

EXECUTIVE SUMMARY

# Moving Cooler

AN ANALYSIS OF TRANSPORTATION STRATEGIES FOR REDUCING GREENHOUSE GAS EMISSIONS

Cambridge Systematics, Inc.



Urban Land Institute

## **Executive Summary**

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An Analysis of  
Transportation Strategies  
for Reducing  
Greenhouse Gas Emissions

**Prepared for**  
*Moving Cooler Steering Committee*

**Prepared by**  
**Cambridge Systematics, Inc.**

**July 2009**



**Urban Land  
Institute**

## About the Urban Land Institute

The mission of the Urban Land Institute is to provide leadership in the responsible use of land and in creating and sustaining thriving communities worldwide. ULI is committed to

- Bringing together leaders from across the fields of real estate and land use policy to exchange best practices and serve community needs;
- Fostering collaboration within and beyond ULI's membership through mentoring, dialogue, and problem solving;
- Exploring issues of urbanization, conservation, regeneration, land use, capital formation, and sustainable development;
- Advancing land use policies and design practices that respect the uniqueness of both built and natural environments;
- Sharing knowledge through education, applied research, publishing, and electronic media; and
- Sustaining a diverse global network of local practice and advisory efforts that address current and future challenges.

Established in 1936, the Institute today has more than 35,000 members worldwide, representing the entire spectrum of the land use and development disciplines. ULI relies heavily on the experience of its members. It is through member involvement and information resources that ULI has been able to set standards of excellence in development practice. The Institute has long been recognized as one of the world's most respected and widely quoted sources of objective information on urban planning, growth, and development.

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## **Cambridge Systematics, Inc.**

Cambridge Systematics, Inc., specializes in transportation, dedicated to ensuring that transportation investments deliver the best possible results. It is recognized as a leader in the development and implementation of innovative policy and planning solutions, objective analysis, and technology applications. Cambridge Systematics works to build the capacity of the transportation community to understand and address both sides of the climate change challenge: to develop strategies to reduce greenhouse gas emissions from transportation, and to prepare for the potential effects of climate change on transportation systems.

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## **Collaborative Strategies Group, LLC**

Collaborative Strategies Group, LLC, is a consulting firm specializing in facilitation, public outreach and communication, project management, and public policy development for governments, businesses, communities, and organizations that need help navigating complex problem-solving, decision-making, and relationship-building issues.

# Preface

**TWO RECENT STUDIES HAVE TAKEN** a look at transportation and climate change issues: the 2007 McKinsey & Company and Conference Board report, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* and *Growing Cooler: The Evidence on Urban Development and Climate Change*, published by the Urban Land Institute in 2008. Respectively, these studies offer insight into the potential effects that strategies related to advances in technology and fuels have on greenhouse gas (GHG) emissions and how land-use strategies affect emissions through changes in travel behavior. To date, little research has taken a critical look at the full range of transportation measures that would influence greenhouse gas emissions, by reducing the amount of vehicle-miles traveled, reducing fuel consumption, and improving the performance of the transportation system. *Moving Cooler* is an effort to fill this knowledge gap.

The intent of the *Moving Cooler* study is to assess the potential effectiveness of a broad variety of transportation strategies—under a wide range of different assumptions—to reduce greenhouse gas emissions. This study was not intended to result in any specific recommendations about the direction of transportation and climate change policies. Therefore, the report does not purport to provide any interpretations about the implications of the *Moving Cooler* findings.

We wish to acknowledge the co-sponsors who funded the study, worked with the research team to identify and define the strategies and assumptions to be assessed, provided access to data, tested conclusions, and prepared for the release of the report:

- 🌀 American Public Transportation Association
- 🌀 Environmental Defense Fund
- 🌀 Federal Highway Administration
- 🌀 Federal Transit Administration
- 🌀 Intelligent Transportation Society of America
- 🌀 Kresge Foundation
- 🌀 Natural Resources Defense Council
- 🌀 Rockefeller Brothers Fund
- 🌀 Rockefeller Foundation
- 🌀 Shell
- 🌀 Surdna Foundation
- 🌀 Urban Land Institute
- 🌀 U.S. Environmental Protection Agency

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We also extend our thanks to the peer reviewers who helped evaluate the study results and the final report:

- 🌀 Robert B. Cervero, PhD, MCP, MS, University of California at Berkeley
- 🌀 Emil H. Frankel, LLB, Bipartisan Policy Center and Independent Consultant
- 🌀 Michael D. Meyer, PhD, MS, Georgia Institute of Technology

While the work presented in *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions* has benefited from these contributions, the views and findings expressed in this report are solely the responsibility of Cambridge Systematics, Inc., and do not necessarily reflect the views of the report co-sponsors or peer reviewers.

