforcement Network
ASTAE	Asia Alternative Energy Program
ATV	Advanced Technology Vehicle Program
AWS	Alternative Work Schedule
B100	Biodiesel
BAU	Business As Usual
BEES	Board on Energy and Environmental Systems
BEV	Battery-Electric Vehicle
BRIC	Brazil, Russia, India, and China
BTU	British Thermal Unit
CAFÉ	Corporate Average Fuel Economy
CAI-Asia	Clean Air Initiative for Asian Cities
Caltrans	California Department of Transportation
CAP	Climate Action Plan
CBO	Congressional Budget Office
CCAP	Center for Clean Air Policy
CCS	Carbon Capture and Storage/Sequestration
CCS	Center for Climate Strategies
CFC	Chlorofluorocarbons
CfIT	Commission for Integrated Transport
CH ₄	Methane
CIER	Center for Integrative Environmental Research
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
CO _{2e}	Carbon Dioxide Equivalent
COFC	Container on Flat Car
CTR	Commute Trip Reduction
DEPS	Division on Engineering and Physical Sciences
DME	Dimethyl Ether
DOT	Department of Transportation
E85	Ethanol (85% ethanol by volume)
ECMT	European Conference of Ministers of Transport
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
EU	European Union

EV	Electric Vehicle
FCV	Fuel-Cell Vehicle
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ/ha	Gigajoule Per Hectare
GPR	General Reporting Protocol
GTEC	Growth and Transportation Efficiency Centers
GWP	Global Warming Potential
HDV	Heavy-Duty Vehicle
HEV	Hybrid-Electric Vehicle
HFC	Hydrofluorocarbons
HFCV	Hydrogen Fuel Cell Vehicle
HOV	High Occupancy Vehicle
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITS	Intelligent Transportation Systems
KM	Kilometer
kWhr	Kilowatts Per Hour
LCFS	Low Carbon Fuel Standard
LDV	Light-Duty Vehicle
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LPG	Liquefied Petroleum Gas
LTA	Land Transportation Authority
MLIT	Ministry of Land, Infrastructure and Transport
MMT	Million Metric Tons
MMtCO ₂ e	Million Metric Tons of Carbon Dioxide Equivalent
MPG	Miles Per Gallon
MPGGE	Miles Per Gallon Gasoline Equivalent
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
MRGHGRA	Midwestern Regional Greenhouse Gas Reduction Accord
N ₂ O	Nitrous Oxide
NCHRP	National Cooperative Highway Research Program
NEG-ECP	New England Governors and Eastern Canadian Premiers
NEPA	National Environmental Policy Act
NGCC	Natural Gas Combined Cycle
NHTSA	National Highway Traffic Safety Administration
NO _x	Nitrogen Oxide
NPC	National Petroleum Council
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PAYD	Pay-As-You-Drive Insurance

PB	Parsons Brinckerhoff
PHEV	Plug-in Hybrid Vehicle
PMT	Passenger Miles Traveled
PPM	Parts Per Million
PM	Particulate Matter
R&D	Research and Development
RFF	Resources For the Future
RFS	Renewable Fuel Standard
RGGI	Regional Greenhouse Gas Initiative
ROW	Right of Way
SAIC	Science Applications International Corporation
SB	Senate Bill
SBA	Small Business Administration
SFOBB	San Francisco Oakland Bay Bridge
SOV	Single Occupancy Vehicle
SPO	State Planning Office
STPA	Sensible Transportation Policy Act
tCO _{2e}	Tons of Carbon Dioxide Equivalent
TCRP	Transit Cooperative Research Program
TGM	Transportation and Growth Management Program
TOD	Transit-Oriented Development
TOFC	Trailer on Flat Car
TRB	Transportation Research Board
UK	United Kingdom
ULI	Urban Land Institute
UMN	University of Minnesota
U.S. DOE	United States Department of Energy
U.S. EPA	United States Environmental Protection Agency
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
WCI	Western Climate Initiative
WSDOT	Washington State Department of Transportation

APPENDIX C: Strategies to Reduce GHG from Surface Freight Transportation

A 2007 report for U.S. DOT identified 33 “best practices” for reducing GHG from the trucking sector. The authors estimated that these 33 practices could reduce trucking GHG in 2025 by 12% below 2003 (compared to an increase of 67% in truck GHG if the best practices are not implemented) (1).

EPA estimates that through improvements in truck and engine technologies, there is a potential for GHG emissions reductions of up to 40% from a typical heavy-duty truck in the 2015 timeframe, with greater reductions possible looking beyond 2015 (2).

Approaches for increasing efficiency of heavy-duty commercial trucks available now include reduced idling, improved aerodynamics for both trailer and tractor, lower rolling resistance tires, properly inflated tires ensured through automatic inflation systems, low-friction lubricants, reduced vehicle weight, reduced speed, and driver training (3). There are no mandatory fuel efficiency standards for HDVs, although other nations, such as Japan, are considering HDV standards and the 2007 EISA mandates a study and rulemaking by U.S. DOT to establish fuel economy requirements for HDVs.

In addition, pricing strategies may be helpful in the freight sector, as in Germany’s use of a 50% increase in autobahn fees for older, less efficient trucks. The effectiveness of pricing is also reflected in trucking companies’ response to higher fuel prices in the U.S., which are spurring trucking companies to lower speeds and find other ways to economize on fuel use. Higher prices would also stimulate shifts of freight to rail, barges, and ships

Engine idling is a large contributor to HDV emissions. According to U.S. EPA’s ANPR on July 11, 2008, a typical truck, on average, will emit 18 pounds of CO₂ per hour of idling. Reduction of emissions and idling may be achieved by providing electric plug-ins at truck stops to allow truck heating and air conditioning to be operated without running the diesel engine, use of auxiliary power units for heating or air conditioning during idling, automatic engine start-stop systems, anti-idling laws, or driver education. EPA offers a voluntary low-interest loan program, SmartWay, for trucking companies interested in improving fuel efficiency.

For high volume shipments, GHG reductions can be achieved by switching from trucks to barges, ships, and railroads. Doublestack trains can be especially efficient, but tunnel clearances may need to be increased or other infrastructure changes may be needed to accommodate doublestack trains.

Table B-1 describes a wide variety of strategies to reduce surface transportation freight GHG, based on strategies identified in state climate action plans.

Table B-1

Strategies to Reduce GHG from Surface Freight Transportation, Drawn from State Climate Action Plans	
Strategy	Description
Vehicle Technology Improvements	
Hybrid Power Train Technology	<p>Hybrid vehicles have two propulsion power sources, making it possible to capture energy otherwise lost during braking and provide boost to the main engine. One truck manufacturer (Eaton Corp) is building medium-duty diesel-electric hybrid trucks which the company says will achieve a 60% reduction in fuel consumption, plus an 87% reduction in engine idling by electrifying key systems such as heating, cooling, and hydraulics. Also, Pacific Gas & Electric Co. is now using hybrids for certain services (emergency response and "bucket trucks" that are used in electrical system repair and maintenance), with fuel savings of 40-60% and emission reductions of 50-90% (the latter is largely because PG&E can operate the trucks on electricity while repairs are performed) (4).</p> <p>Hybrid vehicles can provide roughly \$2,000 in annual fuel savings when used in stop and go freight applications like parcel delivery service (5). However, hybrid trucks are more expensive initially, as much as 50% more expensive than conventional trucks, so accelerating the use of hybrid trucks may require grants or tax credits, unless/until fuel costs increase further and improve the payback for purchase and use of hybrid trucks. A bill is expected to be introduced in Congress to provide grants for truck manufacturers to build, test, and sell plug-in hybrid utility and delivery trucks (6).</p>
Low-Viscosity Lubricants	<p>Low-viscosity synthetic and semi-synthetic lubricants reduce friction losses in a truck's drive train, transmission, and its engine, saving fuel and reducing emissions. Synthetic transmission and axle lubricants can improve fuel economy by at least 0.5% in the summer and 2% in the winter. Replacing all conventional transmission lubricants with low-viscosity products saves fuel with little or no additional cost. The combined effect of low-viscosity synthetic engine oils and drive train lubricants can improve fuel economy by about 3%, saving nearly 500 gallons of fuel and eliminating five metric tons of greenhouse gas emissions per year for a typical freight truck (7).</p>
Single Wide-Base Tires	<p>Single wide-base tires (as opposed to double wide-base tires) on new production trucks can reduce rolling resistance, improve fuel economy, and offer substantial fuel cost savings. Wide-base tires can improve fuel economy by 2% or more compared to equivalent dual tires. By using wide-base tires, a typical long-haul truck could save over 400 gallons of</p>

	fuel per year, resulting in cost savings of over \$600, and reduce greenhouse gas emissions by four or more metric tons annually. A single wide-base tire costs about the same as two equivalent dual tires and a single wide-rim wheel costs less than two standard wheels. If wide-base tires and wheels are installed on a new truck, the initial cost savings can reach \$1,000 (8).
Automatic Tire Inflation Systems	Automatic tire inflation systems monitor and continually adjust the level of pressurized air to tires, maintaining proper tire pressure even when the truck is moving. Automatic tire inflation systems can extend tire life by 8%. Installing an automatic tire inflation system on the truck drive and trailer axles can save over \$200 per year in tire replacement costs and tire pressure inspection time. Automatic tire inflation systems can reduce fuel consumption by over 100 gallons per year for a typical combination truck, resulting in annual cost savings of about \$170 and the elimination of over one metric ton of greenhouse gas emissions (9).
Black Carbon Control Technologies	Diesel particulate matter includes black carbon aerosols, which are thought to contribute to global warming through positive radiative forcing. Diesel particulate emissions can be reduced through the use of several types of exhaust retrofit devices and particulate traps. Some examples include use of particulate traps, filters and other complementary technologies (10).
Adoption of New Clean Technologies—Rail and Marine Engines	There are new proposed EPA criteria air pollutant emission standards for locomotive engines and commercial marine vessel diesel engines that would reduce soot and nitrogen oxide emissions by more than 90%. Although these are classified as criteria air pollutants, they also contribute to global warming. Steps or incentives might be taken to introduce these technologies to the marketplace earlier than the Federal requirements (11).
Freight System Management and Operational Efficiency	
Anti-Idling	Vehicle idling can be reduced by enforcing anti-idling ordinances and/or encouraging the use of alternatives to idling. Many states and local governments have adopted idling regulations for trucks and buses. For a typical long-haul combination truck that eliminates unnecessary idling, 1900 gallons of fuel a year could be saved, which is equivalent to saving nearly \$3,000 in fuel costs, and removing 19 metric tons of carbon dioxide annually. Alternatives to long-term truck idling include the use of technologies such as automatic engine shut-down/start-up system controls, direct-fired heaters, auxiliary power units, and truck stop electrification (12).
Truck Stop Electrification	Truck emissions can be reduced by providing electrification at truck stops to reduce idling. These electrical hook-ups can provide power for

	<p>heating, cooling, and other needs while trucks are stopped. This could be particularly beneficial at overnight rest stop locations (13). In fact, according to the Climate Trust and Argonne National Laboratory, truck stop electrification can save nearly 90,000 metric tons of CO2 each year or 10,397 grams/hour (14). Co-benefits as noted by the U.S. EPA include NOx, VOC and PM 2.5/10 with savings of 135 grams/hour, 6.84 grams/hour, and 3.68 grams/hour, respectively.</p>
<p>Freight Logistics Improvements</p>	<p>Improved freight logistics can optimize trucking operation efficiency, saving fuel and increasing profits for trucking companies. Logistics strategies include load matching, more efficient routing and scheduling of vehicles, and improved receiving policies. Better load matching, which ensures full trucks, improves the efficiency of trucking operations, allowing carriers to carry the same amount of freight with fewer vehicle miles of travel. Not only does this help profitability, but it reduces fuel use and emissions. Trucking companies can make use of routing and scheduling software to structure more efficient truck routes. Changes to loading dock and receiving policies, such as allowing for early truck arrivals, allows trucking companies more productively utilize their vehicle fleets, thereby saving fuel and increasing profitability. For a long-haul carrier that operates 15% of miles without a load, reducing empty mileage by just 1% can save over 100 gallons of fuel and eliminate over 1 metric ton of greenhouse gas emissions per truck each year (15).</p>
<p>Intermodal Freight Initiatives / Shifting from Truck to Rail</p>	<p>Intermodal ground freight transportation makes it possible to combine the best characteristics of trucked and railed freight, especially for shipments over 500 miles. Innovative intermodal options like trailer on flat car (TOFC) and container on flat car (COFC) can improve efficiency and save money. For shipments over 1,000 miles, using intermodal transport can cut fuel use and greenhouse gas emissions by about 65%, compared to a truck-only move (16). The most efficient way to move containers long distances over land is to “double stack” them on top of another onto a railroad well car. Multiple double stack railroad well cars may be permanently coupled together to decrease stress and cargo damage during train braking and acceleration. In these instances, it is particularly important to raise tunnel clearances, especially in the Northeast. Additionally, by encouraging more use of rail freight, emissions and fuel consumption can be reduced, while also reducing congestion on major roadways. Shifting freight from trucks to rail also decreases impacts on highway infrastructure, and may reduce truck-related idling and greenhouse gas emissions and particulate matter.</p> <p>Trains can move freight at a rate of 423 ton-miles per gallon (CSX: http://www.csx.com/?fuseaction=about.environment_sustainability), compared with trucks at a rate of 59 ton-miles per gallon (Grier, 2002). All other parameters being equal, the GHG gas reduction for each ton-</p>

	<p>mile of freight shifted from trucks to trains is almost a factor of 4. -- Grier, D. V. 2002. Comparison of inland waterways and surface freight modes. <i>TR News</i>. Transportation Research Board, No. 221, July-August 2002. (http://onlinepubs.trb.org/onlinepubs/trnews/trnews221.pdf)</p>
Feeder Barge Container Service	<p>Marine container shipping is often assumed to be too slow for domestic freight, but Europe has seen high growth rates in water-borne (especially river) container freight over relatively short distances. This option would support policies and infrastructure investment to shift more freight back to marine shipments (17).</p>
Freight Villages / Consolidation Centers	<p>Economic incentives and siting assistance can be provided for the development of freight consolidation centers. These centers can reduce the number of truck trips taken by combining the loads of multiple underutilized trucks. When paired with intermodal railyards they can also help make rail freight transportation, which produces fewer GHGs than trucking, more attractive (18). Many examples can be found in Europe and along the Northeastern region of the U.S. (19).</p>
Clean Freight Operating Improvements	<p>States or agencies could require or enforce the covering of rail cars. Uncovered coal trains result in fugitive coal dust emissions during transportation. States could also consider ways to improve truck operations to reduce associated particulate (black carbon) emissions, which is also a significant contributor to global warming. For example, ports could maximize the implementation of “paperless gates,” such as through the use of a web-based booking system to prevent gate congestion and idling (20).</p>
Enforce Speed Limits	<p>Truck fuel economy drops significantly as speeds rise above 55 mph. By limiting top highway speeds, trucks can save fuel, reduce emissions, and prolong engine life. Reducing the number of trucks traveling over the speed limit can improve the fuel economy of these trucks, which reduces GHG emissions and can also improve safety (21). Speed cameras, both for intercity highways and urban roads have proven to be an effective and cost-effective means for enforcing speed limits. In addition, it may be possible to lower the speed limit on interstates, freeways, and major arterials to improve the fuel efficiency of vehicles. However, reducing speed limits on facilities designed to support higher speeds may require significant enforcement (22).</p>
Improve Traffic Flow	<p>Improving vehicle flow on the roadway system can reduce fuel use and GHG emissions for all vehicles, including trucks. Coordinated operation of the regional transportation network, such as through the use of freeway ramp metering, can improve system efficiency, reliability, and safety (23).</p>
Pre-Clearance at	<p>Truck queuing and idling time can be reduced through pre-clearance at</p>

Scale Houses	highway truck weigh stations and expanded use of weigh-in-motion systems (24).
Maintenance and Driver Training	Driving practices can have a large impact on truck fuel economy. Even highly experienced drivers can enhance fuel economy using simple techniques like cruise control, coasting whenever possible, limiting use of cab accessories, smooth and gradual acceleration, progressive shifting (up shifting at the lowest rpm possible), reducing maximum freeway speeds, and limiting truck idling and stops. Driver training can reduce fuel consumption by 5% or more, saving more than \$1,200 in fuel costs and eliminating about eight metric tons of greenhouse gas emissions per truck each year. For a typical long-haul truck, the annual fuel cost savings could recover the initial cost of driver training within two years (25).
EPA SmartWay Program (26)	<p><u>EPA Smartway Carriers:</u></p> <p>Agencies with railroad and trucking vehicle fleets could sign on as SmartWay carrier partners. They would measure their environmental performance with the fleet model and develop a plan to improve that performance. The partnership provides information and suggested strategies to improve fuel economy and environmental performance of vehicle fleets.</p> <p><u>EPA SmartWay Shippers:</u></p> <p>Agencies that buy transportation services or ship goods could sign on as SmartWay shippers. As shipper partners, state agencies would seek to select SmartWay partners when they purchased the services of carriers. One way that the state could help would be to add SmartWay certification to the list of factors that they may consider when selecting carriers. Alternatively, they could encourage the carriers that they do business with to join the partnership. Shippers can also implement direct strategies, for instance, developing no idle policies for their loading areas.</p> <p><u>SmartWay Affiliates:</u></p> <p>State and local agencies could sign on to SmartWay as affiliates. As affiliates, they would help to distribute information on the program to interested parties. This could be as easy as putting a link on their Web site, or it could involve a more active role.</p>

<p>EPA SmartWay Upgrade Kits (27)</p>	<p>A variety of fuel- and emissions-saving technologies (See above vehicle technology section for examples), typically consisting of engine idle reduction technology, Low Rolling Resistance tires, improved aerodynamics, and exhaust after-treatment devices. In tests, these kits can reduce fuel consumption by 10% to 15%, saving more than \$8,000 in fuel costs annually. They also reduce pollution: carbon dioxide and nitrogen oxide emissions are cut 10% to 15%, and when a kit includes an exhaust after-treatment device, PM emissions are reduced by 25% to 90%.</p>
<p>Fiscal Measures (Incentives, Disincentives, Funding)</p>	
<p>Increased Emission-Based Truck Tolls or Highway User Fees</p>	<p>Emission-based truck tolls and/or highway user fees can help reduce congestion and thereby reduce GHG emissions. In addition, roadway tolling can be used to provide revenue for construction or operation of more energy efficient modes of transportation (e.g., rail improvements). In Germany, GHG emissions of trucks on the autobahns have been cut by 7% as a result of a new system of pricing truck use of the autobahns, implemented in January 2005. This includes a 50% premium charge for older, more polluting trucks, which has doubled the rate of replacement of older trucks with newer trucks (28).</p>
<p>Incentives To Retire or Improve Older, Less Efficient Vehicles</p>	<p>GHG emissions can be reduced from heavy-duty diesel vehicles by developing and implementing an incentives program to accelerate the replacement and/or retirement of the highest-emitting diesel vehicles. Starting with the 2007 model year, stringent new federal emission standards for new heavy-duty diesel vehicles take effect. In addition, the fuel efficiency of vehicles declines over time due to wear and tear. Incentives can be offered to the owners of older vehicles to retire their vehicles early and replace them with vehicles meeting the 2007 emission standards (29).</p>
<p>EPA SmartWay Loan Initiative</p>	<p>Incentives to reduce emissions in the trucking industry are also available through the EPA SmartWay Loan Initiative. The U.S. EPA is partnering with the Small Business Administration (SBA) to make loans available to purchase SmartWay Upgrade Kits. This loan initiative uses SBA Express Loans and partners with Bank of America, Business Loan Express, Superior Financial Group, and other SBA lenders to help small trucking companies finance the purchase of SmartWay Upgrade Kits. Participating lenders will provide quick approval and affordable monthly payments. Small trucking firms can borrow from \$5,000 to \$25,000 with no collateral, an easy online or telephone application, and flexible loan terms.</p>

Although Table B-1 focuses on freight strategies from state climate change action plans, the *Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation*, authored by the Center for Transportation and Environment at North Carolina State University, identifies other promising freight measures such as truck driver training programs, use of B20 biodiesel fuel, air conditioning system improvements, and others.