Cambridge Systematics, Inc.  
July 2009

# Sponsors of the Study



## American Public Transportation Association

American Public Transportation Association (APTA) is a nonprofit international association of 1,500 member organizations, including public transportation systems; planning, design, construction, and finance firms; product and service providers; academic institutions; and state associations and departments of transportation. APTA members serve the public interest by providing safe, efficient, and economical public transportation services and products. APTA members serve more than 90 percent of persons using public transportation in the United States and Canada.



**ENVIRONMENTAL DEFENSE FUND**

finding the ways that work

## Environmental Defense Fund

Environmental Defense Fund, a leading national nonprofit organization, represents more than 500,000 members. Since 1967, Environmental Defense Fund has linked science, economics, law, and innovative private sector partnerships to create breakthrough solutions to the most serious environmental problems.



U.S. Department of Transportation  
**Federal Highway Administration**

## Federal Highway Administration

The Federal Highway Administration (FHWA) is an agency of the U.S. Department of Transportation. FHWA strives to improve mobility on U.S. highways through national leadership, innovation, and program delivery.



## Federal Transit Administration

The Federal Transit Administration (FTA) is an agency of the U.S. Department of Transportation. FTA supports locally planned and operated public transportation systems throughout the United States through grants and technical assistance.



## Intelligent Transportation Society of America

The Intelligent Transportation Society of America (ITS America) was established in 1991 as a not-for-profit organization to foster the use of advanced technologies in surface transportation systems. It is the leading advocate for technologies that improve the safety, security, and efficiency of the nation's surface transportation system.

## THE KRESGE FOUNDATION

### Kresge Foundation

The Kresge Foundation is a private, national foundation that seeks to influence the quality of life for future generations through its support of nonprofit organizations in six fields of interest: health, the environment, community development, arts and culture, education, and human services.



## Natural Resources Defense Council

The Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, its lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, and Beijing.



## Rockefeller Brothers Fund

Founded in 1940, the Rockefeller Brothers Fund (RBF) encourages social change that contributes to a more just, sustainable, and peaceful world. The RBF's grant making is organized around three themes: democratic practice, sustainable development, and peace and security, and three pivotal places: New York City, western Balkans, and southern China. On October 12, 2006, the RBF trustees approved a new cross-programmatic grant-making initiative on energy.



## Rockefeller Foundation

The work of the Rockefeller Foundation for the 21st century is to enable "smart globalization." It attempts to harness the creative forces of globalization to ensure that the tools and technologies that have significantly improved the human condition in many parts of the world during the past half century are accessible today to more people, more fully, in more places. It seeks to shape efforts in planning, finance, infrastructure, and governance to manage a world in which, for the first time in history, more people live in urban communities than rural ones.



## Shell

Shell Oil Company is part of the Royal Dutch Shell group of companies (collectively referred to as Shell), which is a global group of energy and petrochemical companies. With around 102,000 employees in more than 100 countries and territories, Shell helps to meet the world's growing demand for energy in economically, environmentally, and socially responsible ways. In the United States, Shell has exploration and production, refining, chemical, lubricants, distribution, retail, natural gas, power, and alternative energy operations.



## Surdna Foundation

Surdna is a family foundation that makes grants in the areas of environment, community revitalization, effective citizenry, the arts, and nonprofit sector support. The Surdna Foundation's Environment Program is national in scope and supports a healthy natural environment, the foundation upon which human communities flourish. It believes that the social and economic concerns of communities are inextricably, and crucially, linked to the natural world. The program's goals include: building support for programs to stabilize climate change at the local, state, and national level; and improving transportation systems and patterns of land use across metropolitan areas, working landscapes, and intact ecosystems.



## Urban Land Institute

The Urban Land Institute is a global nonprofit education and research institute supported by its members. Its mission is to provide leadership in the responsible use of land and in creating and sustaining thriving communities worldwide. Established in 1936, the Institute has more than 35,000 members representing all aspects of land use.



## U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) leads the nation's environmental science, research, education, and assessment efforts. The mission of the EPA is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people.



# Executive Summary



**THE DEBATE ON HOW TO MEET** the nation's climate change challenge is well underway, and ambitious goals for greenhouse gas (GHG) reductions are likely to be established. Proposals under discussion would set national targets for reductions in GHG emissions, from all sectors of the economy, of up to 83 percent from 2005 levels by 2050—equivalent to a reduction of more than 5,900 million metric tonnes (mmt) of GHGs during this period of time. Transportation contributes roughly 28 percent of the United States' total GHG emissions—and transportation emissions have been growing faster than those of other sectors. In fact, between 1990 and 2006, growth in U.S. transportation GHG emissions represented almost one-half (47 percent) of the increase in total U.S. GHGs. Success in reducing GHGs through transportation strategies will be critical to meeting national goals.