Additionally, the U.S. DOE's 21st Century Truck Program (21CTP) provides support for research and development of commercially viable technologies that will dramatically cut the fuel use and emissions of commercial trucks and buses while enhancing their safety, affordability and performance. Under this program's roadmap, a goal was established to improve truck fuel economy by 60%, compared to today's conventional, non-hybridized heavy-duty vehicles.

References for Appendix C

- (1) Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation, Center for Transportation and Environment at North Carolina State University, October 2007.
- (2) EPA Advance Notice of Proposed Rulemaking (ANPR), July 11, 2008
- (3) Ang-Olson, J. and W. Schroeer (2002) Energy efficiency strategies for freight trucking: potential impact on fuel use and greenhouse gas emissions. Transportation Research Record Volume, 11-18
- (4) Transportation/Environment Alert, published by Bureau of National Affairs, Vol 10, Issue 40, June 13, 2008.
- (5) U.S. Environmental Protection Agency SmartWay Transport Partnership, "Freight Carrier Innovative Strategies," http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information visit: <http://www.epa.gov/smartway/documents/hybrid%20powertrain.pdf>.
- (6) Transportation/Environment Alert, published by Bureau of National Affairs, Vol 10, Issue 40, June 13, 2008.
- (7) U.S. Environmental Protection Agency SmartWay Transport Partnership, "Freight Carrier Innovative Strategies," http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information visit: <http://www.epa.gov/smartway/documents/lowviscositylubes.pdf>.
- (8) Ibid. For more information visit: <http://www.epa.gov/smartway/documents/supersingles.pdf>.
- (9) Ibid. For more information visit: <http://www.epa.gov/smartway/documents/tireinflate.pdf>.
- (10) Center for Climate Strategies, "Brief Descriptions of State Climate Actions: Transportation and Land Use," <http://www.climatestrategies.us/ewebeditpro/items/O25F17651.PDF> (Accessed 30 June 2008).
- (11) Ibid.

- (12) U.S. Environmental Protection Agency SmartWay Transport Partnership, “Freight Carrier Innovative Strategies,” http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information on idle reduction technologies visit: <http://www.epa.gov/smartway/idlingtechnologies.htm> or <http://www.epa.gov/smartway/documents/apu.pdf>.
- (13) Center for Climate Strategies, “Brief Descriptions of State Climate Actions: Transportation and Land Use,” <http://www.climatestrategies.us/ewebeditpro/items/O25F17651.PDF> (Accessed 30 June 2008).
- (14) The Climate Trust, “Truck Stop Electrification,” http://www.climatetrust.org/offset_truckstop.php (Accessed 10 July 2008).
- (15) U.S. Environmental Protection Agency SmartWay Transport Partnership, “Freight Carrier Innovative Strategies,” http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information visit: <http://www.epa.gov/smartway/documents/loadmatching.pdf>.
- (16) U.S. Environmental Protection Agency SmartWay Transport Partnership, “Freight Carrier Innovative Strategies,” http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information visit: <http://www.epa.gov/smartway/transport/documents/carrier-strategy-docs/intermodal%20shipping.pdf>.
- (17) Center for Climate Strategies, “Brief Descriptions of State Climate Actions: Transportation and Land Use,” <http://www.climatestrategies.us/ewebeditpro/items/O25F17651.PDF> (Accessed 30 June 2008).
- (18) Ibid.
- (19) For examples of freight villages visit: New Jersey (http://www.fhwa.dot.gov/download/hep/freightplanning/talkingfreight05_18_05rw.ppt), New York (http://www.nymtc.org/download_file.cfm?filename=FrtVillage.pdf), Europlatform – European Association of Freight Villages (<http://www.freight-village.com/index.php>).
- (20) Ibid.
- (21) U.S. Environmental Protection Agency SmartWay Transport Partnership, “Freight Carrier Innovative Strategies,” http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information visit: <http://www.epa.gov/smartway/documents/reducedspeed.pdf>. For more information on speed limits and safety visit: <http://www.truckline.com/issues/governmentpolicy/safety/speedlimits>.
- (22) Center for Climate Strategies, “Brief Descriptions of State Climate Actions: Transportation and Land Use,” <http://www.climatestrategies.us/ewebeditpro/items/O25F17651.PDF> (Accessed 30 June 2008).

- (23) Ibid.
- (24) Ibid.
- (25) U.S. Environmental Protection Agency SmartWay Transport Partnership, “Freight Carrier Innovative Strategies,” http://www.epa.gov/smartway/smartway_fleets_strategies.htm#lub (Accessed 30 June 2008). For more information on driver training visit: <http://www.epa.gov/smartway/documents/drivertraining.pdf>.
- (26) U.S. Environmental Protection Agency, “SmartWay,” <http://www.epa.gov/smartway/> (Accessed 1 July 2008).
- (27) Ibid.
- (28) Testimony of U.S. DOT Deputy Secretary Thomas J. Barrett, to Senate Committee on Commerce, Science and Transportation, June 24, 2008.
- (29) Center for Climate Strategies, “Brief Descriptions of State Climate Actions: Transportation and Land Use,” (Accessed 30 June 2008).

APPENDIX D: Literature Review

The authors would like to acknowledge William Malley of Akin Gump Strauss Hauer & Feld LLP, at the time of the work, and now at Perkins Coie, who conducted the research for some of this literature review as part of development of the *AASHTO Primer on Climate Change and Road Transportation*.

Table of Contents

I.	Science of Climate Change	p. 1
II.	Transportation Energy Consumption and Travel Behavior	p. 3
III.	Vehicles and Fuels	p. 10
IV.	Overall Strategies to Reduce GHG Emissions	p. 19
V.	Strategies to Reduce GHG Emissions in Transportation Sector	p. 29
VI.	Transportation and Climate Change in Europe	p. 48
VII.	Infrastructure Impacts of Climate Change	p. 53
VIII.	Public Opinion Surveys	p. 57

I. SCIENCE OF CLIMATE CHANGE

REPORT

Intergovernmental Panel on Climate Change, “Fourth Assessment Report: Summary for Policy Makers” (Feb. 2007)

The Intergovernmental Panel on Climate Change (IPCC) is an international body created by the United Nations in 1988. The IPCC includes leading climate scientists from around the world. Its purpose is to review and report on the current state of scientific knowledge regarding climate change. The IPCC has issued four “assessment reports” on the science of climate change. The reports were issued in 1990, 1996, 2001, and 2007. The 2007 report is the “Fourth Assessment.”

The IPCC’s Fourth Assessment included several key findings regarding the existence, causes, and likely impacts of climate change. Some of the IPCC’s key findings, as stated in their “Summary for Policymakers,” include:

- “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels.” (p.1)
- “Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.” (p.2)

- “Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.” (p.4)
- “Most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic [man-made] GHG concentrations. It is likely there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica).”
- “Anthropogenic [man-made] warming over the last three decades has likely had a discernible influence at the global scale on observed changes in many physical and biological systems.”
- “There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades.”
- “Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems.” (p.12)
- “Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilised.” (p.13)
- “Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change.” (p.13)
- “There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change.”
- “Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels. Delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts.” (p.20)
- “Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity, and attitudes to risk.” (p. 23)

REPORT

Pew Center on Global Climate Change, “Climate Change 101: Understanding and Responding to Global Climate Change, Overview” (2007)

The Pew Center on Global Climate Change is an independent, non-partisan organization that conducts research on issues related to climate change. The Pew Center is widely respected for the quality and objectivity of its research on climate change issues. The Pew Center's "Climate Change 101" series includes reports on a range of topics. The reports summarize recent scientific findings for a general (non-technical) audience.

- "An overwhelming body of scientific evidence paints a clear picture: climate change is happening, it is caused in large part by human activity, and it will have many serious and potentially damaging effects in the decades ahead." (p.1)
- "Due largely to the combustion of fossil fuels, atmospheric concentrations of carbon dioxide, the principal greenhouse gas, are at a level unequaled for more than 400,000 years." (p.1)
- "Scientists predict that if the increase in greenhouse gas emissions continues unabated, temperatures will rise by as much as 10 degrees Fahrenheit by the end of this century, causing dramatic —and irreversible—changes to the climate." (p. 1)
- "To avoid the worst effects, scientists say we will need to stabilize greenhouse gas concentrations in the atmosphere; that means reducing emissions of these gases by about 50 to 80%." (p.2)
- "[T]he largest contributors to total U.S. emissions are the electricity generation and transportation sectors; significant emissions also come from other commercial and agricultural activity and from buildings in all sectors." (p.2)
- "Key policy solutions include investments in science and technology research; efficiency standards for buildings, vehicles, and appliances; and perhaps most importantly, an overall limit on GHG emissions and a market for reductions. One such system, known as cap-and-trade, would set a cap on GHG emissions and allow companies to trade emission allowances so they can achieve their reductions as cost-effectively as possible." (p.3)

REPORT

The Climate Registry, "General Reporting Protocol" (May 2008)

In 2007, U.S. states, Canadian provinces, Mexican states, and Tribal Nations established a common GHG registry for North America: The Climate Registry. As members of the Registry, these jurisdictions agreed to establish and endorse a voluntary entitywide GHG registry that collects GHG data consistently across jurisdictions; encourage entities in their jurisdictions to join the Registry; and incorporate the Registry's GHG quantification methodologies into any future mandatory GHG programs or GHG emissions reduction programs in their jurisdictions. The Registry is now the broadest based GHG initiative in North America; its membership covers 80 percent of the populations of the U.S. and Canada.

The purpose of the General Reporting Protocol (GRP) is to ensure the complete, consistent, transparent, and accurate measurement and reporting of GHG emissions to

the Registry's voluntary reporting program. The GRP provides guidelines on determining what emissions to report; quantifying emissions; and reporting emissions.

II. TRANSPORTATION ENERGY CONSUMPTION AND TRAVEL BEHAVIOR

REPORT

Short-Term Energy Outlook Supplement: Motor Gasoline Consumption 2008 -- A Historical Perspective and Short-Term Projections

The U.S. Department of Energy's Energy Information Administration released a report that explores how gasoline markets relate to population, income, prices, and the growing role of ethanol. The report also examines the structural shift in motor gasoline markets that took place in the late 1990s.

Some of the EIA's key findings include:

- "Between 1950 and 1973, motor gasoline consumption growth averaged 4.2% per year, similar to the average highway travel growth of 4.7% per year..." (p. 1)
- "... the 1973-1997 period was of fluctuating crude oil and product prices and a sharp slowdown in motor gasoline consumption growth to an average of 0.8% per year. Highway travel growth averaged 2.8% per year... Vehicle miles traveled (VMT) resumed its upward march after the 1980-1982 recession, but gasoline consumption was slowed by the continuing increase in average fleet fuel efficiencies as the new generation of more fuel efficient cars replaced the old." (p. 2-3)
- "The post-1997 period witnessed a structural shift in motor gasoline markets. Motor gasoline consumption growth averaged 1.5% per year, almost twice the growth rate of the turbulent 1973-1997 period; but highway travel growth averaged only 1.6% per year, indicating little, if any, increases in average fleet fuel efficiency". (p. 3)
- "Recently, motor gasoline demand growth has been particularly slow. Following growth of 1.0% in 2006, consumption grew by only 0.4% in 2007 and is projected to decline by 0.3% in 2008 before recovering with 0.8% growth in 2009." (p. 3)
- "Many of the socio-economic factors that drove gasoline consumption growth to average over 4% a year in the 1950s and 1960s do not have the same influence today. For example, population growth has slowed from 1.6 to 1.0% a year; the baby boomers are beginning to pass the peak driving years; and the market for automobiles has approached saturation so that income growth no longer drives an increase in the average number of vehicles per capita, which averaged over 2% a year up until the late 1970s." (p. 13)

- “Also slowing growth in gasoline consumption is the doubling of retail gasoline price over the last 3 years.” (p. 13)
- “The weakness in gasoline consumption is expected to continue, even as the economy recovers from its current slowdown and prices begin to subside. For the foreseeable future, demographic shifts, the impact of high prices on vehicle efficiency, and the more recent shift characterized by reduced impact of income on vehicle miles traveled are likely to keep growth in gasoline consumption well below that seen for much of the post-war period.” (p. 14)

REPORT

Hughes, Jonathan E., Christopher R. Knittel, Daniel Sperling, “Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand,” National Bureau of Economic Research Working Paper Series (2006)

In this paper the authors estimated and compared the price and income elasticities of gasoline demand in two periods, from November 1975 through November 1980 and from March 2001 through March 2006.

Following are some of the findings:

- “We conclude that the short-run price elasticity of gasoline demand is significantly more inelastic today than in previous decades. In the short-run, consumers appear significantly less responsive to gasoline price increases.” (p. 5)
- “The short-run results suggest that consumers today are less responsive in adjusting miles driven to increases in gasoline price. This component seems unlikely to change significantly for long-run behavior. This is because factors that may contribute to inelastic short-run price elasticities such as land use, employment patterns and transit infrastructure typically evolve on timescales greater than those considered in long-run decisions.” (p. 17)
- “In terms of vehicle fuel economy, consumers may respond to higher gasoline prices in the long-run by purchasing more fuel efficient vehicles. However, if consumers in the period from 2001 to 2006 were purchasing more fuel efficient vehicles in response to higher gasoline prices, one would expect to see at least a portion of this effect in the short-run elasticity. While our results do not preclude a significant shift to more fuel efficient vehicles in the long-run response, the highly inelastic values that we observe suggest that the vehicle fuel economy component is small. If the long-run price elasticity is in fact more inelastic than in previous decades, smaller reductions in gasoline consumption will occur for any given gasoline tax level. As a result, a tax would need to be significantly larger today in order to achieve an equivalent reduction in gasoline consumption.” (p. 18)

REPORT

Congressional Budget Office, Effects of Gasoline Prices on Driving Behavior and Vehicle Markets, (January 2008).

This Congressional Budget Office (CBO) study relates rising gasoline prices to changes in how fast people drive, the volume of highway traffic, and rail transit ridership. It also examines the effects on market shares, fuel economy, and pricing of cars and light trucks purchased over the past several years. This study provides an indication of the kinds of adjustments consumers would make if gasoline prices continue to rise, and of the implications of rising gasoline prices for policies that would discourage gasoline consumption and thus limit the growth in carbon dioxide emissions.

Key findings include:

- “Recent empirical research suggests that total driving, or vehicle miles traveled (VMT), is not currently very responsive to the price of gasoline. A 10% increase in gasoline prices is estimated to reduce VMT by as little as 0.2% to 0.3% in the short run and by 1.1% to 1.5% eventually.” (p. 1)
- “CBO’s findings suggest, however, that a large increase in the price of gasoline might cause only a small shift from automobiles to public transportation, at least in the short run.” (p. 2).
- “Average weekday traffic volumes on some freeways have declined slightly in response to higher gasoline prices, CBO’s analysis shows. The routes on which that response was detected are adjacent to commuter rail systems. Weekly average gasoline prices appear to have had little effect on traffic volume at other freeway locations or on weekends. In the California data that CBO analyzed, higher gasoline prices also are associated with slightly greater ridership on transit rail systems.” (p. 2)
- “...as gasoline prices have increased, the average number of riders gained by the rail transit systems in CBO’s sample has been reasonably consistent with the reduction in the number of vehicles per weekday, about 730, on the adjacent freeways. In CBO’s analysis, all five transit systems exhibited positive relationships between ridership and gasoline prices, although for the two (interconnected) Los Angeles systems, the effect was small and not statistically different from zero.” (p. 4)
- “Higher gasoline prices from 2003 through the end of 2006 caused many motorists to drive a little more slowly on uncongested highways. Median speeds in free-flow conditions declined slightly as gasoline prices increased. The slowdown was more pronounced for vehicles moving at the somewhat lower 5th%ile speeds; there was no discernible effect on 95th%ile speeds. The median effect is consistent with recent estimates of gasoline price elasticity, which indicate that short-run demand declines by around 0.6% when the price rises by 10%, all else being equal. The diverse effects of gasoline prices on vehicles traveling at different speeds are consistent with the notion that motorists who set

- a lower value on their time may be more willing to trade (slightly) longer travel times for (slightly) lower fuel costs.” (p. 7)
- “Thus, along with conventionally understood sources of elasticity in the demand for gasoline—changes in the length and frequency of automobile trips and in the types of vehicles people drive—the way vehicles are operated could be a meaningful source of short-run elasticity in the demand for gasoline. In particular, although the implied elasticity of -0.06 is objectively small, it is consistent with current estimates of the overall short-run elasticity, which range from about -0.03 to -0.09.” (p. 9)
 - “All major car categories—from two-seaters and subcompacts to large sedans and wagons—have gained market share as the price of gasoline has risen, with gains of between 4.5% and about 9% for every 60 cent increase in the price of gasoline above \$2.30 per gallon. At the same time, the market shares of all types of light trucks, from minivans and SUVs to pickup trucks and passenger or cargo vans, have fallen by 4 % to 6 %. For example, at average values, a 60 cent increase in the price of gasoline would have increased the market share of midsize cars by about 0.8 percentage points, which is a 5 % increase over its average value of 16.6 %. That price increase also would be associated with a decline of 1.2 percentage points or 4.5 % in the share of new SUVs, on average, from a baseline share of about 27 %.” (p. 18)
 - “Beginning with the 2001 model year, when the average fuel economy rating for new cars was 28.4 miles per gallon, the average began to increase, peaking at 29.2 mpg for the 2005 model year before slipping back slightly in 2006.”(p. 19)
 - “The recently observed price shifts for new vehicles are reflected in used-vehicle prices as well. Average prices of fuel-efficient used vehicles have been rising, and those of less-efficient vehicles have been falling.” (p. 20)

REPORT

[Greene, David L., Modeling the Oil Transition: A Summary of the Proceedings of the DOE/EPA Workshop on the Economic and Environmental Implications of Global Energy Transitions \(February 2007\)](#)

This workshop focused on the sweeping changes that the global energy system will face in next few decades, and the methods of forecasting, analyzing, and planning for global energy transitions and their economic and environmental consequences. Specifically, this workshop focused on the transition from conventional to unconventional oil and other energy sources likely to result from a peak in non-OPEC and/or global production of conventional oil. Leading energy models from around the world in government, academia and the private sector met, reviewed the state-of-the-art of global energy modeling and evaluated its ability to analyze and predict large-scale energy transitions.