*Moving Cooler* was commissioned by a wide range of agencies and interest groups who seek objective information about the potential contributions of transportation strategies to meet these GHG reduction goals. Considerable research has been conducted on the role of advanced vehicle and fuel technologies in reducing the carbon footprint of transportation. However, there is less information about the potential contribution of transportation actions and strategies to reduce the amount of vehicle travel that occurs, or to make changes to the transportation system and services that improve fuel efficiency. *Moving Cooler* provides information on the effectiveness and costs of almost 50 of these types of strategies and com-

binations of strategies. The results of the *Moving Cooler* findings can help shape effective, integrated approaches for reducing GHG emissions nationally, regionally, and locally, while meeting broader transportation objectives as well.

Transportation GHG emissions are the result of the interaction of four factors: vehicle fuel efficiency, the carbon content of the fuel burned, the number of miles that vehicles travel, and the operational efficiency experienced during travel. Therefore, the range of transportation strategies that can be used to reduce GHGs fall into four basic approaches, as follows:

- ❋ **Vehicle Technology**—Improving the energy efficiency of the vehicle fleet by implementing more advanced technologies,
- ❋ **Fuel Technology**—Reducing the carbon content of fuels through the use of alternative fuels (for instance, natural gas, biofuels, and hydrogen),
- ❋ **Travel Activity**—Reducing the number of miles traveled by transportation vehicles, or shifting those miles to more efficient modes of transportation, and
- ❋ **Vehicle and System Operations**—Improving the efficiency of the transportation network so that a larger share of vehicle operations occur in favorable conditions, with respect to speed and smoothness of traffic flow, resulting in more fuel efficient vehicle operations.

The focus of *Moving Cooler* is on strategies that fall within these last two approaches to reducing transportation GHGs.



## Research Approach

The *Moving Cooler* analysis estimates the potential effectiveness of strategies to reduce GHG emissions by reducing the amount of vehicle travel that occurs, by inducing people to use less fuel-intensive means of transportation (e.g., walking, bicycling, riding in a bus or train, or carpooling), or by reducing the amount of fuel consumed during travel through transportation system improvements. Strategies are first assessed individually, and are then combined into “bundles” that illustrate the potential cumulative effects that could be achieved. Finally, bundles are examined using an economy-wide pricing overlay that analyzes the effect of fuel tax and carbon pricing and other nationwide pricing measures.

For both the individual strategies and the bundles, the analysis examined the following performance outcomes:

- 🔗 **GHG Reduction**—What level of GHG reduction could be achieved during what time frame?
- 🔗 **Implementation Costs**—What are the costs to implement the strategy or bundle?
- 🔗 **Change in Vehicle Costs**—What would be the effects on the costs of vehicle ownership, maintenance, and fuel from a nationwide perspective?
- 🔗 **Equity Effects**—How would implementation of various bundles affect different groups of people, and how might inequitable effects be addressed?

## Moving Cooler Strategies

The strategies considered by *Moving Cooler* are grouped into nine categories, as follows:

- 🔗 **Pricing and taxes.** Strategies raise the costs associated with the use of the transportation system, including the cost of vehicle miles of travel and fuel consumption. Both local and regional facility-level pricing strategies (e.g., congestion pricing) and economy-wide pricing strategies (e.g., carbon pricing) are considered.
- 🔗 **Land use and smart growth.** Strategies focus on creating more transportation-efficient land use patterns, and by doing so reduce the need to make motor vehicle trips and reduce the length of the motor vehicle trips that are made.
- 🔗 **Nonmotorized transport.** Strategies encourage greater levels of walking and bicycling as alternatives to driving.
- 🔗 **Public transportation improvements.** Strategies expand public transportation by subsidizing fares, increasing service on existing routes, or building new infrastructure.
- 🔗 **Ride-sharing, car-sharing, and other commuting strategies.** Strategies expand services and provide incentives to travelers to choose transportation options other than driving alone.
- 🔗 **Regulatory strategies.** Strategies implement regulations that moderate vehicle travel or reduce speeds to achieve higher fuel efficiency.

- ❸ **Operational and intelligent transportation system (ITS) strategies.** Strategies improve the operation of the transportation system to make better use of the existing capacity; strategies also encourage more efficient driving.
- ❸ **Capacity expansion and bottleneck relief.** Strategies expand highway capacity to reduce congestion and to improve the efficiency of travel.
- ❸ **Multimodal freight sector strategies.** Strategies promote more efficient freight movement within and across modes.