Key findings include the following:

- "... this workshop has also revealed that we do not have the analytical tools necessary to predict, analyze and plan for such a massive change in the global energy system. The analytical tools at our disposal are not able to provide satisfactory answers to many of the important questions about a transition from conventional oil." (p. xvii)
- "Another critical area in which existing modeling methods appear to be deficient is modeling disrupted markets and disruptive changes. Yet if global energy markets are surprised by oil peaking, energy markets will almost certainly be disrupted. What will the consequences be? It does not appear that existing models are adequate to predict the consequences of a disruptive transition for world economic growth and to understand what might be done to mitigate the damage." (page xviii)
- "Finally, it appears that there will be significant local and regional environmental and social impacts of the massive energy developments that are likely to be necessary to avoid large-scale demand destruction during an oil transition. Local and regional objections to these impacts could slow or halt their development. Existing models do not appear to be able to predict these impacts or analyze options for mitigation." (page xviii)

REPORT

National Petroleum Council, *Hard Truths: Facing the Hard Truths about Energy – A Comprehensive View to 2030 of Global Oil and Natural Gas* (2007)

In a letter dated October 5, 2005, Secretary of Energy Samuel W. Bodman requested that the National Petroleum Council (NPC) undertake a study on the ability of global oil and natural gas supply to keep pace with growing world demand. The NPC advises the Secretary of Energy, and represents the views of the oil and natural gas industries. Specifically, the Secretary stated that key questions to be addressed in the study might include: (1) What does the future hold for global oil and natural gas supply? (2) Can incremental oil and natural gas supply be brought on-line, on-time, and at a reasonable price to meet future demand without jeopardizing economic growth? (3) What oil and gas supply strategies and/or demandside strategies does the Council recommend the U.S. pursue to ensure greater economic stability and prosperity?

Responding to the Secretary's request, the Council established a Committee on Global Oil and Gas to study this topic and to supervise preparation of a report for the Council's consideration. The report was completed in 2007 and focuses on energy demand, energy supply, technology, geopolitics, and carbon management. Following are a few findings on the section that focused on carbon management in the transportation sector:

- "There is potential to almost double the efficiency of existing gasoline- and diesel-powered vehicles. And there are technologies to augment internal-combustion engines in cars using electric hybrids and plug-in electric hybrids, which are already available. So long as the centralized electricity generating plants control CO₂ emissions, then the electrification of cars helps reduce overall CO₂ emissions as well as reduce the requirements for oil imports. Examples of

such solutions include integrated coal-fired power with CCS or alternative low-carbon electricity sources such as nuclear, wind, or other renewables.” (p. 236)

- “However, technical efficiency improvements may not, by themselves, lead to a reduction in the demand for hydrocarbon fuels. Over the past two decades, light-duty vehicle efficiency improvements in the United States have been countered by increased miles driven and heavier, higher-performance vehicles. Active policies to reduce demand for transportation fuel would be an important element in any portfolio of strategies to reduce CO₂ emission in a carbon constrained world.” (p. 236)
- “Demand reduction could be achieved by combining approaches that reflect the following considerations:

Reducing carbon emissions from transportation would have key importance in a carbon constrained world.

Public education, particularly of the next generation of consumers, would play an important role in long-term strategies to reduce demand.

Improved engine efficiency enables demand reduction, especially if accompanied by other mechanisms to reduce demand.

Increasing fuel price is unlikely to be sufficient by itself. A combination of increased price and regulation would probably be necessary to reduce demand effectively.

Government incentives to increase the use of public transport would help reduce demand for transportation fuel.

Congestion charges and high-occupancy vehicle (HOV) systems would further help reduce fuel demand.

Government incentives to retire older, less-efficient vehicles would help reduce fuel demand, and programs to audit the energy efficiency of the existing fleet would be an effective complement to such incentives.” (p. 236-237)

REPORT

What You Need to Know About Energy, The National Academies (May 2008)

This publication from the National Academies is an informational booklet that explores the issue of energy in terms of sources and uses, supply and demand, efficiency, and emerging technologies.

A few quotes:

- “Another familiar form of conversion loss occurs in a vehicle’s internal combustion engine. The chemical energy in the gasoline is converted to heat

energy, which provides pressure on the pistons. That mechanical energy is then transferred to the wheels, increasing the vehicle's kinetic energy. Even with a host of modern improvements, current vehicles use only about 20% of the energy content of the fuel as power, with the rest wasted as heat. Electric motors typically have much higher efficiency ratings. But the rating only describes how much of the electricity input they turn into power; it does not reflect how much of the original, primary energy is lost in generating the electricity in the first place and then getting it to the motor." (p. 9)

- "Efforts are already well under way to find suitable alternatives to oil. In the short term, the leading liquid substitute is ethanol ("grain alcohol"), now chiefly made from corn. The federal government has an aggressive program to encourage its production. As a result, in 2005 about 4 billion gallons of fuel ethanol mixed with gasoline hit the domestic market. But in the same year, the United States consumed about 140 billion gallons of gasoline and 40 billion gallons of diesel fuel, so ethanol accounted for only a small percentage of the total gasoline pool." (p. 15)
- "Ethanol raises other concerns. One drawback of corn ethanol production is that it requires a large amount of land and fresh water, along with inputs of fertilizers and energy. This results in potential competition with food sources for land use and fresh water for other industrial and commercial uses. In addition, with current technology, two-thirds of the energy value of corn ethanol is used just to produce the fuel—and most of that energy comes from fossil fuel-based electricity or heating, offsetting much of the benefit." (p. 15).

III. VEHICLES AND FUELS

REPORT

Matthew A. Kromer and John B. Heywood, *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet* (May 2007)

This study quantifies the potential of electric and hybrid-electric powertrains, such as gasoline hybrid-electric vehicles (HEVs), plug-in hybrid vehicles (PHEVs), fuel-cell vehicles (FCVs), and battery-electric vehicles (BEVs), to offer reductions in petroleum consumption and greenhouse gas (GHG) emissions.

Key findings:

- "A broad theme of this study is that, while electric powertrains can make a valuable contribution to reducing one or both of petroleum consumption and GHG emissions in the long-run, they do not offer the prospect for solving these problems on their own." (p. 134)
- "Over the next several decades, conventional technologies – vehicles using a spark-ignition or diesel engine – are likely to continue to dominate the in-use vehicle fleet. As such, it is vital that technological development focus on

improving the fuel efficiency of conventional technologies over this period.” (p. 134)

- “While conventional technology is likely to continue to dominate for the next two decades, continued technical development and increasing sales volume of hybrid vehicles are likely to drive down costs and improve performance. These improvements, in combination with aggressive policy measures to overcome consumer reluctance to pay a premium for high efficiency vehicles, can bring the hybrid vehicle into the fleet in large numbers in the year 2030 and beyond.” (p. 134)
- “The evolution of battery and fuel-cell technology over the next 10-20 years will likely dictate whether the plug-in hybrid or the fuel-cell vehicle succeeds the hybrid vehicle. The plug-in hybrid, which has lower technical risk than the fuel-cell and addresses many of the shortcomings of the electric vehicle, may be deployed in low numbers in the next ten years; depending on consumer response, market drivers, and technical development, it might remain as a niche vehicle or grow into an increasing fraction of vehicle sales. Based on historical rates of change in the auto industry, it could comprise 25% of the cars on the road by mid-century. Over the long-term, the plug-in hybrid may bridge the way to a transportation system based either on battery-electric or on fuel-cell vehicles; alternatively, with successful deployment of bio-fuels at scale, it could form a long-term solution in its own right. In this sense, the plug-in hybrid offers a valuable “plan-B” if the other options do not pan out or develop too slowly.” (p. 135)
- “The fuel-cell, which faces significant technical and infrastructure hurdles, is likely to have minimal impact over the 30-year time horizon of this study, even with successful development.” (p. 135)
- “Historically, consumers have been unwilling to pay a price premium for fuel efficiency; they are motivated instead by performance, comfort, and safety. As such, aggressively penetrating the market with high efficiency vehicles will require strong market drivers to overcome this reluctance: such drivers could include a system of feebates and fuel taxes.” (p. 135)
- “To meet long-term targets, it is vital that, in parallel with aggressively pursuing efficiency improvements in vehicle technologies, domestic, non-GHG emitting fuel feedstocks and production processes be developed. This point is particularly compelling in light of the fact that the more futuristic powertrain options (the plug-in hybrid, the fuel-cell, and the electric vehicle) offer limited GHG reduction benefits over hybrid vehicles according to the base-case projections. In a similar vein, transitioning transportation energy from petroleum to natural gas (which, like petroleum, is subject to high price volatility and much of which is imported) does not necessarily solve energy security issues: hence, producing hydrogen or generating electricity from natural gas must be carefully evaluated in light of the over-arching goals in question. There is a temptation to assume that deploying new powertrains with low in-use emissions will solve the GHG problem on their own, but the reality is that developing clean fuel pathways will require extensive technological and infrastructure development in their own right.” (p. 135)

- “Electric powertrains offer the opportunity to achieve a step-change reduction in petroleum use and GHG emissions in the United States light-duty fleet. However, it will be several decades before these technologies can penetrate the in-use fleet and are likely to come at a higher cost than conventional technologies. In addition, these technologies cannot meet long-term petroleum or GHG reduction targets by themselves. They must be deployed in combination with other aggressive measures such as improved conventional technology, development of low carbon fuels and fuel production pathways, and demand-side reductions.” (p. 135)

REPORT

California Energy Commission’s State Alternative Fuels Plan, California Air Resources Board and California Energy Commission (December 2007)

This plan was prepared as a requirement of California Assembly Bill 1007, and presents strategies and actions California must take to increase the use of alternative non-petroleum fuels in a manner that minimizes costs to California and maximizes the economic benefits of in-state production. The Plan assessed various alternative fuels and developed fuel portfolios to meet California’s goals to reduce petroleum consumption, increase alternative fuels use, reduce greenhouse gas emissions, and increase in-state production of biofuels without causing a significant degradation of public health and environmental quality.

A top down 2050 assessment on how the widespread use of alternative fuels, efficiency measures, and changes in travel habits would impact transportation fuel demand and diversity indicated there are plausible ways to meet 2050 goals of an 80 % reduction in GHG emissions associated with personal transportation. As indicated in the report, the following set of measures could be combined to produce this result:

- “Lowering the energy needed for personal transportation by tripling the energy efficiency of on-road vehicles in 2050 with:

Conventional gas, diesel, and FFVs averaging more than 40 miles per gallon (mpg).

Hybrid gas, diesel, and FFVs averaging almost 60 mpg.

All electric and PHEVs averaging well over 100 mpg (on a GGE basis) on the electricity cycle.

FCVs averaging over 80 mpg (on a GGE basis).

- Moderating growth in per capita driving, reducing today’s average per capita driving miles by about 5 % or back to 1990 levels.
- Changing the energy sources for transportation fuels from the current 96 % petroleum-based to approximately:

30 % from gasoline and diesel from traditional petroleum sources or lower GHG emission fossil fuels such as natural gas.

30 % from transportation biofuels.

40 % from a mix of electricity and hydrogen.

- Producing transportation biofuels, electricity, and hydrogen from renewable or very low carbon-emitting technologies that result in, on average, at least 80 % lower life cycle GHG emissions than conventional fuels.
- Encouraging more efficient land uses and greater use of mass transit, public transportation, and other means of moving goods and people.” (p. 67-68)

REPORT

Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards Around the World, Prepared for the Pew Center on Global Climate

This study focused on comparing countries and regions that have established or proposed their own motor vehicle fuel economy or GHG emission standards. Following are some of the findings:

- “Almost all industrialized countries use standards on new vehicles to reduce vehicle oil consumption and CO₂ emissions. Yet the three largest automobile markets, the United States, the European Union and Japan, approach these standards quite differently.” (p. 5)
- “The United States uses Corporate Average Fuel Economy (CAFE) standards ...In the European Union, the automobile industry has signed a voluntary agreement with the government to reach an overall fleet CO₂ emission level of 140 g CO₂/km by 2008. ... In Japan, as in China, fuel economy standards are based on a weight classification system where vehicles must comply with the standard for their weight class.” (p. 5)
- “The European Union (EU) and Japan have the most stringent standards in the world.” (p. 1)
- “The fuel economy and greenhouse gas emission performance of the U.S. cars and light trucks—both historically and projected based on current policies—lags behind most other nations. The United States and Canada have the lowest standards in terms of fleet-average fuel economy rating, and they have the highest greenhouse gas emission rates based on the EU testing procedure.” (p. 1)

- “The new Chinese standards are more stringent than those in Australia, Canada, California, and the United States, but they are less stringent than those in the European Union and Japan.” (p. 1)
- “If the California GHG standards go into effect, they would narrow the gap between U.S. and EU standards, but the California standards would still be less stringent than the EU standards.” (p. 1)

REPORT

United States Environmental Protection Agency, "Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle," (February 2005)

This document provides a framework for the use of consistent assumptions to use for estimating greenhouse gas emissions from passenger vehicles, and includes recommendations on values to use in the calculations. The estimate calculated is for vehicle emissions only, and does not include lifecycle emissions such as emissions associated with the production and distribution of fuel.

Key findings:

- “There are six key steps to estimate the annual greenhouse gas emissions associated with a passenger vehicle:
 1. *Determining the carbon dioxide (CO₂) produced per gallon of gasoline*
 2. *Estimating the fuel economy of passenger cars and light trucks (in miles per gallon [mpg])*
 3. *Determining the number of miles driven*
 4. *Determining the emissions of greenhouse gases other than CO₂ (methane [CH₄], nitrous oxide [N₂O], and hydrofluorocarbons [HFCs])*
 5. *Estimating the relative percentages of passenger cars and light trucks*
 6. *Calculating the resulting annual greenhouse gas emissions.” (p. 2)*
- “To translate GHG reductions into an equivalent number of cars off the road, annual emissions from a typical passenger vehicle should be equated to 5.5 metric tons of carbon dioxide equivalent or 1.5 metric tons of carbon equivalent.” (p. 2)

REPORT

Lee Schipper, the World Resources Institute Center for Sustainable Transport, “Automobile Fuel; Economy and CO₂ Emissions in Industrialized Countries: Troubling Trends through 2005/6,” (2007)

This paper reviews recently available data on both on-road fuel economy and new car test fuel economy in the U.S., several European countries, and Japan to assess more recent trends in light of higher fuel prices and increased concern about global climate change.

Key findings include:

- “On-road fuel economy is improving in Japan and Europe, but hardly at all in the US, at least through 2006. Fuel economy (miles/gallon) is higher in Europe and to some extent Japan than in the U.S. In 2005, on-road fuel economy in the U.S. was slightly above 11 l/100 km (about 21 mpg). Japan’s average was 10.5 km/100 km (22 mpg), while Germany, the U.K. and France were 8 (29), 7.7 (31) and 7.5 (32) respectively. These “real world” on-road figures include diesel and other fuels. For the US, the figure includes the portion of light trucks that are household vehicles, such as SUVs, all of which are far less significant in the other countries.” (p. 16)
- “The shift to diesel cars was expected to spark significant fuel economy improvements in Europe to meet this target. But for a variety of reasons, new diesel cars show only slightly lower energy- or CO₂ intensities than new gasoline cars. The same is true when comparing on road fuel economy. Test fuel economy of both new diesel and gasoline cars, as well as their respective on-road values have improved in Europe. But when the higher yearly usage of diesel is folded in, the real energy or CO₂ savings are disappointing.” (p. 16)
- “Technology has reduced the fuel required for a given car horsepower and weight markedly, but in the U.S. (and to some extent Europe) this has been offset by greater new car power and weight. Further improvements in fuel economy depend both on technology to reduce fuel use per unit of weight or power, and a slowing, halting, or even reversal (i.e., downsizing or down-weighting) of new vehicle power and/or weight beyond weight reductions in a given car class, i.e., downsizing.” (p. 16)
- “The European Union proposes to strengthen their “Voluntary Agreement” to become a mandatory target with the goal of 120 gm/km CO₂ emissions from new cars, which corresponds to roughly to 5.5 l/100 km or 42 MPG gasoline equivalent. Calls for higher fuel economy in the U.S. start at 35 MPG (6.7 l/100 km) and echo even more stringent values. ... Getting such changes into law and through the planning cycles of manufacturers and then into the stocks would take 20 years, given the delays and turnover times at each stage. While the literature leaves little doubt that these levels could be reached, such an achievement would be made increasingly harder by continued increases in car weight, power and features. Finding a mechanism for this transformation to occur faster than the present rates may indeed be a key goal of all stakeholders in the near future.” (p. 16)

REPORT

Evan Ratliff, "One Molecule Could Cure Our Addiction to Oil," *Wired Magazine* issue 15.10 (September 24, 2007)

This article describes some of the potential and hurdles to overcome for the widespread use of cellulosic ethanol in the transportation sector.

A few quotes:

- “Scientists have long known how to turn trees into ethanol, but doing it profitably is another matter. We can run our cars on lawn cuttings today; we just can't do it at a price people are willing to pay. The problem is cellulose. Found in plant cell walls, it's the most abundant naturally occurring organic molecule on the planet, a potentially limitless source of energy. But it's a tough molecule to break down. ...For scientists, though, figuring out how to convert cellulose into a usable form on a budget driven by gas-pump prices has been neither elegant nor easy.”
- “Most of the plant species suitable for producing this kind of ethanol — like switchgrass, a fast-growing plant found throughout the Great Plains, and farmed poplar trees — aren't food crops. And according to a joint study by the US Departments of Agriculture and Energy, we can sustainably grow more than 1 billion tons of such biomass on available farmland, using minimal fertilizer. In fact, about two-thirds of what we throw into our landfills today contains cellulose and thus potential fuel. Better still: Cellulosic ethanol yields roughly 80 % more energy than is required to grow and convert it.”
- “Neither government funding nor venture capital, of course, guarantees research breakthroughs or commercial blockbusters. And even ardent proponents concede that cellulosic ethanol won't solve our fuel problems — or do much to stop global warming — without parallel efforts to improve vehicle efficiency. They also worry that attention could again fade if the first demonstration plants fail or oil prices plummet. ‘To get this industry going, you need some short-term breakthroughs, by which I mean the next five to seven years,’ says Martin Keller, a micro biologist at Oak Ridge National Laboratory in Tennessee and director of its new BioEnergy Science Center. ‘Otherwise, my fear is that people may leave this field again.’”
- “The problem comes from the quotidian difficulties of making benchtop science work on an industrial scale. Undoubtedly, even some well-funded efforts will fail. But the proliferation of research — the prospect of Lee Lynd's superbug, the evolution of current cellulases, and the addition of new enzymes harvested from nature — stacks the deck in favor of cellulosic ethanol. Alexander Karsner, assistant secretary for the DOE's Office of Energy Efficiency and Renewable Energy, says that with plants going up around the country, the industry could make cellulosic ethanol cost-competitive within six years. ‘I think there won't be a silver-bullet process, where you say, ‘That has won, and everything else is done,’ he says. ‘So you need many of these technologies.’ Having known lean times, Lynd is reluctant to predict the future. But given the freedom of fat wallets, he says, ‘I truly think that in five years all the hard issues about converting cellulosic biomass to ethanol may be solved.’”

REPORT

Nicholas Paul Lutsey, "Prioritizing Climate Change Mitigation Alternatives: Comparing Transportation Technologies to Options in Other Sectors" (2008)

This is Lutsey's Ph.D. dissertation from the University of California at Davis. This dissertation formulates an analytical method to better prioritize future climate change policy actions. Light duty vehicle GHG reduction measures analyzed were: (1) incremental (20%) new vehicle rated fuel consumption improvement, (2) improved "on-road" fuel economy (reduce by half the 20% shortfall between rated and "onroad" fuel economy), (3) hybrid-electric vehicles (50% of new vehicle sales by 2025), (4) cellulosic ethanol to reduce carbon-fuel content (13% of motor fuel by volume by 2025), and (5) air-conditioning refrigerant replacement (from HFC-134a to CO₂).

Key findings include the following:

- "There are many net-beneficial "no regrets" climate change mitigation technologies – where the energy savings of the technologies outweigh the initial costs – and most of these technologies are not being widely adopted. (Abstract)
- Transportation technologies are found to represent approximately half of the "no regrets" mitigation opportunities and about one-fifth of the least-cost GHG mitigation measures to achieve the benchmark 1990 GHG level. (Abstract)
- "Approximately half of the 1990 GHG emission target by 2030 could be achieved with GHG mitigation technologies that are below \$0/tonne CO₂e." (p. 141)
- "At lower lifetime cost-effectiveness values, the total potential reductions are dominated by the transportation and building sectors." (p. 144)
- "Historical and current environmental policy-making in the U.S. have demonstrated a strong proclivity for technological approaches over any types of behavior-changing policies." (p. 154)
- "The great magnitude of GHG reductions that would be required for worldwide climate change stabilization will almost surely require behavioral, or actor-based, modifications of some sort by individuals – beyond simply withstanding incremental cost increases in their vehicles, electricity bills, appliances, and fuels due to the deployment of new technologies." (p. 154)
- "After deploying the level of GHG reduction technology for vehicles and fuels as described in this study (and no further advances), the travel demand reduction to achieve the 2050 target would be quite severe. For this amount of GHG reductions to come from travel reductions, national light-duty vehicle travel would have to be reduced annually by approximately 4%, instead of the forecasted increase of about 1.8% annually from 2010 on." (p. 155)

- “Even after a new crop of vehicle and fuel technologies (e.g., plug-in hybrid-electric vehicles) emerges, it appears safe to speculate that some significant amount reduction in vehicle-miles-traveled will be needed to augment technology shifts to achieve deeper, longer-term GHG reductions.” (p. 155)

REPORT

Tim Searchinger, "The Impacts of Biofuels on Greenhouse Gases: How Land Use Change Alters the Equation" (2008)

Previous studies have found that substituting biofuels for gasoline will reduce greenhouse gases because biofuels sequester carbon through the growth of feedstock. Searchinger describes how these analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland.

Key findings include the following:

- “New analyses are now showing that the loss of greenhouse gases from direct and indirect land use changes exceeds the other benefits of many biofuels over decades.”
- “Some biofuels, such as those produced from municipal, industrial and agricultural waste, remain viable ways of reducing greenhouse gases.”
- “Policies need to focus on biofuels that do not trigger significant land use change.”

REPORT

National Academy of Sciences, "Transitions to Alternative Transportation Technologies: A Focus on Hydrogen" (July 2008)

The Board on Energy and Environmental Systems (BEES), part of the National Academies' Division on Engineering and Physical Sciences (DEPS), has released a report that estimates the maximum practicable number of hydrogen fuel cell vehicles that could be deployed in the United States by 2020 and beyond, together with the investments, time, and government actions needed to carry out this transition. The report also examines the consequent reductions in U.S. oil consumption and emissions of carbon dioxide that could be expected. In addition, the report compares those reductions with the potential impact that the use of alternative vehicle technologies and biofuels might have on oil consumption and carbon dioxide emissions. Key findings include the following:

- “The NRC’s Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies concluded that the maximum practical number of HFCVs that could be operating in 2020 would be approximately 2 million in a fleet of 280 million light-duty vehicles. The number of HFCVs could grow rapidly thereafter to about 25 million by 2030.” (p. Abs-1)

- “The use of HFCVs can achieve large and sustained reductions in U.S. oil consumption and CO₂ emissions, but several decades will be needed to realize these potential long-term benefits. Considerable progress is still required toward improving fuel cell costs and durability, as well as on-board hydrogen storage. ...HFCVs and hydrogen production technologies could be ready for commercialization in the 2015-2020 time frame. Such vehicles are not likely to be cost-competitive until after 2020, but by 2050 HFCVs could account for more than 80 percent of new vehicles entering the fleet.” (p. Abs-1)
- “The main advantage of a transition to HFCVs is the potential for reducing the use of oil and emissions of CO₂. Although hydrogen could not replace much gasoline before 2025, the 25 years after that would see a dramatic decline in the use of gasoline in the light-duty vehicle fleet to about one-third of current projections, if the assumptions of the maximum practical case are met. CO₂ emissions will decline almost as much if hydrogen is produced with carbon capture and sequestration or from nonfossil sources. (p. Abs-2)
- “The committee also found that alternatives such as improved fuel economy for conventional vehicles, increased penetration of hybrid vehicles, and biomass-derived fuels could deliver significantly greater reductions in U.S. oil use and CO₂ emissions than could use of HFCVs over the next two decades, but that the longer-term benefits of such approaches were likely to grow at a smaller rate thereafter, even with continued technological improvements, whereas hydrogen offers greater longer-term potential. Thus, as estimated by the committee, the greatest benefits will come from a portfolio of R&D technologies that would allow the United States to achieve deep reductions in oil use, nearly 100 percent by 2050 for the light-duty vehicle fleet. Achieving this goal, however, will require significant new energy security and environmental policy actions in addition to technological developments. Although broad policies aimed at reducing oil use and CO₂ emissions will be useful, they are unlikely to be adequate to facilitate the rapid introduction of HFCVs. A competitive and self-sustaining HFCV fleet is possible in the long term but will require hydrogen-specific policies in the nearer term. These policies must be substantial and durable in order to assure industry that the necessary long-term investments can be made safely.” (p. Abs-2)

IV. OVERALL STRATEGIES TO REDUCE GHG EMISSIONS

REPORT

Sir Nicholas Stern, “Stern Review on the Economics of Climate Change”
(Oct. 2006)

Sir Nicholas Stern, former Chief Economist for the World Bank, was commissioned by the government of Great Britain to prepare a report on the effects of climate change on the global economy. The report, known as the Stern Review, was published in October 2006. The key conclusion of the report is that “the benefits of early action on climate change outweigh the costs.” Key findings in this report include:

- “The effects of our actions now on future changes in the climate have long lead times. What we do now can have only a limited effect on the climate over the next 40 or 50 years. On the other hand what we do in the next 10 or 20 years can have a profound effect on the climate in the second half of this century and in the next.” (p.i)
- “No-one can predict the consequences of climate change with complete certainty; but we now know enough to understand the risks. Mitigation - taking strong action to reduce emissions - must be viewed as an investment, a cost incurred now and in the coming few decades to avoid the risks of very severe consequences in the future.... For this to work well, policy must promote sound market signals, overcome market failures and have equity and risk mitigation at its core.” (p.i)
- “CO2 emissions per head have been strongly correlated with GDP per head. As a result, since 1850, North America and Europe have produced around 70% of all the CO2 emissions due to energy production, while developing countries have accounted for less than one quarter. Most future emissions growth will come from today’s developing countries, because of their more rapid population and GDP growth and their increasing share of energy-intensive industries.” (p.xi)
- “This Review has focused on the feasibility and costs of stabilization of greenhouse gas concentrations in the atmosphere in the range of 450-550ppm CO2e. Stabilizing at or below 550ppm CO2e would require global emissions to peak in the next 10 - 20 years, and then fall at a rate of at least 1 - 3% per year.... By 2050, global emissions would need to be around 25% below current levels. These cuts will have to be made in the context of a world economy in 2050 that may be 3 - 4 times larger than today - so emissions per unit of GDP would need to be just one quarter of current levels by 2050.” (p.xi)
- “To stabilize at 450ppm CO2e, without overshooting, global emissions would need to peak in the next 10 years and then fall at more than 5% per year, reaching 70% below current levels by 2050.” (p.xi)
- “Achieving these deep cuts in emissions will have a cost. The Review estimates the annual costs of stabilization at 500-550ppm CO2e to be around 1% of GDP by 2050 - a level that is significant but manageable.” (p.xii)
- “Greenhouse-gas emissions can be cut in four ways. Costs will differ considerably depending on which combination of these methods is used, and in which sector:

Reducing demand for emissions-intensive goods and services

Increased efficiency, which can save both money and emissions

Action on non-energy emissions, such as avoiding deforestation

Switching to lower-carbon technologies for power, heat and transport.” (p.xii)

- “The power sector around the world will have to be least 60%, and perhaps as much as 75%, decarbonised by 2050 to stabilize at or below 550ppm CO₂e. Deep cuts in the transport sector are likely to be more difficult in the shorter term, but will ultimately be needed.” (p.xiii)
- “Stabilization at 450ppm CO₂e 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. Costs rise significantly as mitigation efforts become more ambitious or sudden. Efforts to reduce emissions rapidly are likely to be very costly.” (p.xv)
- “An important corollary is that there is a high price to delay. Delay in taking action on climate change would make it necessary to accept both more climate change and, eventually, higher mitigation costs. Weak action in the next 10-20 years would put stabilization even at 550ppm CO₂e beyond reach – and this level is already associated with significant risks.” (p.xv)
- “Establishing a carbon price, through tax, trading or regulation, is an essential foundation for climate-change policy.... Putting an appropriate price on carbon – explicitly through tax or trading, or implicitly through regulation – means that people are faced with the full social cost of their actions. This will lead individuals and businesses to switch away from high-carbon goods and services, and to invest in low-carbon alternatives. Economic efficiency points to the advantages of a common global carbon price: emissions reductions will then take place wherever they are cheapest.” (p.xviii)
- “Securing broad-based and sustained co-operation requires an equitable distribution of effort across both developed and developing countries. There is no single formula that captures all dimensions of equity, but calculations based on income, historic responsibility and per capita emissions all point to rich countries taking responsibility for emissions reductions of 60-80% from 1990 levels by 2050.” (p. xxiii)
- “Transport is one of the more expensive sectors to cut emissions from because the low carbon technologies tend to be expensive and the welfare costs of reducing demand for travel are high. Transport is also expected to be one of the fastest growing sectors in the future. For these two reasons, studies tend to find that transport will be among the last sectors to bring its emissions down below current levels.” (Annex 7c, p.3)
- “If innovation policy is used to bring down the cost of low carbon transport technologies (such as hydrogen or electric powered vehicles), then these will become viable options in the longer term. However the electricity or hydrogen would have to be generated in a low carbon way for these technologies to be truly low carbon. It is very uncertain how quickly the costs of these technologies might come down. A study by the IEA found that hydrogen could fuel up to 30% of road transport vehicles by 2050, but with significant downside potential.” (Annex 7c, p.3)

- “Whilst transport is likely to be largely oil-based in 2050, it is important for it to decarbonise in the longer term if stabilisation at 550ppm CO₂e is to be achieved. For example, in the period beyond 2100, total GHG emissions will have to be just 20% of current levels (around 5 GtCO₂e, which is roughly the same as today’s emissions from agriculture). It is impossible to imagine how this can be achieved without a decarbonised transport sector.” (Annex 7c, p.4)

REPORT

McKinsey & Company – “Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?” (Dec. 2007)

McKinsey & Company, a business consulting firm, issued a report in December 2007 that comprehensively reviewed potential strategies for reducing GHG emissions in the U.S. This study was funded by several major corporations as well as a number of environmental groups. The study analyzed more than 250 options, comparing them in terms of their cost-effectiveness – that is, the cost per ton of reduction of GHG emissions.

Key findings include:

- “Annual GHG emissions in the U.S. are projected to rise from 7.2 gigatons [billion tons] CO₂e in 2005 to 9.7 tons in 2030 – an increase of 35 % – according to an analysis of U.S. government reference forecasts.... Growth in emissions would be accompanied by a gradual decrease in the absorption of carbon by U.S. forests and agricultural lands. After rising for 50 years, carbon absorption is forecast to decline from 1.1 gigatons in 2005 to 1.0 gigatons in 2030. On this path – with emissions rising and carbon absorption starting to decline – U.S. emissions in 2030 would exceed GHG reduction targets contained in economy-wide bills currently before Congress by 3.5 to 5.2 gigatons.” (p.x)
- “Relying on tested approaches and high-potential emerging technologies, the U.S. could reduce annual GHG emissions by as much as 3.0 gigatons in the mid-range case to 4.5 gigatons in the high-range case by 2030. These reductions ... would bring U.S. emissions down 7 to 28 % below 2005 levels, and could be made at a marginal cost less than \$50 per ton, while maintaining comparable levels of consumer utility.” (p.xii)
- “Five clusters of initiatives, pursued in unison, could create substantial progress – 3.0 gigatons (mid-range case) to 4.5 gigatons (high-range case) – of abatement per year against proposed GHG reduction targets for 2030. We will discuss these clusters in order, from least to highest average cost:

“Improving energy efficiency in buildings and appliances – 710 megatons (mid-range to 870 megatons (high-range).

“Increasing fuel efficiency in vehicles and reducing carbon intensity of transportation fuels – 340 megatons to 660 megatons.

“Pursuing various options across energy-intensive portions of the industrial sector – 620 megatons to 770 megatons.

“Expanding and enhancing carbon sinks – 440 megatons to 590 megatons.

“Reducing the carbon intensity of electric power generation – 800 megatons to 1,570 megatons.” (p. xv)

- “To address rising GHG emissions comprehensively, the nation would also need to consider abatement options outside the scope of this project. Additional reductions could be achieved by encouraging changes in consumer lifestyle and behavior (e.g., driving habits, spending decisions) through measures such as price signals or education and awareness campaigns; they could also be achieved by pursuing abatement options with marginal costs greater than \$50 per ton.” (p.xvii)
- “The faster the U.S. moves toward a services-oriented, consumer-driven economy featuring larger houses, more electrical devices, and more miles traveled, the more its energy consumption will rise. Above-average growth in commercial and residential building stock ... are major drivers of increased electricity demand. At the same time, increases in vehicle miles traveled and the number of vehicles on the road would boost transportation emissions.” (p.10)
- “Projected increases in vehicle efficiency and lower-carbon fuels would be more than offset by growth in vehicle miles traveled, which is a function of the number of vehicles on the road and the average miles per vehicle. As a result, the transportation sector, the nation’s second-largest emitter of GHGs, would see its emissions grow 1.3 % per year, rising from 2.1 gigatons in 2005 to 2.8 gigatons by 2030.” (p.11)
- “The government emissions reference case [the baseline on which the above projection is based] assumes relatively small improvements in vehicle fuel efficiency. By 2030, cars are projected to average 33 miles per gallon versus 28 today, and the penetration of hybrid electric vehicles would reach 5 % of new vehicle sales.” (p.11)
- “The use of alternative fuels and improvements in fuel efficiency would moderate, but not substantially offset, growth in demand.” (p.11)
- “[W]e organized transportation-related abatement options into three groups: reducing the carbon intensity of the fuel supply, improving fuel efficiency of vehicles, and adopting alternative propulsion technologies.” (p.42)
- “Given our intent to hold consumer utility constant, we did not evaluate demand-management schemes, such as incentives for mass-transit use, congestion pricing, or pay-as-you-go insurance. Nor did we assess the potential for urban designs that foster denser, more transport-efficient communities.” (p.42)
- “Land-based carbon sinks, specifically the carbon stored in U.S. lands and forests, have grown steadily over the past 50 years. Purposeful management

could enhance the ability of these sinks to absorb carbon by some 440 megatons by 2030. This represents a significant opportunity that could be used in the near-term to offset carbon emissions until other sectors develop more cost-effective methods of abatement.” (p.53)

- “The key areas of opportunity [for carbon sinks] include afforestation of pastureland and cropland, conservation tillage, forest management, and usage of winter cover crops.” (p.54)

REPORT

Resources for the Future, “Assessing U.S. Climate Policy Options” (Nov. 2007)

Resources for the Future (RFF) is an independent, non-partisan think tank, which focuses on energy, natural resources, and environmental issues. RFF has established the U.S. Climate Policy Forum, which conducts and disseminates research on climate topics. The RFF has compiled a series of policy papers on climate issues in its report, “Assessing U.S. Climate Policy Options.” The papers in this report focus on options for cost-effectively reducing GHG emissions, and focuses in particular on a “pricing mechanism” as the central element of an economy-wide policy for reducing GHG emissions.