### Deployment Levels Used to Test Strategy Effectiveness

Each of the individual strategies is defined at three levels of deployment to test their effectiveness at different degrees of implementation. These levels of deployment are defined in terms of: (1) *Geographic scale*—Where and how broadly are these strategies implemented? (2) *Time frame*—How quickly are these strategies deployed, and when will they take effect? and (3) *Intensity*—How aggressively are these strategies structured? Using this combination of factors, three levels of deployment were defined to estimate potential GHG emission reductions for each strategy and bundle of strategies:

- ❸ **Expanded Current Practice**, which assumes the steady expansion of existing practices that could reduce GHG emissions focused predominately on major metropolitan areas;
- ❸ **Aggressive**, which assumes that the strategies are implemented sooner, more broadly geographically, and more aggressively than under the expanded current practice deployment; and
- ❸ **Maximum Effort**, which assumes that the strategies are implemented within the framework of major changes in national policy and levels of investment consistent with a singular commitment to reduction in GHG emissions nationally, regionally, and locally.

The intent of defining these levels of deployment is to provide insight into the magnitude of GHG reductions and other socioeconomic impacts that might occur over a wide range of “what if” assumptions.

### Moving Cooler Strategy Bundles

In practice, most strategies would typically be implemented as part of a package of transportation activities. To test the combined impact of strategies, *Moving Cooler* developed six illustrative bundles of strategies and estimated the total GHG reductions that might be achieved through an in-

tegrated set of actions. Each bundle was designed to bring together strategies that emphasize a common thrust or action plan.

The six strategy bundles used for the *Moving Cooler* analysis are as follows:

- 1. The Near-Term/Early Results Bundle** focuses on strategies that could be implemented broadly in the short term (i.e., before 2015) and that could result in early GHG reduction benefits. Examples of the variety of strategies that can be implemented relatively quickly include: reduced speed limits, increases in urban center parking fees, increased transit level of service, eco-driving programs, and truck stop electrification.
- 2. The Long-Term/Maximum Results Bundle** focuses on maximizing efforts to reduce GHG emissions without regard to cost, scale, or time frame of the implementation. This “all-out” bundle includes most of the *Moving Cooler* strategies assessed for this study: both near-term strategies, as well as land use changes, infrastructure investment to expand transportation services, pricing measures, operational improvements, and freight strategies.
- 3. The Land Use/Transit/Nonmotorized Transportation Bundle** emphasizes the interaction of urban area-focused strategies that increase density and encourage travelers to shift to more energy efficient modes, with shorter average trip lengths and increased walking and biking, which would eliminate some vehicle trips.
- 4. The System and Driver Efficiency Bundle** focuses on strategies that improve multimodal system efficiency by adding capacity, removing bottlenecks, reducing congestion, and improving traffic flow.
- 5. The Facility Pricing Bundle** focuses on local and regional pricing and incentive strategies (e.g., tolls, congestion pricing, parking fees) that will induce changes in travel behavior by changing the cost of travel. These strategies also could be coupled with service expansion.
- 6. The Low Cost Bundle** focuses on achieving GHG emission reductions through the deployment of strategies that are more cost-effective.

While these bundles represent logical combinations of strategies, any number of other combinations could also be designed and tested. The purpose of evaluating bundles in the *Moving Cooler* study is to provide analyses that demonstrate potential GHG reductions that could be achieved by combining multiple strategies.

### The *Moving Cooler* Baseline

The effectiveness of each strategy in reducing GHG emissions is measured against a baseline developed by the authors of *Moving Cooler* that projects GHG emissions from years 2010 to 2050 (Figure ES.1). This baseline is based on an annual rate of vehicle and fuel technological change, consistent with forecasts of the U.S. Department of Energy in its “Annual Energy Outlook” and the U.S. Department of Transportation’s examination of alternative Corporate Average Fuel Economy (CAFE). This baseline shows that innovations in vehicle and fuel technology will have a substantial impact on GHGs, but that these gains will largely be offset by increases in travel along with growth in the U.S. population. Consequently, the *Moving Cooler* baseline shows GHG emissions remaining roughly at 2005 levels through 2050.

The reductions in GHG emissions estimated to result from implementation of the *Moving Cooler* strategies and bundles are expressed as a percentage reduction from this baseline.