Key conclusions from this report include:

- “Reliance on a pricing mechanism as the core element of domestic climate policy promises lower overall costs to the economy because it creates incentives to exploit the cheapest emissions-reduction options wherever they exist.... Reliance on a pricing mechanism also provides flexibility over time because the aggressiveness of the policy can be adjusted relatively easily in the future by changing a primary parameter: the emissions price.” (p.4)
- “In some areas – particularly in the electricity and transportation sectors – additional policies are likely to be implemented to promote lower-carbon technologies.... These policies can act as complements to a pricing policy, possibly reducing the cost of achieving a particular emissions goal. However, they can also work against an otherwise efficient pricing policy – raising costs at best and creating conflicting incentives at worst.” (p.4)
- “A pricing strategy is appealing because it responds to the need for both policy clarity and flexibility – making it possible, on the one hand, to predict prices and emissions over reasonable timeframes with a reasonable degree of certainty while also facilitating smooth adjustments over time.... Setting a price on GHG emissions sends a transparent signal to everyone engaged in emissions-producing activities – including direct emitters as well as downstream consumers of emissions-producing products – about the value of reducing emissions. Those who can reduce emissions will do so, while those who cannot will face a common CO2 price.” (p.6)

- “The alternative to a single price policy is a more traditional approach to government regulation in which emissions abatement requirements or technology standards and incentives are applied to various GHG sources, such as power plants, factories, cars, and households. While this type of strategy is feasible, evidence suggests it could be much more expensive.... [the cost] could be 10 times higher than achieving the same result through a pricing policy.” (p.7).
- “[N]umerous additional policies [in addition to pricing carbon] have been proposed to reduce GHG emissions and advance other policy objectives in the transportation sector.... [V]arious policies have been proposed to directly address two of the three factors that drive overall GHG emissions from this sector: the fuel economy of new vehicles and net GHG emissions from the production and use of different transportation fuels. The remaining factor is vehicle miles traveled, which has increased by 25 % over the last decade for light-duty as well as larger vehicles. There are few policy alternatives to a carbon price for delivering incentives to reduce travel demand.” (p.17).
- “The argument is also often made that demand for transportation fuel is relatively inelastic at the level of price signal contemplated in most current GHG cap-and-trade proposals; therefore, excluding the transportation sector from an economy-wide CO2 price would not be expected to have the effect of foregoing a significant quantity of GHG emissions abatement. Nevertheless, over time excluding transport sector emissions from a broader pricing policy and relying instead on fuel and vehicle standards is likely to be increasingly inefficient, as CO2 prices rise and the potential impact of higher fuel prices on vehicle miles traveled could become more important.
- “There are many similarities between CO2 taxes and tradable allowance or permits [i.e., cap-and-trade programs]. Both reduce emissions by associating a uniform price with emitting activities at any point in time, leading to efficient, low-cost emission reductions. Both can be administered on upstream fossil-fuel producers (based on the carbon content of the fuel) to capture economy-wide emissions, or on downstream emitters to capture emissions from large sources.” (p.80)
- “Traditional forms of regulation – technology and performance standards – can represent an alternative to emissions trading or CO2 taxes, but can be much more costly because they do not allow the flexibility to shift efforts toward the cheapest emission reduction opportunities. As a complement to emissions trading or CO2 taxes, however, flexible standards can address possible additional market failures and potentially lower costs.” (p.81).
- “Three factors affect CO2 emissions from light-duty vehicles: vehicle use (typically expressed as vehicle miles traveled or VMT), fuel economy (typically expressed as miles per gallon or mpg), and net greenhouse gases associated with the consumption and use of the transportation fuel(s) used....” (p. 162)
- “Growth in VMT has been the principal driver of rising emissions from the light-duty vehicle fleet, since fleet fuel economy and fuel carbon content have remained relatively unchanged over the last decade.” (p. 162)

- “An emissions tax or cap-and-trade system (or other carbon pricing mechanism) is the only incentive policy that simultaneously addresses all three factors, efficiently allowing trade-offs among them. Policies that target vehicle fuel economy or fuel carbon content, by contrast, do not provide incentives for reducing VMT.” (p.162)
- “If it becomes necessary over time to undertake very deep reductions in transport-sector emissions, fundamentally new technologies, infrastructure, and related institutions could be needed. Policies that may work well in the near term to elicit early emission reductions at a reasonable cost may not be as effective in a context where much deeper reductions and significant technology breakthroughs are required.” (p. 163)

REPORT

Congressional Budget Office, “Policy Options for Reducing CO2 Emissions” (Feb. 2008)

The Congressional Budget Office (CBO) conducts research and analysis on budget-related issues for the U.S. Congress, including the potential budgetary effects of pending legislation. At the request of the chairman of the Senate Committee on Energy and Natural Resources, the CBO recently prepared a report on policy options for reducing CO2 emissions.

Key Findings:

- “Most analyses suggest that a carefully designed program to begin lowering CO2 emissions would produce greater benefits than costs.” (p.vii)
- “The most efficient approaches to reducing emissions involve giving businesses and individuals an incentive to curb activities that produce CO2 emissions, rather than adopting a ‘command and control’ approach in which the government would mandate how much individual entities could emit or what technologies they should use. (p.vii)
- “Incentive-based policies include a tax on emissions, a cap on the total annual level of emissions combined with a system of tradable emission allowances, and a modified cap-and-trade program that includes features to constrain the cost of emission reductions that would be undertaken in an effort to meet the cap.” (p.vii)
- “A tax on emissions would be the most efficient incentive-based option for reducing emissions and could be relatively easy to implement.” (p.viii)
- “An inflexible annual cap (one whose level was not affected by the price of emission allowances and under which firms would not be allowed to bank or borrow allowances) would be the least efficient option among those considered here, although it could be relatively easy to implement, depending on key design

features.” (p. viii)

- “A cap-and-trade program that included a price ceiling (safety valve) and either a price floor or banking provisions could be significantly more efficient than an inflexible cap, although somewhat less efficient than a tax. It might also be relatively easy to implement, depending on specific design decisions.” (p.ix)
- “Moderating the price of allowances by altering the stringency of a cap—or the extent to which firms could use banked and borrowed allowances—would be considerably more difficult to implement than setting a price floor or ceiling directly.” (p.ix)

REPORT

Jonathan L. Ramseur, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns*, Congressional Research Service Report for Congress (April 4, 2008)

This report evaluated the role of offsets in a greenhouse gas emissions cap-and-trade program.

A few key findings include:

- “The ability to generate offsets may:

Provide an incentive for non-regulated sources to reduce, avoid, or sequester emissions (where these actions would not have occurred if not for the offset program);

Expand emission mitigation opportunities, thus reducing compliance costs for regulated entities;

Offer environmental co-benefits for certain projects;

Support sustainable development in developing nations; and create new economic opportunities and spur parties to seek new methods of generating offsets.” (p. 24)

- “The main concern with offset projects is whether or not they produce their stated emission reductions. To be credible, an offset ton should equate to a ton reduced from a direct emission source, such as a smokestack or exhaust pipe. If offset projects generate emission credits for activities that would have occurred anyway (i.e., in the absence of the emission trading program), these credits would not satisfy the principle of additionally. For many offset projects, determining additionally will likely pose a challenge.” (p. 24)
- “Another concern is whether the inclusion of offsets would send the appropriate price signal to encourage the development of long-term mitigation technologies. Policymakers may consider a balance between price signal and program costs.” (Summary)

- “If eligible in a U.S. program, international offsets are expected to dominate in early decades, because they would likely offer the lowest-cost options.” (Summary)
- “Another debate may focus on the possible effects of offsets in the developing world (assuming international offsets are allowed in a federal program). On one hand, many of the offset projects may offer significant benefits — more efficient energy infrastructure, improved air quality — to local communities. On the other hand, some maintain that if developed nations use all of the low-cost offsets in developing nations, the developing nations will face higher compliance costs if and when they establish GHG emission reduction requirements. Moreover, there is some concern that international offsets may serve as a disincentive for developing nations to enact laws or regulations limiting GHG emissions, because they would lose funding from the offset market.” (p. 25)

REPORT

World Resources Institute and World Business Council for Sustainable Development, *The GHG Protocol for Project Accounting* (December 2005).

This report provides specific principles, concepts, and methods for quantifying and reporting GHG reductions from climate change mitigation projects. It was produced using a collaborative process involving businesses, NGOs, governments, academics, and others.

Overview:

- “The Project Protocol’s objectives are to:
 - Provide a credible and transparent approach for quantifying and reporting GHG reductions from GHG projects;*
 - Enhance the credibility of GHG project accounting through the application of common accounting concepts, procedures, and principles; and*
 - Provide a platform for harmonization among different project-based GHG initiatives and programs.” (p. 5)*
- “The Project Protocol has four parts. Part I presents GHG project accounting concepts and principles, as well as background information and a discussion of policy issues related to GHG project accounting. Part II contains the procedures and analyses that are required to quantify, monitor, and report GHG reductions. Part III provides two case study examples of how to quantify GHG reductions from GHG projects, and Part IV includes annexes to supplement the requirements and guidance contained in Parts I and II.” (p. 5)

REPORT

Marilyn A. Brown, Frank Southworth, and Andrea Sarzynski;
Brookings Institution, "Shrinking the Carbon Footprint of Metropolitan America" (May, 2008)

This report quantifies transportation and residential carbon emissions for the 100 largest U.S. metropolitan areas. The transportation analysis was based on data from the FHWA's Highway Performance Monitoring System (HPMS) to compare vehicle travel activity across different metropolitan areas, but the analysis did not include carbon emissions from public transportation. Key findings include the following:

- "Metro area residents have smaller carbon footprints than the average American, although metro footprints vary widely." (p. 3)
- "Residential density and the availability of public transit are important to understanding carbon footprints, as are the carbon intensity of electricity generation, electricity prices, and weather.." (p. 3)
- "The average metro area resident's partial carbon footprint (2.24 metric tons) in 2005 was only 86 percent of the average American's partial footprint (2.60 metric tons). The difference owes primarily to less car travel and residential electricity use, rather than freight travel and residential fuels." (p. 16)
- Five targeted federal policies were recommended:
 - "Promote more transportation choices to expand transit and compact development options
 - Introduce more energy-efficient freight operations with regional freight planning
 - Require home energy cost disclosure when selling and "on-bill" financing to stimulate and scale up energy-efficient retrofitting of residential housing
 - Use federal housing policy to create incentives for energy- and location efficient decisions
 - Issue a metropolitan challenge to develop innovative solutions that integrate multiple policy areas." (p. 3 and 4)

V. STRATEGIES TO REDUCE GHG EMISSIONS IN TRANSPORTATION SECTOR

REPORT

David L. Greene and Andreas Schafer, Pew Center on Global Climate Change, "Reducing Greenhouse Gas Emissions from U.S. Transportation" (May 2003)

This study, prepared by scientists from the Oak Ridge National Laboratory and Massachusetts Institute of Technology on behalf of the Pew Center, provides an overview of options for reducing GHG emissions from all transportation modes (air, rail, marine, and roads).

- “In 2000, GHG emissions from U.S. transportation amounted to 515 million metric tons of carbon equivalent, more than a quarter of total U.S. GHG emissions. Carbon dioxide is the most important greenhouse gas produced by the transportation sector, accounting for 95 % of the warming effect of transportation’s GHG emissions.” (p.2)
- “Within the transportation sector, highway transportation dominates both energy use and GHG emissions. Highway vehicles account for 72 % of transportation energy use and carbon emissions.” (p.2)
- “Within the highway mode, light-duty vehicles (passenger cars and light trucks) account for 75 % of highway energy use.” (p.3)
- “Since 1980, CO2 emissions from transportation have increased more rapidly than from any other energy-using sector.” (p.3)
- “Transportation’s energy use and GHG emissions since 1970 have increased more slowly than transportation activity because of significant improvements in energy efficiency by nearly all modes of transport. From 1975 to 1988, new passenger car miles per gallon increased from 15.8 to 28.6, and new light truck miles per gallon grew from 13.7 to 21.2.” (p. 8)
- “Over the past decade, however, improvements in transportation energy efficiency have been modest to non-existent.... Today’s new passenger cars and light trucks get fewer miles per gallon than the vehicles sold fifteen years ago. Because it takes 15 years or more for changes in new vehicle fuel economy to fully transform the on-road vehicle fleet, the average fuel economy of all passenger cars and light trucks on the road continued to inch upward from 19.6 mpg in 1991 to 20.1 mpg in 2000..” (p.9)
- “There are four fundamental ways to reduce carbon emissions from the transportation sector: (1) increase the energy efficiency of transportation vehicles, (2) substitute energy sources that are low in carbon for carbon-intensive sources,(3) increase the efficiency with which transportation systems provide mobility, and (4) reduce transportation activity. Various options are available to achieve these goals.” (p.10)
- “Despite decades of efforts, no one has found the key to unlock the massive potential of carpooling. Success has been achieved in specific areas under special conditions (High-Occupancy-Vehicle requirements, parking restrictions) or for limited periods of time. Increased occupancy rates have made a sustained contribution to the energy efficiency of air travel, but how to raise automobile occupancy rates nationwide remains a mystery. Until a workable approach is found, the practical potential for reducing GHG emissions by increasing vehicle occupancy is small, despite the 10 trillion empty seat miles Americans produce each year.” (p.37)
- “Achieving large-scale shifts in transportation activity to favor more efficient modes has proven difficult. For example, although there are very large

differences in the energy intensities of freight modes, little effort has been expended trying to shift freight traffic from truck to rail or rail to water in order to reduce energy use and GHG emissions. Attempts to do so would run counter to the increasing requirements for speed and reliability of an increasingly service-oriented economy. In addition, because different modes offer different services in terms of cost, speed, and performance, the differences in energy intensity are greatly reduced when one compares modes based on equivalent levels of service.” (p.37)

- “Significantly reducing national GHG emissions via increased use of transit would require momentous efforts. All modes of transit (bus and rail) account for only 1 % of passenger-miles traveled in the United States today. Doubling national transit use would affect only 1 % of total passenger travel. This suggests that even innovative solutions, such as Bus Rapid Transit (BRT), which seeks to combine the speed, reliability and comfort of rail transit with the flexibility of buses, can have only a very limited impact on GHG emissions at the national scale.” (pp.38-39)
- “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 % over a period of thirty years, and perhaps 9 to 10 % 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 % by changing the design of subdivision development to more closely resemble the grid street layouts and mixed land uses of pre-WWII communities.” (p.40)
- “A synthesis of recent studies finds that travel is relatively insensitive to changes in the built environment alone, estimating that doubling local densities of population and employment could be expected to reduce vehicle miles traveled by only about 5 %. Improving regional accessibility (defined by the distances to regional centers) could have a much larger impact. The implication is that major changes in the geography of American cities would be needed, combined with additional pricing policies, to achieve reductions in travel of more than 10 %.” (p.41)
- “A historical review of non-pricing measures to reduce travel, such as ridesharing, transit improvements, HOV lanes, bicycle and pedestrian facilities, flexible work hours, telecommuting, and land-use planning, found that the most effective programs reduced vehicle travel by less than 6 %. Frequently, the impacts were fractions of a% reduction. Obviously, historical achievements do not necessarily predict the performance of future programs. Furthermore, it could well be that the combined effect of an integrated suite of programs could reduce vehicle travel by 10 %, or more. However, realizing significant improvements at a national scale in the United States would be an enormous challenge.” (p.45)
- “Land-use and transportation infrastructure policies will have little immediate impact on GHG emissions, but they could be among the most important policies in the long run.... There is clear evidence that mixed land uses and

neighborhoods designed to accommodate walking and cycling reduce the need for motorized trips without loss of accessibility. Investments in transit infrastructure and land-use policies favoring transit-oriented development not only reduce automobile trips but also increase transit occupancy rates and increase the density of development. Moreover, there are other valid reasons for striving for more efficient land use, including reducing traffic congestion, protecting habitats, and improving air quality.” (p.50)

REPORT

Kelly Gallagher and others, “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)

Researchers at the John F. Kennedy School of Government at Harvard University prepared a discussion paper in July 2007 analyzing potential strategies for reducing GHG emissions from the transportation sector. This paper provides an overview of policy options, weighing the pros and cons of each, and combines those options into “illustrative packages” but does not recommend any specific approach.

Key Findings:

- “The numbers show that U.S. greenhouse gas emissions cannot be sufficiently reduced by focusing on motor vehicles alone, but neither can they be sufficiently reduced without a significant effort in the transport sector.” (p.3)
- “Several circumstances conspire to make the policy-making challenge in this domain especially complex. The four most difficult challenges are (1) the combination of low current fleet fuel economy and long vehicle lifetime, (2) the role of consumer choice in driving and purchasing decisions, (3) the various liabilities of all of the alternative fuels, and (4) the limited likely influence on the transportation sector of economy-wide climate-change policies as compared to transportation-sector-specific policies.” (p. 5)
- “Between 1995-2005, vehicle-miles traveled by cars grew on average 1.6% each year. SUVs, vans, and light trucks experienced a higher growth rate of 3.0%. The EIA Annual Energy Outlook 2007 reference case projects a 1.9% average annual growth rate for light-duty vehicles (<8,500 pounds) through 2030. If the EIA’s projection is correct, Americans will drive their cars twice as far in 2045 as they drive them today.” (p.6)
- “[T]he projected increase in miles driven by American cars in the future could swamp the gains made through improved fuel efficiency in cars. ... [E]ven if vehicle fuel economy is significantly improved, it is difficult to attain any decrease in total passenger vehicle gasoline consumption (and corresponding GHG emissions) if nothing is done to curb the growth in vehicle-miles traveled.” (p.6)

- “Despite the recent enthusiasm for biofuels by many analysts and investors, they are not a ‘silver-bullet’ solution to the oil-dependence and climate-change problems. The fossil alternatives to conventional oil in transport applications – natural gas, tar sands, oil shales, and coal-to-liquids technologies – likewise have constraints and liabilities, as does hydrogen no matter how it is produced.” (p.6-7)
- “There seems to be an emerging consensus that a mandatory ‘economy-wide’ cap on U.S. GHG emissions is needed because it would provide a foundation for the suite of policies that will be needed to address climate change and the other externalities of the existing energy system (such as high foreign oil dependence or air pollution).... Likewise, a national carbon tax would create a national price per ton of CO₂eq. But, if either economy-wide system is adopted, it is not likely that such a policy would address the oil security problem, nor is it likely to significantly reduce GHG emissions from the transportation sector.” (p.9)
- “A national policy that resulted in a tradable permit price of \$100 per ton carbon equivalent (\$27 per ton CO₂eq.), for example, would translate into an increase in the cost of gasoline of only 25 cents per gallon of gasoline. At \$33 per ton of carbon equivalent (\$9 per ton CO₂eq), the carbon permit price or tax would translate into 8 cents per gallon of gasoline, which would be lost in the noise of day-to-day oil price volatility.” (p.9)
- “A suitable strategy is likely to entail a portfolio of approaches and policies constructed so that its elements address different parts of the problem, different paths to achieving the aim, and/or different time frames. In addition, the portfolio approach allows employment of policies that offset each other’s weaknesses and to achieve redundancy where the importance of the aim is deemed to justify paying for this.” (p.12)
- [Policy options discussed in this report include]:
 - Fuel-economy standards*
 - GHG performance standards for vehicles*
 - GHG performance standards for fuels*
 - Volumetric requirements for biofuels*
 - Carbon tax on transportation fuels*
 - Economy-wide GHG cap-and-trade program*
 - Transportation-sector cap-and-trade program*
 - Transportation fuels cap-and-trade program*
 - Feebates*
 - Tariffs on imported fuels and vehicles*
 - Research, development, and demonstration in advanced transportation technologies*
 - Tax incentives and government purchasing*

REPORT

Science Applications International Corporation (SAIC), “Public Transportation’s Contribution to U.S. Greenhouse Gas Reduction” (Sept. 2007)

Science Applications International Corporation (SAIC) prepared this report on behalf of the American Public Transit Association (APTA). The report addresses the potential role of public transportation in reducing greenhouse gas emissions. Following are some key findings:

- “In 2005, public transportation reduced CO₂ emissions by 6.9 million metric tonnes. If current public transportation riders were to use personal vehicles instead of transit they would generate 16.2 million metric tonnes of CO₂. Actual operation of public transit vehicles, however, resulted in only 12.3 million metric tonnes of these emissions. In addition, 340 million gallons of gasoline were saved through transit’s contribution to decreased congestion, which reduced CO₂ emissions by another 3.0 million metric tonnes. An additional 400,000 metric tonnes of greenhouse gases (GHG) were also avoided, including sulfur hexafluoride, hydrofluorocarbons (HFC), perfluorocarbons, and chlorofluorocarbons (CFC).” (p.1)
- “A solo commuter switching his or her commute to existing public transportation in a single day can reduce their CO₂ emissions by 20 pounds or more than 4,800 pounds in a year.... This represents slightly more than two metric tonnes of CO₂ or about 10 % of a two-car family household’s carbon footprint of 22 metric tonnes per year.” (p.2)
- “The carbon footprint of a typical U.S. household is about 22 metric tonnes per year. Reducing the daily use of one low occupancy vehicle and using public transit can reduce a household’s carbon footprint between 25-30%.” (p.2)
- “Public transportation provides many benefits that go beyond energy and CO₂ savings – as transit assets are being used to accomplish these important functions. Investments in public transportation have the benefit of supporting higher density land uses that allow for fewer vehicle miles of travel. While it is difficult to precisely measure this impact, a number of studies have attempted to estimate the relationship between transit passenger miles and vehicle miles traveled (VMT) reduction as a proxy for this effect. The results range from a reduction in VMT of between 1.4 miles and 9 miles for every transit passenger mile traveled. The outcome would be more efficient use of roadways, reduced road maintenance, shorter highway commute times and reduced need for street and off- street parking.” (p.3)

REPORT

Reid Ewing, et al., "Growing Cooler: The Evidence on Urban Development and Climate

Change" Urban Land Institute (Oct. 2007)

The Urban Land Institute (ULI) and other organizations commissioned this report to address the relationship between urban development, travel, and GHG emissions from automobiles. The other organizations that sponsored the report were Smart Growth America, the Center for Clean Air Policy, and the National Center for Smart Growth Research and Education.

Key Findings:

- "For climate stabilization, a commonly accepted target would require the United States to cut its carbon dioxide (CO₂) emissions by 60 to 80 % as of 2050, relative to 1990 levels. Carbon dioxide levels have been increasing rapidly since 1990, and so would have to level off and decline even more rapidly to reach this target level by 2050." (p.1)
- "This publication demonstrates that the U.S. transportation sector cannot do its fair share to meet this target through vehicle and fuel technology alone. We have to find a way to sharply reduce the growth in vehicle miles driven across the nation's sprawling urban areas, reversing trends that go back decades." (p.1)
- "The United States is the largest emitter worldwide of the greenhouses gases that cause global warming. Transportation accounts for a full third of CO₂ emissions in the United States, and that share is growing as others shrink in comparison, rising from 31 % in 1990 to 33 % today It is hard to envision a "solution" to the global warming crisis that does not involve slowing the growth of transportation CO₂ emissions in the United States." (p.1)
- "Transportation CO₂ reduction can be viewed as a three-legged stool, with one leg related to vehicle fuel efficiency, a second to the carbon content of the fuel itself, and a third to the amount of driving or vehicle miles traveled (VMT). Energy and climate policy initiatives at the federal and state levels have pinned their hopes almost exclusively on shoring up the first two legs of the stool, through the development of more efficient vehicles (such as hybrid cars) and lower-carbon fuels (such as biodiesel fuel). Yet a stool cannot stand on only two legs." (p.2)
- "CO₂ emissions will continue to rise, despite technological advances, as the growth in driving overwhelms planned improvements in vehicle efficiency and fuel carbon content. The U.S. Department of Energy's Energy Information Administration (EIA) forecasts that driving will increase 59 % between 2005 and 2030 ..., outpacing the projected 23 % increase in population. The EIA also forecasts a fleetwide fuel economy improvement of 12 % within this time frame, primarily as a result of new federal fuel economy standards for light trucks.... Despite this improvement in efficiency, CO₂ emissions would grow by 41 %...." (p.3)

- " As the projections show, the United States cannot achieve such large reductions [15 to 30 % by 2020, and 60 to 80 % by 2050] in transportation-related CO2 emissions without sharply reducing the growth in miles driven." (p.4)
- "The potential of smart growth to curb the rise in greenhouse gas emissions will, of course, be limited by the amount of new development and redevelopment that takes place over the next few decades, and by the share of it that is compact in nature.... According to the best available analysis... two-thirds of the development on the ground in 2050 will be built between now and then. Pursuing smart growth is a low-cost climate change strategy, because it involves shifting investments that have to be made anyway." (p.9)
- "When viewed in total, the evidence on land use and driving shows that compact development will reduce the need to drive between 20 and 40 %, as compared with development on the outer suburban edge with isolated homes, workplaces, and other destinations. It is realistic to assume a 30 % cut in VMT with compact development." (p.11)
- "Making reasonable assumptions about growth rates, the market share of compact development, and the relationship between CO2 reduction and VMT reduction, smart growth could, by itself, reduce total transportation-related CO2 emissions from current trends by 7 to 10 % as of 2050. This reduction is achievable with land-use changes alone. It does not include additional reductions from complementary measures, such as higher fuel prices and carbon taxes, peakperiod road tolls, pay-as-you drive insurance, paid parking, and other policies designed to make drivers pay more of the full social costs of auto use." (p.11)
- "Addressing climate change through smart growth is an attractive strategy because, in addition to being in line with market demand, compact development provides many other benefits and will cost the economy little or nothing. Research has documented that compact development helps preserve farmland and open space, protect water quality, and improve health by providing more opportunities for physical activity." (p.11)
- "The key to substantial greenhouse gas (GHG) reductions is to get all policies, funding, incentives, practices, rules, codes, and regulations pointing in the same direction to create the right conditions for smart growth. Innovative policies often are in direct conflict with the conventional paradigm that produces sprawl and automobile dependence." (p.12)
- "Here, we outline three major policy initiatives at the federal level that would benefit states, metro regions, cities and towns in their efforts to meet the growing demand for compact development." (p.12)
- "*Require Transportation Conformity for Greenhouse Gases.* Federal climate change legislation should require regional transportation plans to pass a conformity test for CO2 emissions, similar to those for other criteria pollutants." (p.12)

- *“Enact “Green-TEA” Transportation Legislation that Reduces GHGs.* The Intermodal Surface Transportation Efficiency Act of 1991 (known as ISTEA) represented a revolutionary break from past highway bills with its greater emphasis on alternatives to the automobile, community involvement, environmental goals, and coordinated planning. The next surface transportation bill could bring yet another paradigm shift; it could further address environmental performance, climate protection, and green development. We refer to this opportunity as “Green-TEA.” (p.12)
- *“Provide Funding Directly to Metropolitan Planning Organizations (MPOs).* Metropolitan areas contain more than 80 % of the nation’s population and 85 % of its economic output. Investment by state departments of transportation in metropolitan areas lags far behind these percentages. The issue is not just the amount of funding; it is also the authority to decide how the money is spent. What is necessary to remedy the long history of structural and institutional causes of these inequities is a new system of allocating federal transportation funds directly to metropolitan areas. The amount of allocation should be closer to the proportion of an MPO’s population and economic activity compared to other MPOs and non-MPO areas in the same state.” (p.12)

REPORT

Matthew Barth and Kanok Boriboonsomsin, “Real-World CO2 Impacts of Traffic Congestion” University of California at Riverside (Nov. 2007)

Researchers at the University of California at Riverside prepared this paper for the Transportation Research Board Annual Meeting in January 2008. The paper focuses on the potential for GHG emissions to be reduced by relieving traffic congestion. It concludes that congestion-relief projects and related strategies can help to reduce GHG emissions.

- “In order to reduce CO2 emissions from the transportation sector, policy makers are primarily pushing for more efficient vehicles and the use of alternative fuels.” (p.3)
- “Although these options look very promising, they are unlikely to make a great impact in the near term. Some of them (e.g. fuel-cell vehicles) are still in their early stages of technology development and probably will need a dramatic breakthrough before they can be fully implemented. For those that are technology-ready and have started to enter the market (e.g. hybrid vehicles and alternative fuels), it will still probably take several years for a majority of the existing fleet to be turned over before a significant impact on CO2 can be seen.” (p.3)
- “With all that being said, it can be pointed out that comparatively less attention has been given to CO2 emissions associated with traffic congestion and possible short-term CO2 reductions as a result of improved traffic operations.” (p.3)

- “When average speeds are very low, vehicles experience frequent acceleration/deceleration events. They also do not travel very far. Therefore, grams per mile emission rates are quite high. In fact, when a car is not moving, a distance-normalized emission rate reaches infinity. Conversely, when vehicles travel at higher speeds, they experience higher engine load requirements and, therefore, have higher CO2 emission rates. As a result, this type of speed-based CO2 emission-factor curve has a distinctive parabolic shape, with high emission rates on both ends and a minimum rate at moderate speeds of around 45 to 50 mph.” (p.9)

- “Several important results can be derived from this information ...:

“In general, whenever congestion brings the average vehicle speed below 45 mph (for a freeway scenario), there is a negative net impact on CO2 emissions. Vehicles spend more time on the road, which results in higher CO2 emissions. Therefore, in this scenario, reducing congestion will reduce CO2 emissions.

“If moderate congestion brings average speeds down from a free-flow speed of about 65 mph to a slower speed of 45 to 50 mph, this moderate congestion can actually lower CO2 emissions. If relieving congestion increases average traffic speed to the free-flow level, CO2 emissions levels will go up.

“Extremely high speeds beyond 65 mph can cause adverse impact on CO2 emissions. If these excessive speeds can be controlled, there will not only be direct safety benefits but also indirect benefits of CO2 reduction.

“If the real-world, stop-and-go velocity pattern of vehicles could somehow be smoothed out so an average speed could be maintained, significant CO2 emissions reductions could be achieved.” (p.9)

- “It is clear that traffic congestion has a significant impact on CO2 emissions. Overall, even small changes in traffic speed can have significant effect on CO2 emissions. This paper has examined several methods that CO2 can be reduced by improved traffic operations (with particular emphasis on freeway operations). These include:
 1. Congestion mitigation strategies that reduce severe congestion such that higher average traffic speeds are achieved (e.g. ramp metering, incident management);
 2. Speed management techniques that can bring down excessive speeds to more moderate speeds of approximately 55 mph (e.g. enforcement, active accelerator pedal); and
 3. Traffic flow smoothing techniques that can suppress shock waves, and thus, reduce the number of acceleration and deceleration events (e.g. variable speed limits, ISA [intelligent speed adaptation]).” (p.9-10)

REPORT

Center for Clean Air Policy, "CCAP Transportation Emissions Guidebook, Part One: Land Use, Transit, and Travel Demand Management," (2005) and Part Two: Vehicle Technology and Fuels (2006)

Part One of this report focuses on policies related to travel demand and examines the impacts of land use and investment decisions on transportation emissions. Policies analyzed include transit-oriented development, bicycle initiatives, pay-as-you-drive insurance, light rail, comprehensive smart growth policy, etc.

Part Two focuses on measures that influence vehicle technology, fuel and operational choices that impact transportation emissions. Policies discussed include: feebates, hybrid vehicles, biofuels, low-rolling resistance tires, truck stop and vessel electrification, locomotive technologies, driver training, etc.

Summary of Guidebook and Key Findings:

- “The purpose of the CCAP Transportation Emissions Guidebook is to provide basic ‘rules of thumb’ to calculate emissions reductions from the implementation of specific transportation and land use policies. The guidebook is a unique tool that consists of a user-friendly spreadsheet tool, or Guidebook Emissions Calculator, which enables users to quantify the emissions benefits from a variety of projects and policies, a series of policy briefs, and a technical appendix.” (Part One, p. 3)
- “Each part of the guidebook contains a series of policy briefs subdivided into a few key subject areas. An important point to note is that the dividing line between these subject areas is not hard and fast, rather, its purpose is to allow for a more navigable report. Each of the policy briefs includes:

A qualitative description including case studies, implementation issues, and key references

A quantitative analysis including an assessment of potential air quality benefits, energy savings, and GHG reductions (note: the default data tables from the spreadsheet tool are included in the policy briefs)

Web-links to relevant models and resources” (Part One, p. 4)

- “Transportation emissions are the result of three main factors; vehicle technology, fuel characteristics and vehicle miles traveled (VMT). Dramatic progress in emissions control technology and fuel quality has reduced emissions over the past 30 years per mile for NO_x, VOCs and CO (with the exception of CO₂); but rapid growth in the amount of driving is offsetting these reductions, especially in some fast-growing regions. In the case of CO₂ per vehicle, fleet-wide vehicle emission rates have been essentially stagnant since 1991 while VMT grew 25% over the same period. As seen in the figure below, long-term

growth in driving is expected to outpace the CO2 emissions benefits of vehicle technology improvements.” (Part One, p. 6)

- “... policies that at the larger scale tend to have the largest impact on VMT. While this is perhaps intuitive, it points to the fact that if, for example, a municipality had a regional TOD policy rather than just working project by project, it could have a significant impact on city-wide VMT. In other words, the implementation of such smaller scale policies or strategies cannot occur in isolation. If only implemented at the site scale, smart growth approaches, such as TOD or infill/brownfield development, are not enough to curb growing rates of automobile use and subsequent transportation emissions. A balance must be achieved across urban regions enabling residents to meet employment, housing, transportation, recreational, education and commercial needs to minimize the need to drive.” (Part One, p. 8)
- “Despite increases in freight transportation productivity, growth in demand for goods over the next two decades will result in freight sector fuel use and GHG emissions increases by up to 50 %. In effect freight growth virtually eliminates any freight’s efficiency gains to date. If such trends continue we will also see an increase in pressure on infrastructure, leading not only to higher rates of GHG emissions but also to lost work time, safety and health concerns.” (Part Two, p. 7)

REPORT

Washington State Department of Transportation (WSDOT), "Climate Change Initiatives of State Departments of Transportation: Synthesis," Jan 10, 2008.

This report was prepared based on a request from Katy Taylor, WSDOT Public Transportation Division Director, who requested a synthesis report on the role of state departments of transportation in climate change initiatives.

Key Findings:

- “...a summary of current initiatives detailed in this report ...:

Incentives to promote the use of low-emissions vehicles, such as carpool-lane access or discounted toll rates;

Stricter emission regulations than those of the federal government (many states have adopted California’s strict low-emission vehicle standards);

Enhanced construction methods that incorporate recycled materials, improved energy efficiency, or other green building strategies;

Programs to promote commuting alternatives to driving, such as telecommuting, transit use, or bicycling;

Intermodal truck-to-rail freight-transfer facilities that reduce congestion and emissions by removing trucks from the roadway;

Fuel efficiency programs that aim to reduce idling or improve transportation flow, such as “No Idling” campaigns, truck stop electrification, and intelligent transportation systems;

Public campaigns to improve awareness of transportation alternatives; and

Grants for local smart-growth development.” (p. 1)

- “In addition to the strategies above, DOTs and their states have developed action plans to propose emission-reduction goals and measures. States are also joining in regional partnerships to advance climate change programs, such as the Western Climate Initiative of which Washington is a member.” (p. 1)

REPORT

Nicholas Lutsey, Daniel Sperling, “America’s bottom-up climate change mitigation policy,” *Elsevier Energy Policy* 36, pp. 673 to 685 (November, 2007)

In this paper, Lutsey and Sperling inventory and analyze local, state, and regional policy actions in the US as to their potential effect on national emissions.