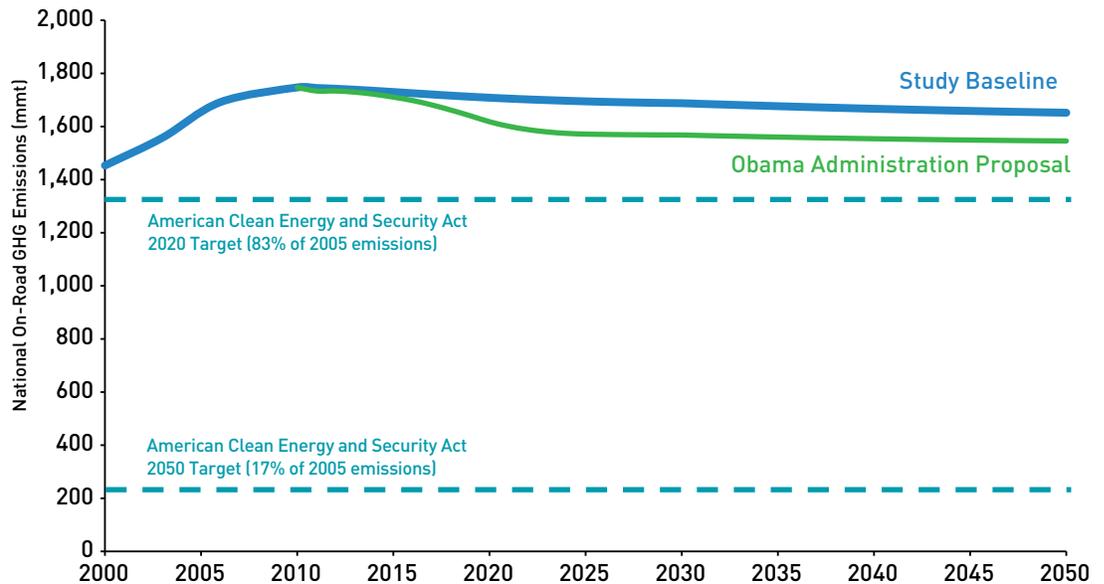
Figure ES.1 illustrates the relationship between the *Moving Cooler* baseline and some

targets for national GHG emission reductions. The American Clean Energy and Security Act (HR 2454) (ACESA)<sup>1</sup> sets economy-wide GHG reduction targets in 2012, 2020, 2030, and 2050, compared with 2005 emission levels. The *Moving Cooler* baseline projects GHG emissions that are 104 percent of 2005 emissions; this level is 21 percent short of the ACESA target for 2020 (assuming that the ACESA reduction targets are distributed proportionately across all sectors).

Because the results of the strategy analysis are tied to the values in the baseline, and in recognition of the degree of uncertainty associated with a forecast that extends more than 40 years, three alternative baseline scenarios were developed to investigate the sensitivity to differing baseline assumptions of individual strategy and strategy bundle GHG reduction estimates. The results fall under these assumed scenarios: (1) high fuel prices and low VMT growth; (2) low fuel prices and high VMT growth; and (3) high-technology and fuel economy combined with high VMT (Figure ES.2).

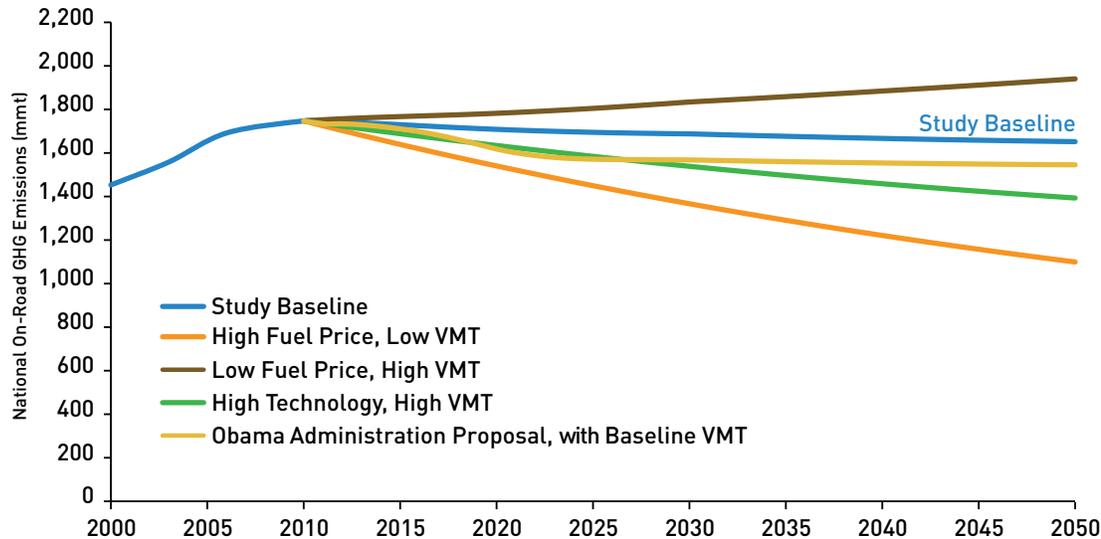
The recent national fuel efficiency standard proposal from President Obama was also extrapolated beyond 2016, assuming the same VMT growth