Key findings:

- “US climate change policy is far more complex and rich than what is commonly thought. A wide variety of subnational initiatives are underway. Many are leading to direct and significant emission reductions. Others are setting the stage for future incentives and enforceable policies and rules.” (p. 683)
- “The commitments of lower governments on climate action are steadily amounting to substantial emission-reduction commitments. Sub-national US mitigation efforts represent engagement by 43–89% of the affected populations and responsible parties—including 53% coverage of GHG emissions by state climate change mitigation action plans; 43% coverage of emission sources by state or city emission-reduction targets; 58% coverage of US electricity production by state renewable electricity standards; 47% coverage of US vehicle sales by state vehicle GHG regulations; and 89% coverage of US GHG emissions by multi-government partnerships supporting the establishment of GHG market mechanisms. If the 17 states that have set their own GHG emission-reduction targets (generally to 1990 levels by the year 2020) in fact were to achieve those targets, nationwide US GHG emissions would be stabilized at 2010 levels by 2020 — without any serious mitigation action taken by over half the states.” (p. 683)
- “Of course, governments (and industry) are still at the bottom of the learning curve, though now perceptibly moving up that curve. Even so, these efforts

should not be overstated. The adoption and pursuit of targets, goals, and potential reductions should not be confused with actual mitigation performance, and what has been accomplished still falls far short of the much deeper longer-term cuts that will be needed for global climate stabilization. Moreover, even the best intentions of multiple multi-government partnerships developing consistent emission-tracking systems does not ensure that a cross-jurisdiction and cross sectoral emissions trading mechanism will come to fruition anytime soon, never mind function well.” (p. 683)

REPORT

Kathy Leotta, Implementing the Most Effective Transportation Demand Management (TDM) Strategies to Quickly Reduce Oil Consumption, Parsons Brinckerhoff (January, 2007)

This report helps local and regional government agencies prepare for fuel supply disruptions by (1) describing fuel supply vulnerabilities, (2) reviewing lessons learned from previous fuel supply disruptions, (3) identifying the transportation demand management strategies that offer the most potential to quickly reduce fuel and oil consumption, (4) suggesting implementation timeframes and potential barriers to implementation for these strategies, and (5) recommending pre-planning actions to better prepare for an oil supply disruption. As a case study, this report describes strategies that could be implemented in the central Puget Sound region.

Key Findings:

- “Following are conclusions drawn from a revisiting of lessons learned from previous fuel shortages...

Changes in non-work trips may occur far more frequently than changes in work trips.

Transit systems have only limited capabilities for quickly increasing service to respond to fuel price increases or shortages due to a small supply of extra vehicles and drivers.

Fuel availability has historically affected travel behavior much more than price.

Panic buying of fuel as well as food may be expected during future fuel shortages, especially if the fuel shortages are extreme.

Government agencies at all levels should reassess how they can quickly secure fuel in emergencies.

Government agencies at all levels should better understand their daily fuel requirements and typical fuel supply (especially for police, fire, transit, and other essential services), and buy some fuel under firm contracts.

Although planners in the 1970s and 1980s concluded that fuel shortage planning and response should occur at the lowest levels of government, currently nearly all fuel shortage planning occurs at the state level.” (p. 5)

- *“...the research conducted and described in this report presents a case study of the Puget Sound region to better understand implementation barriers and timeframes for fuel saving strategies.” (p. 5)*

“Alternative work arrangements could be implemented within a few days of a fuel supply emergency in response to a request by the Governor, the state Energy Office, or local or regional government agencies. In particular, flexible work hours and compressed work weeks could be implemented fairly quickly. Increased telecommuting could also occur fairly quickly but could require more preparation by companies or organizations that do not have established telecommuting programs.” (p. 7)

“Although drivers could be encouraged immediately to reduce their maximum speed to 55 mph to conserve fuel, legally reducing the speed limit (e.g., passing the required legislation, fabricating and installing signs, and implementing a public information campaign) would take about three to six months in Washington State, and, assuming a continuing shortage of troopers, a reduced speed limit would be hard to enforce in the short-term. Therefore, if the fuel shortage was viewed as a “temporary” problem lasting just a few months it would be an unlikely strategy. Instead, a public information campaign urging travelers to voluntarily travel at no more than 55 mph might be preferable.” (p. 8)

“The timeframe required to implement public transit service improvements varies widely. Transit fares could be reduced or eliminated very quickly, but only for a very short period of time due to budget constraints. Off-peak transit service capacity could be increased within three to six months, depending on the nature of the emergency. Fixed route bus schedules could be modified to increase ridership within about three to six months. Widely expanding transit service, however, would take much longer. Due to the time needed to purchase buses (18 months) and the additional support system required (e.g., bus maintenance and layover facilities) it would likely take at least two years to widely expand transit service. (p. 10)

“Although carpooling could increase within days of an emergency, there could be some hurdles to overcome if park-and-ride lots fill, or if transit agencies run out of vans for vanpools. Making changes to HOV lanes, however, is more time consuming. According to WSDOT, changing the occupancy requirement of existing HOV lanes would likely take several months, and converting general purpose lanes on major arterials and freeways to HOV lanes would take six months or more, depending on the number of roads involved.” (p. 12)

“...it is important to call out the importance of non-work trips for potential fuel savings because only a small portion of all trips in the Puget Sound region are work-related trips. In addition, during previous fuel shortages or roadway closures, discretionary trips tended to be the first to be altered.” (p. 13)

REPORT

The Role of State DOTs in Support of Transit-Oriented Development (TOD)

Requested by: American Association of State Highway and Transportation Officials (AASHTO), Standing Committee on the Environment (April 2006)

This report describes the role that State Departments of Transportation (DOTs) can play in supporting transit-oriented development (TOD). Activities that have been undertaken or planned by State DOTs to support TOD included and described in this report include the following:

- Establishing TOD as a Priority for the Agency
- Revising Agency Policies and Practices
- Establishing Partnerships
- Conducting Education and Outreach
- Advocating for State Policy Changes
- Providing Technical Assistance
- Leading or Supporting Planning Efforts
- Funding TOD-Supportive Transportation Improvements
- Assisting with Land Purchase and Sale
- Providing Information and Tools to Support Decision-Making

REPORT

AASHTO, "Primer on Transportation and Global Climate Change" (April, 2008)

AASHTO developed this primer as an introduction to the issue of climate change and its implications for transportation policy in the United States. Part I of this primer focuses on the causes and impacts of climate change, and Part II focuses on climate change and public policy. Part III focuses on trends in GHG emissions from road travel, while Part IV focuses on how to reach GHG emissions reduction goals.

Key findings include the following:

- "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.." (p. 4)
- "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.." (p. 4)

- “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 CO₂ emission reductions in the range of 7 to 10 percent.” (p. 5)
- “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 mpgge, and VMT increasing one percent annually through 2050. This scenario achieved a decrease in CO₂ emissions from light-duty vehicles of 68 percent from 2005 levels by 2050.” (p. 5)

REPORT

Tiffany Batac and Lewison Lem, "Transportation Strategies to Mitigate Climate Change," in *ASCE Leadership and Management in Engineering* (July 2008)

This article focuses on state climate action plans in the Western states, examining where they have anticipated receiving the most GHG reductions while also highlighting some of the more cost effective GHG reducing strategies. The purpose is to highlight some of those states that have been in the lead, and to provide guidance to other states that are in the process of, or starting to embark on the process of creating state climate action plans. Analyses were drawn from the state climate action plans of Arizona, New Mexico, Montana, and Colorado.

Key findings include the following:

- “Climate change action plans not only have the potential to mitigate impacts of global warming, they also can save the economy billions of dollars and could greatly impact how we plan transportation projects in the future.” (p. 125)
- The majority of transportation-related mitigation measures can be classified into the following categories: vehicle technology and improvements; low-carbon fuel alternatives; location and land-use efficiency; and transportation system efficiency. (p. 124)
- Future directions include more interstate collaboration in climate action plans, integration with aviation and other modes of travel; and a strategic planning and engineering role in the development of state climate action plans. (p. 131)

REPORT

Center for Transportation Studies, University of Minnesota, "Reducing Greenhouse Gas Emissions From Transportation Sources in Minnesota" (June 2008)

The study focused on three types of emission-reduction strategies: those that improve vehicle fuel economy, those that reduce the number of vehicle-miles traveled, and others that decrease the carbon content of fuel. The researchers used a quantitative model to test the effectiveness of specific strategies for GHG emission reduction from transportation in Minnesota.

Key findings include the following:

- “Our study shows that Minnesota’s 2015 and 2025 reduction goals are technologically achievable. The goals are nearly met in 2015 and are exceeded in 2025 using a combination of strategies targeted to reduce fuel consumption, vehicle-miles traveled, and fuel carbon content for the light-duty vehicle fleet.” (p. 37)
- The research analyzed the effect of varying VMT growth between high (2.3% annually), projected (0.9%), and low (0%) rates (assuming improvements to vehicles and fuels). “With no VMT growth, the reduction goals for 2015 and 2025 are exceeded using a policy bundle consisting of CAFE standards plus LCFS. With the projected VMT growth rate of 0.9%, the goals are nearly achieved, but with the high growth rate, this combination contributes less than half of the target reductions for the two years. This finding illustrates the importance of considering VMT growth rate, rather than only vehicles or fuels, in crafting a comprehensive transportation GHG emission reduction strategy.” (p. 30)
- “Modeled scenario outcomes—which depend strongly on input assumptions—lead us to the following main conclusions:
 - 1. Meeting state goals will require all three types of policies. For example, Minnesota could adopt a GHG emissions standard, a low-carbon fuel standard, and comprehensive transit and Smart Growth policies.
 - 2. Technologies are available today to substantially improve fuel economy and vehicle GHG emissions. Requiring these technologies could save Minnesota consumers money and better insulate them from oil price volatility.
 - 3. Changes in vehicle-miles traveled (VMT) have a strong impact on whether the goals can be met, and increases in VMT can offset GHG reductions.” (Executive Summary)

REPORT

ICF International, "Integrating Climate Change Considerations into the Transportation Planning Process" (July 2008)

This report explores the possibilities for integrating climate change considerations into long range transportation planning processes at state DOTs and MPOs; reviews the

experience of a number of DOTs and MPOs that are already incorporating climate change into their planning processes and identifies their successes as well as challenges; and, reviews the federal planning factors, regulations and statutes that govern transportation planning to determine where and how climate change could be considered. Key findings include the following:

- “Absent any federal action, the treatment of climate change in transportation planning is likely to continue to vary depending on the interests and concerns of local stakeholders, the size of agencies and their capacity to address climate change, and the vulnerabilities specific to regions and their transportation systems. A number of agencies DOTs and MPOs are waiting on decisions or recommendations from state agencies or committees on how they should address climate change. Others see a need for greater involvement from federal or state government in climate change issues. Many agencies are wary of taking steps to change their planning process before more direction from higher government levels is provided.” (p. 35)
- “Small MPOs in particular may benefit from higher level guidance on how and where to incorporate climate change in LRTPs. Small MPOs have fewer resources and less power to set policy precedents than do larger MPOs. The potential burden imposed by future climate change regulations at the state or federal levels is likely greater for small MPOs.” (p. 35)
- “The quantification of GHG emissions in the transportation planning process is a new challenge for transportation agencies. While the estimation of mobile source CO₂ emissions is conceptually simpler than the estimation of criteria pollutant emissions that most transportation agencies already do, there are some unique challenges with the quantification of GHGs” (p. 35)
- “Many transportation agencies are anticipating the need to develop and quantify the benefits of strategies to reduce GHG emissions. A number of DOTs and MPOs have been involved in this exercise through their participation in state climate action plans. A few MPOs are taking steps to incorporate GHG mitigation into their planning, prompted by state mandates. There is concern among some transportation agencies that many of the most effective mitigation strategies are outside their sphere of direct influence (such as vehicle fuel efficiency, alternative fuels, and land use), while other potentially effective strategies (such as widespread use of roadway pricing) may be politically difficult.” (p. 35)
- “Most transportation agencies are not currently seeking to incorporate climate change adaptation measures into long range planning. While there is general recognition of the threat that climate change poses to transportation infrastructure, agencies feel that significant impacts are at least several decades away, so there is little sense of urgency. In addition, the large uncertainty in the location and magnitude of impacts makes agencies reluctant to take major action on adaptation, given the multitude of other pressing demands for DOTs and their funding limitations. Over the next several years, as more sea level rise studies are completed and scientists improve the precision of climate change forecasts, adaptive responses are likely to be more substantially incorporated into long range planning.” (p. 35)

PRESENTATION

Steve Heminger, Metropolitan Transportation Commission, "Regional Policies for TOD: the San Francisco Bay Area Experience," Rail-Volution (November 2007)

Key findings from this presentation include the following:

- Even with aggressive pricing (five-fold increase in auto operating costs), infrastructure (primarily HOV, transit and rail), and land use strategies, the region falls far short of meeting GHG reduction goals to 2035.
- To close the gap, more aggressive measures will be required such as:
 - Pricing near-term;
 - Greater land use changes in longer-term
 - Diversion of auto trips with pricing and focused growth: + 2.1 million bike/pedestrian trips and +700,000 new transit trips.
 - Greater increases in fuel economy will be needed (to 54 mpg),
 - Increasing the share of zero-emission vehicles to 55 percent, and
 - Increasing telecommuting from 3 percent to 10 percent.

VI. TRANSPORTATION AND CLIMATE CHANGE IN EUROPE

REPORT

Transport and Climate Change, Commission for Integrated Transport (2007)

The UK Government set a 60% reduction target by 2050 for the carbon emissions that are widely accepted as one of the key causes of climate change. Much of the responsibility for hitting this target rests on the UK transport sector, as one of the prime and growing causes of carbon emissions in the UK today. In its role as a key advisory body to Government on transport, the Commission for Integrated Transport (CfIT) put together a report in order to (1) identify areas of transport in which carbon emissions could most cost-effectively be targeted; (2) look at practical and deliverable ways of targeting those areas of transport mode and behavior; and (3) evaluate those measures in terms of affordability, acceptability, fairness and deliverability, to recommend a package of readily implementable solutions.

Key findings of this study include:

- "Technological improvements have delivered carbon-reduction benefits, but in some cases these have been either offset or out-stripped by rising demand and choices made by transport users – trends that are set to continue in future unless action is taken now. Transport (including international transport) is now the largest end-use category of emissions in the UK, accounting for between a quarter and one-third of UK carbon emissions (depending on which definitions are used). Within this, road transport is the main component, of which cars are the most significant element." (p. 9)

- “In the UK, transport has been the only sector whose carbon emissions were higher in 2005 than they were in 1990, a period in which reductions achieved by other sectors of the economy helped deliver a cut in total UK carbon emissions of just over 5%.” (p. 9)
- “Emissions from air travel, and from the movement of vans and lorries, have been among the fastest-growing sources of transport emissions in the UK. Emissions from cars have been stable since 1990, while those from public transport have fallen.” (p. 9)
- “The Government’s own approach is informed by modeling which indicates that transport emissions could potentially fall by as much as 45% against 2000 levels by 2050, helping to deliver its goal to cut UK emissions by 60% by this date against 1990 levels. In the shorter term, the impact of the main programme of current policies to tackle transport emissions, if delivered successfully, would be to avoid growth that would otherwise happen and to stabilize transport emissions at broadly 2005 levels by 2020.” (p. 9)
- “While we support the Government’s efforts in tackling CO2 emissions within the transport sector, the transport element of the Climate Change Programme (CCP) appears to depend heavily on relatively expensive, technology-based measures to deliver emissions savings by 2020 – and there is an additional opportunity to capture greater cost-effective carbon savings through measures to encourage behavioral change.” (p. 9)
- “We have identified scope for an integrated set of measures that builds on the measures included in the Government’s Climate Change Programme in a cost-effective way. This would significantly increase the carbon savings that would otherwise be expected from the CCP and would mean that, for the first time, emissions from this sector could begin to fall against 1990 levels. The combined effect would increase cost-effectively the carbon savings expected from the CCP by 71%, which would mean that transport emissions would fall by 14% against 1990 levels by 2020, instead of stabilizing broadly at 2005 levels.” (p. 9)
- “Key features of our approach are a focus on tackling either the largest or fastest-growing areas of transport emissions, and an emphasis on measures to encourage behavior change by transport users as a way of ‘locking in’ the benefits from technological developments.” (p. 9)
- “We have identified five key packages of measures to deliver additional carbon savings from transport by 2020:

A mandatory EU target for new car sales of 100 g CO2/km but with a deadline (2020) that allows a more cost-effective response by the industry, combined with measures to stimulate demand for lower-emission vehicles;

An incentive and reward approach to promoting more efficient use of cars through the price of fuel, greater promotion of eco-driving and better enforcement of speed limits;

More intensive promotion of smarter choices to encourage take-up of alternatives to car travel supported by improvements to the carbon performance of public transport;

Measures to capture the significant opportunities for carbon reduction in van and lorry fleets; and

The inclusion of aviation in the EU-ETS and consideration of supplementary measures to crystallize and develop further the emissions reduction potential of this sector.” (p. 9)

REPORT

European Conference of Ministers of Transport, "Transport and Environment: Review of CO2 Abatement Policies for the Transport Sector," (June 2006)

This report reviews the progress the European Conference of Ministers of Transport (ECMT) and Organization for Economic Cooperation and Development (OECD) countries have made in reducing transport sector CO2 emissions and makes recommendations for the focus of future policies.

Key Findings:

- "... transport sector CO2 emissions steadily increased over the last 10 years despite significant efforts to cut them in some countries. Assuming real household disposable incomes continue to grow at a faster rate than the real cost of transport this trend is likely to continue. Slowing the growth of transport sector CO2 emissions would require more government action and an increasingly proactive role from transport sector industries in improving energy efficiency." (p. 2)
- "Carbon and fuel taxes are the ideal measures for addressing CO2 emissions. They send clear signals and distort the economy less than any other approach. Fuel taxes already exist in all member countries and whilst changes in tax rates are sensitive politically, because they are highly visible, developing substitute policies usually increases costs significantly." (p. 3)
- "Within the transport sector, policies currently tend to focus on some of the higher cost measures available, for example subsidies for biofuels, whilst some low cost measures are neglected. The focus should now switch to the lower cost options identified in the report submitted to Ministers, notably: regulation and labeling for some vehicle components, such as tyres, not included in standard tests of vehicle efficiency; support for eco-driving and for improved freight logistics; better use of differentiated vehicle taxes, particularly in markets where stringent but voluntary emissions standards apply; tightening of vehicle emissions standards in regions where they are relatively weak in order to benefit from the technology already developed for markets elsewhere; and as noted, fuel taxes." (p. 3)

- “The largest CO2 abatement opportunities in the transport sector lie in initiatives to improve energy efficiency: improving the rated fuel efficiency of new vehicles as measured by vehicle certification testing; improving the efficiency of components and accessories not covered in current test procedures; and improving on-road vehicle performance.” (p. 4)
- “Examination of policies for CO2 emissions reduction in the transport sector so far adopted by OECD/ECMT governments, in terms of the number of policies being pursued, reveals that countries place improving fuel efficiency and modal shift on an equal footing. Policies to promote alternative fuels have also been given a prominent role, while reducing demand for transport is largely ignored.” (p. 6)
- “The large number of modal shift policies is believed to be the result of following a “co-benefits” approach to CO2 abatement policy. That is, governments have selected abatement policies that also contribute to the achievement of other transport policy goals or wider objectives beyond the transport sector. This includes providing access to low cost public transport and reducing congestion. This is a valid approach to public policy and, indeed, was part of the recommendations of ECMT’s 1997 review of CO2 emissions from transport. The present situation may, however, reflect an over-emphasis on the co-benefits approach. Modal shift policies are usually weak in terms of the quantity of CO2 abated and have generally been inadequately assessed in national communications on CO2 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 CO2 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 focusing on fuel efficiency.” (p. 7)
- “The official estimates for the impact of the electronic truck km-charges introduced in Europe and the London Congestion Charge suggest they have significantly reduced emissions. Truck km-charges provide strong incentives to rationalize distribution systems and logistic organization. Electronic charging for road use is expected to spread, albeit with the primarily aim of ensuring foreign vehicles contribute to road costs and managing congestion.” (p. 7)
- “For the short and medium term, policies that target fuel efficiency offer most potential for reducing CO2 emissions. The most effective measures available include fuel taxes, vehicle and component standards, differentiated vehicle taxation, support for eco-driving and incentives for more efficient logistic organization, including point of use pricing for roads. For the long term, more integrated transport and spatial planning policies might contain demand for motorized transport. Ultimately higher cost energy sources, including clean energy carriers such as hydrogen and electricity, produced from renewable energy sources, or from fossil fuels with carbon sequestration and storage, will be required if there are to be further cuts in transport sector CO2 emissions. Major R&D programs will be required to bring these technologies to commercial viability.” (p. 9)

REPORT

Jonas Noreland, EuroStat Statistics in Focus, Modal split in the inland transport of the EU, Freight and passenger transport up to 2006 (2008)

This report explores trends and modal splits for freight and passenger transport for 2006 in rail, road, inland waterways, and pipelines.

Key findings on passenger transportation:

- “In 2004, road passenger transport in the EU-27 by passenger cars, motor coaches, buses and trolley buses was almost 5 000 billion pkm, an increase of 16 % compared to 1995. In 2004, passenger cars accounted for 87% of the transport of passengers by road.” (p. 1)
- “Rail passenger transport reached 380 billion pkm in the EU-27 in 2006. Four countries accounted for more than 65% of the EU passenger transport: France and Germany (79 billion and 78 billion pkm), followed by the United Kingdom and Italy (47 and 46 billion pkm).” (p. 3)
- In 2004, road passenger transport performed in the EU-27 by passenger cars, motor coaches, buses and trolley buses was slightly over 5 000 billion pkm. This represented an increase of 17 % compared to 1995 (4 351 billion pkm). Road passenger transport continuously increased over the period 1995 to 2004. (. 5)
- “All Member States recorded increases in their road passenger transport, the highest increases being recorded in most cases in the Member States that joined the EU since 2004. In 2004, passenger cars accounted for 87% of the transport of passengers by road in the EU-27. Motor coaches, buses and trolley buses were used for 10% of passenger transport, while motorcycles represented only 3% of the transport of passengers by road.” (p. 5)

REPORT

Professor Julia King, The King Review of Low-Carbon Cars, Part I: The Potential for CO₂ Reduction (October 2007) and Part II: Recommendations for Action (March 2008)

The Chancellor of the Exchequer set up the King Review to “examine the vehicle and fuel technologies that, over the next 25 years, could help to decarbonise road transport, particularly cars.” Phase I considers the potential for CO₂ reduction in transportation, while Phase II results in 40 recommendations for action, which focus on vehicle emissions, cleaner fuels, consumer choices, and research and development.

Key findings include the following:

- “In the long-term (possibly by 2050 in the developed world), almost complete decarbonisation of road transport is a possibility. If substantial progress can be made in solving electric vehicle technology challenges and, critically, the power-sector can be decarbonised and expanded to supply a large proportion of road

transport demand, around a 90 per cent reduction per kilometre emissions would be achievable across the fleet.” (Part I p. 4)

- “By 2030, emissions per kilometre could be around 50 per cent below 2000 levels. This would be partly offset by the projected increase in distance traveled, implying an overall reduction in UK emissions from car use of approximately 30 per cent by 2030.” (Part I p. 4)
- “In the long term, carbon-free road transport fuel is the only way to achieve an 80-90 percent reduction in emissions, essentially “decarbonisation”. Given biofuels supply constraints, this will require a form of electric vehicle, with novel batteries, charged by “zero-carbon” electricity (or, possibly, hydrogen produced from zero-carbon sources).” (Part I p. 4)
- “Major changes in power generation therefore need to be delivered alongside the automotive technologies. Making progress on decarbonising power generation represents an even more urgent challenge than electric vehicle technologies because of the time it takes to implement.” (Part I p. 5)
- “Savings of around 10-15 percent could come from consumer behavior, much of this over the next few years.” (Part I p. 5)
- “Recommendations for the short and medium term are aimed at:
 - Bringing existing low emission technologies from ‘the shelf to the showroom’ as quickly as possible;
 - Ensuring a market for these low emission vehicles;
 - Moving the short-term focus back from biofuels to automotive technology;
 - Making sure that further biofuel developments are based on our growing understanding of their indirect effects; and
 - Ensuring the automotive industry has the right requirements and signals to deliver step-change technologies in the medium term.” (Part II, p. 5)
- “In parallel there are a number of recommendations to enable the UK to play a leading role in low-CO2 automotive developments:
 - As an influential international voice;
 - As a location for high technology companies in the field, with good businesses support mechanisms encouraging inward investment, which has the potential to make a significant contribution to the UK economy;
 - Collaborating with developing and emerging economies to enable them to introduce affordable low emissions technology at the earliest opportunity; and
 - As a leader in key areas of underpinning science and engineering for future low CO2 vehicles.” (Part II, p. 5)

REPORT

Parsons Brinckerhoff, " Highways Agency Carbon Accounting Tool – Justification Report," (March, 2008)

This report describes a U.K. Highways Agency carbon accounting tool that was under development as of September, 2008. The accounting tool, when developed, will enable the Highways Agency to identify and collect the data required to establish an emissions baseline, from which the Agency can begin to identify areas in which reductions and savings can be made, and meaningful targets may be set. This report describes how the tool will be developed, emissions factors, tool structure, tool implementation, and a proposed delivery strategy.

VII. INFRASTRUCTURE IMPACTS OF CLIMATE CHANGE

REPORT

TRB Special Report, *The Potential Impacts of Climate Change on U.S. Transportation*, Transportation Research Board Special Report 290, March 2008.

This report explores the consequences of climate change for U.S. transportation infrastructure and operations. It provides an overview of the scientific consensus on the current and future climate changes of particular relevance to U.S. transportation, including the limits of present scientific understanding as to their precise timing, magnitude, and geographic location; identifies potential impacts on U.S. transportation and adaptation options; and offers recommendations for both research and actions that can be taken to prepare for climate change. The report also summarizes previous work on strategies for reducing transportation-related emissions of carbon dioxide—the primary greenhouse gas—that contribute to climate change

Noteworthy findings:

- “Climate change will affect transportation primarily through increases in several types of weather and climate extremes, such as very hot days; intense precipitation events; intense hurricanes; drought; and rising sea levels, coupled with storm surges and land subsidence. The impacts will vary by mode of transportation and region of the country, but they will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems.” (p. 4)
- “Potentially, the greatest impact of climate change for North America’s transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of global rising sea levels, coupled with storm surges and exacerbated in some locations by land subsidence.” (p. 4)
- “As stated at the outset, the fundamental challenge is to reduce the emissions produced per unit of transportation services provided more rapidly than the demand for transportation services grows. While it may be possible to reduce the rate of transportation demand growth somewhat without harming economic growth unacceptably, the committee is aware of no forecast that projects that transportation demand will fail to grow relatively rapidly in the decades ahead,

especially in many of the world's less developed countries. The bulk of the responsibility for reducing emissions will therefore fall on improved vehicle technologies and low-carbon or carbon-free fuels." (p. 199)

REPORT

Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1 (March 2008)

This study assessed the potential impacts of climate change on all major transportation systems in the U.S. central Gulf Coast between Galveston, Texas and Mobile, Alabama. Noteworthy findings include the following:

- "Warming temperatures may require changes in materials, maintenance, and operations. ... As the number of very hot days increases, different materials may be required. Further, restrictions on work crews may lengthen construction times. Rail lines may be affected by more frequent rail buckling due to an increase in daily high temperatures. Ports, maintenance facilities, and terminals are expected to require increased refrigeration and cooling." (ES 5)
- "Changes in precipitation patterns may increase short-term flooding." (ES 6)
- "Relative sea level rise may inundate existing infrastructure. To assess the impact of relative sea level rise (RSLR), the implications of rises equal to 61 cm and 122 cm (2 and 4 ft) were examined. ... Under these scenarios, substantial portions of the transportation infrastructure in the region are at risk: 27 % of the major roads, 9 % of the rail lines, and 72 % of the ports are at or below 122 cm (4 ft) in elevation..." (ES 6)
- "Increased storm intensity may lead to greater service disruption and infrastructure damage. ... With storm surge at 7 m (23 ft), more than half of the area's major highways (64 % of Interstates; 57 % of arterials), almost half of the rail miles, 29 airports, and virtually all of the ports are subject to flooding." (ES 6)
- "Other damage due to severe storms is likely, as evidenced by the damage caused by Hurricanes Katrina and Rita in 2005. Damage from the force of storm surge, high winds, debris, and other effects of hurricanes can be catastrophic, depending on where a specific hurricane strikes. ... given the expectation of increasing intensity of hurricanes in the region, consideration should be given to designing new or replacement infrastructure to withstand more energy-intensive, high-category storms." (ES 7)

REPORT

The US Economic Impacts of Climate Change and the Costs of Inaction, the Center for Integrative Environmental Research (CIER) at the University of Maryland (October 2007)

This report presents a review of economic studies for the United States and relates them to predicted impacts of climate change. Key findings include the following:

- “The effects of climate change will be felt by the entire nation:
- All sectors of the economy - most notably agriculture, energy, and transportation - will be affected;
- essential infrastructures that afford us reliable services and high standards of living (such as water supply and water treatment) will be impacted; and
- ecosystems, on which quality of life relies (such as forests, rivers, and lakes), will suffer.” (p. 3).
- “Not all regions or sectors of the country will be equally affected by climate impacts because of differences in climatic, economic and social conditions whose interplay influences coping capacities.” (p. 4)
- “Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.” (p. 5)
- “The effects of climate change will likely place immense strains on public budgets, particularly as the cost of infrastructure maintenance and replacement increases. At the same time, economic losses may translate into lost tax revenues. As a result, public officials may need to raise taxes or cut services.” (p. 6)
- “The indirect effects of climate change have rarely been quantified, yet they are likely substantial. Such effects may be present in the form of higher prices for products, because the prices of raw materials and energy, transport, insurance and taxes increase. As the costs for doing business increase, competitiveness of individual firms, entire sectors or regions may decline. With this decline may come a loss of employment and overall economic security. As climate change affects jobs and household income in the United States, and as resources are increasingly diverted to help maintain safety and adequate supply of goods and services, national security may be weakened.” (p. 6)

REPORT

ICF International, "The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure -- Phase 1 Final Report: DC, MD, NC, and VA" (December 2007)

This study was designed to produce rough estimates of how future climate change, specifically sea level rise and storm surge, could affect transportation infrastructure on the East Coast of the United States.

This study evaluated the elevation in the coastal areas and created tidal surfaces to describe the current and future predicted sea water levels; identified land that, without

protection, will regularly be inundated by the ocean or is at-risk of periodic inundation due to storm surge at the given temporal intervals; identified the transportation infrastructure that, without protection, will regularly be inundated by the ocean or at-risk of periodic inundation due to storm surge at the given temporal intervals; and provided statistics to demonstrate the potential amount of inundated and at-risk land surge at the given temporal intervals.

Maps developed as part of this study show impacts of sea level rises of 6 cm to 48.5 cm in Washington DC, Maryland, Virginia, and North Carolina. As an example, at 48.5 cm (about 1.6 feet) sea level rise in Washington DC, the percentage of facilities that will either suffer regular inundation or are at risk include 53 % of interstates, 26 % of non-interstate principal arterials; 37 % of the National Highway System; and 43 % of rail.

REPORT

Parsons Brinckerhoff, "Climate Change Adaptation Strategy, Volume 1," Draft Report for the U.K. Highways Agency (July, 2008)

This report presents a Highway Agency's Adaptation Strategy Model (HAASM) to address climate change impacts, by describing a systematic process to identify activities that will be affected by a changing climate, determining associated risks, and identifying preferred options to address and manage them. Specific recommendations for implementation are made. These include the initiation of a 'quick-wins' programme leading to the early application of adaptation actions where these are straightforward, low-cost and their benefits are clear, such as amending design standards for long-life assets to address predicted climatic changes. Key findings include the following:

- The HAASM consists of seven stages:
 - Stage 1: Define Objectives and Decision-making Criteria
 - Stage 2: Identify climate trends that affect the Highways Agency
 - Stage 3: Identify Highways Agency vulnerabilities
 - Stage 4: Risk appraisal
 - Stage 5: Options analysis to address vulnerabilities
 - Stage 6: Develop and implement Adaptation Action Plans
 - Stage 7: Adaptation programme review (p. 5-7)
- Primary criteria for risk appraisal:
 - Uncertainty
 - Rate of climate change
 - Extent of disruption
 - Severity of disruption (p. 13)
- "For each vulnerability, a High/Medium/Low score is assigned against each of the four primary risk appraisal criteria. This is achieved using sub-indicators and reference tables. Scoring is undertaken based on expert opinion, and necessarily involves some judgment." (p. 13)
- "Over eighty Highways Agency activities, or vulnerabilities, have been identified that may be affected by climate change. A preliminary appraisal of the risks associated with these vulnerabilities has been undertaken. This risk appraisal

found that over 60% of them are expected to be materially affected by current predicted levels of climate change within the relevant asset life or activity time horizon. The risk appraisal has also enabled vulnerabilities to be prioritized for attention, based upon several criteria including their potential to disrupt the operation of the Highways Agency network.” (p. 31)

VIII. PUBLIC OPINION SURVEYS

REPORT

Gallup Survey: Americans Assess What They Can Do to Reduce Global Warming (April 24, 2007)

Key Findings:

- “The Mar. 23-25, 2007, poll finds that 60% of Americans say the effects of global warming have already started to happen, while 4% say global warming effects will start happening within the next few years and 7% say within their own lifetime. Roughly one in six Americans say the effects of global warming will not happen in their lifetime, and only 11% of Americans doubt the predicted effects of global warming will ever happen.”
- “Even though Americans say the effects of global warming have already started, they do not think these effects will cause "extreme" weather and climate changes over the next 50 years. Only 28% of Americans say there will be extreme changes "in climate and weather, with disastrous consequences in some parts of the world." Americans are much more inclined to say that there will either be major climate changes that people and animals will be able to adapt to (38%) or that there will be minor changes that will have little effect on the ways people live (19%). Eleven % volunteer that there will be no climate or weather changes.”
- “At least 7 in 10 Americans say individuals should be spending money to make their homes more energy efficient (78%), riding mass transit whenever possible (77%), and installing a solar panel to produce energy for their homes (71%). A solid majority of Americans also say individuals should use only fluorescent light bulbs in their homes (69%), should buy a hybrid car (62%), and should unplug electronic equipment when not using it (57%).”
- “Even if Americans took steps such as driving less, recycling, or turning down their thermostat at home, the public does not necessarily think this alone will help to control the effects of global warming. Only 30% of Americans believe these types of actions will help curb global warming; 58% indicate more drastic measures are needed.”

REPORT

Clear Vision Survey, Americans Consider Global Warming an Urgent Threat (September 27, 2007)

Key Findings:

- “Sixty-two % of respondents to a national survey believe that life on earth will continue without major disruptions only if society takes immediate and drastic action to reduce global warming.”
 - “Further, 68 % of Americans support a new international treaty requiring the United States to cut its emissions of carbon dioxide 90 % by the year 2050 according to the survey conducted by Yale University, Gallup and the ClearVision Institute. By comparison, the Kyoto Protocol would require the United States to cut its emissions 7 % by the year 2012.”
 - “ ‘One of the most surprising findings was the growing sense of urgency,’ said Anthony Leiserowitz, director of the Yale Project on Climate Change and the study’s principal investigator. ‘Nearly half of Americans now believe that global warming is either already having dangerous impacts on people around the world or will in the next 10 years -- a 20-percentage-point increase since 2004. These results indicate a sea change in public opinion.’ ”
 - “The survey also found that 85 % support requiring automakers to increase the fuel efficiency of cars, trucks and SUVs to 35 miles per gallon, even if it meant a new car would cost up to \$500 more.”
-