**Figure ES.1 *Moving Cooler* Baseline: Projected On-Road GHG Emissions**



Note: This figure displays National On-Road GHG emissions as estimated in the *Moving Cooler* baseline, compared with GHG emission estimates based on President Obama’s May 19, 2009, national fuel efficiency standard proposal of 35.5 mpg in 2016. Both emission forecasts assume an annual VMT growth rate of 1.4 percent. The American Clean Energy and Security Act of 2009 (HR 2454) identifies GHG reduction targets in 2012, 2020, 2030, and 2050. The 2020 and 2050 targets, with an example application to the on-road mobile transportation sector, are shown here.

Figure ES.2 **Moving Cooler National GHG Emissions Baseline and Baseline Sensitivity**



Note: This figure displays National On-Road GHG emissions as estimated in the *Moving Cooler* baseline, compared with the study’s three sensitivity analysis baselines and with the GHG emission estimates, based on President Obama’s May 19, 2009, national fuel efficiency standard proposal of 35.5 mpg in 2016.

rate as in the *Moving Cooler* baseline to calculate GHG emissions. Under this scenario, GHG emissions are projected to be 98 percent of 2005 emissions, or 15 percent short of the 2020 target. The Obama Administration proposal thus falls within the range of sensitivity analyses conducted by the *Moving Cooler* study.

## Findings

### Combining Strategies to Reduce GHGs

An integrated, multistrategy approach—combining travel activity, local and regional pricing, operational, and efficiency strategies—can contribute to significant GHG reductions. Implementation of a complete portfolio of *Moving Cooler* strategies without economy-wide pricing could achieve annual GHG emissions ranging from less than 4 percent to 18 percent (Aggressive Deployment) and as high as 24 percent (Maximum Effort Deployment) less than projected baseline levels in 2050 (Figure ES.3). Such reductions would, however, involve considerable—and in some cases major—changes to current transportation systems and operations, travel behavior, land use patterns, and public policy and regulations.

Within these illustrative bundles, the strategies that contribute the most to GHG reductions are local and regional pricing and regulatory strategies that increase the costs of single occupancy vehicle travel, regulatory strategies that reduce and enforce speed limits, educational strategies to encourage eco-driving behavior that achieves better fuel efficiency, land use and smart growth strategies that reduce travel distances, and multi-modal strategies that expand travel options.

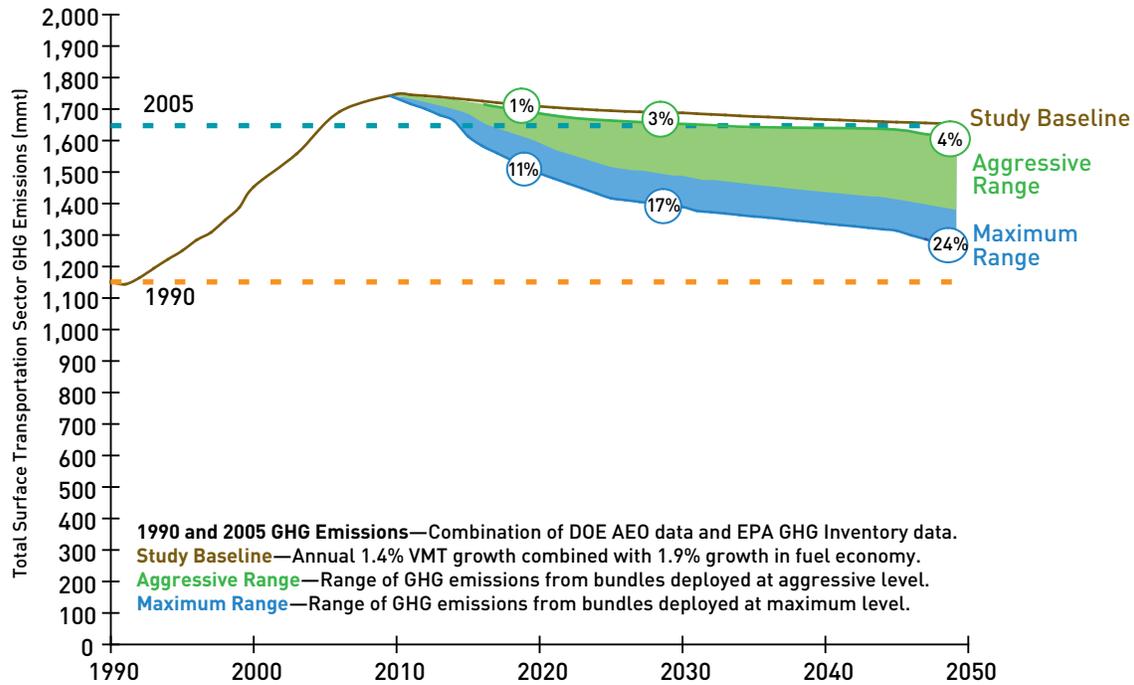
The analysis also shows that some combinations of strategies could create synergies that enhance the potential reductions of individual measures. In particular, land use changes combined with expanded transit services achieve stronger GHG reductions, than when only one option is implemented.

These results demonstrate that transportation agencies and other decision makers could create effective combinations of transportation strategies that provide high-quality transportation services, while achieving meaningful GHG reductions.

### Implementation Costs and Vehicle Costs Savings

The costs of implementing many of the *Moving Cooler* strategies are substantial. So too are the direct vehicle cost savings realized nationally, through reduced travel and reduced fuel consump-

**Figure ES.3 Range of Annual GHG Emission Reductions of Six Strategy Bundles at Aggressive and Maximum Deployment Levels 2010 to 2050**



Note: This figure displays the GHG emission range across the six bundles for the aggressive and maximum deployment scenarios. The percent reductions are on an annual basis from the study baseline. The 1990 and 2005 baselines are included for reference.

tion. For five of the six bundles examined (the facility pricing bundle being the exception), the estimated average annual savings in direct vehicle costs (i.e., ownership, maintenance and repair, and fuel) exceed estimated implementation costs by up to \$72 billion for an aggressive level of deployment and up to \$112 billion for a maximum level of deployment during a 40-year time frame. Figure ES.4 illustrates this effect for one bundle.

Relevant to energy independence, reduced fuel consumption realized nationally through these strategies translates to an average annual savings of 85 million to 470 million barrels of oil at an aggressive level of deployment, and to a savings of as much as 110 to 660 million barrels a year at a maximum level of deployment.

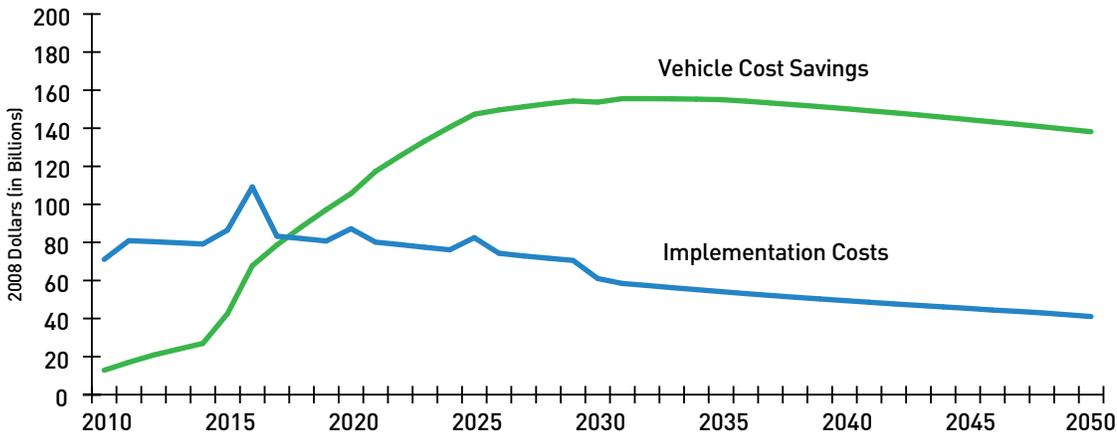
It is important to note that this comparison of implementation costs to vehicle cost savings is not a full assessment of costs and benefits, because the *Moving Cooler* analysis did not address other important benefits and costs, such as changes in mobility, travel time, safety, user fees, environmental quality, economic development, and public health.

### Pricing Measures

Strong **economy-wide** pricing measures, beyond the local and regional pricing strategies included in some of the illustrative bundles, could generate GHG reductions well beyond those that could be achieved by the bundles. For example, an additional fee (in current dollars) starting at the equivalent of \$0.60 per gallon in 2015 and increasing to \$1.25 per gallon in 2050 (Aggressive Deployment) could result in an additional 17 percent reduction in GHG emissions in 2050; a much higher fee similar to current European fuel taxes, starting at \$2.40 a gallon in 2015 and increasing to \$5.00 a gallon in 2050 (Maximum Effort Deployment) could result in an additional 28 percent reduction in GHG emissions in 2050.

Two factors would drive this increased reduction in GHG as a result of pricing signals: reductions in vehicle-miles traveled (VMT) and more rapid technology advances. Implementation of both Pay as You Drive insurance (PAYD) and/or a direct VMT fee would increase consumers' cost

**Figure ES.4 Implementation Costs and Vehicle Cost Savings for the Long-Term/Maximum Results Bundle at Aggressive Deployment 2010 to 2050**



Note: This figure displays estimated annual implementation costs (capital, maintenance, operations, and administrative) and annual vehicle cost savings [reduction in the costs of owning and operating a vehicle from reduced vehicle-miles traveled (VMT) and delay]. Vehicle cost savings **DO NOT** include other costs and benefits that could be experienced as a consequence of implementing each bundle, such as changes in travel time, safety, user fees, environmental quality, and public health.

per mile of travel, and would result in a national reduction in VMT. Pricing of carbon-based fuel leads to higher fuel costs that depress VMT, and also creates market conditions that encourage the purchase of more fuel-efficient vehicles.

### Individual *Moving Cooler* Strategies

When evaluated individually, almost all of the strategies could achieve some GHG reductions. In particular, measures that reinforce efficient driving—either through regulation (speed limit reductions) or education (eco-driving)—could achieve a cumulative (from 2010 to 2050) 1.1 to 3.6 percent reduction from the baseline GHG emissions, depending on the level of deployment. Strategies that aim to reduce VMT by raising the cost of travel (PAYD insurance and VMT fees) could have a comparable effect—a 1.2 to 4.4 percent reduction from cumulative baseline GHG emissions, depending on the level of deployment assumed.

An integrated set of land use strategies achieves cumulative GHG reductions from 0.3 to 2.1 percent improvement from the baseline. Because these strategies take many years to implement and will involve the participation and acceptance of many parties to achieve, the benefits accrue quite slowly in the short-term, before beginning to escalate significantly in the later years.

Transit capital investments, such as urban transit expansion and intercity and high-speed rail, could produce cumulative GHG reductions ranging from 0.4 to 1.1 percent of baseline emissions. This expansion of service requires sustained investment over and above the current levels of investment.

Implementation of a full set of operational and ITS improvements could achieve 0.3 to 0.6 percent cumulative reductions.

If implemented individually, many of the strategies are estimated to achieve cumulative national reductions of less than 0.5 percent from the *Moving Cooler* baseline by 2050, even at maximum levels of deployment. However, the effectiveness of these strategies should be viewed relative to the scale of their potential deployment. *Moving Cooler* measures GHG reduction against a national baseline. At the local and regional scale, many *Moving Cooler* strategies result in greater relative reductions in GHG emissions and could be useful techniques to help meet regional GHG objectives, while enhancing transportation service.

### Other Social, Economic, and Environmental Goals

The fact that many individual strategies will likely make only small contributions to national GHG reductions does not indicate that they should be



discarded. In addition to making a contribution to reducing GHGs, many strategies achieve other important objectives, such as expanded travel options, reduced congestion, greater accessibility, improvements in the livability of urban areas, improved equity, improved environmental quality, enhanced public health, and improved safety. The analysis shows, for example, that additional investment in highway capacity and bottleneck relief could result in GHG reductions through 2030 and a negligible increase in GHG through 2050. Review of other cost-benefit studies demonstrates that higher levels of investment in public transportation and highways have returns of two or three times to one in terms of benefits in relation to the costs of these strategies.

### Near-Term Reductions

Many of the strategies analyzed in *Moving Cooler* could be implemented within a few years and could begin to generate reductions in GHG prior to

2020. For example, near-term strategies such as lower speed limits, congestion pricing, eco-driving, operational improvements, and improved transit level of service, if implemented, are among strategies that would achieve GHG reductions relatively quickly. Achieving early results would reduce the cumulative GHG reduction challenge in later decades. Near-term actions could give the sector an early start in reducing GHGs, while creating the impetus for more aggressive innovation in vehicle and fuel technology.

### Land Use and Improved Travel Options

While some *Moving Cooler* strategies could be implemented quickly, others would require many years to put in place. This observation is particularly true for bundles that involve changes in development patterns and land use to increase density and reduce the distance or need for vehicle travel. The analysis demonstrates that over time, changes in land use and investments in improved transit and transportation options can improve the efficiency and quality of travel, reduce trip lengths, and reduce GHG emissions. The notable reductions for these strategies are realized in the outer decades of this analysis, in 2030 and beyond. These strategies would require changes in development policies and significant funding because of the capital costs of expanded transit services, but these actions could achieve meaningful GHG reductions by 2050, ranging from 9 percent to 15 percent without economy-wide pricing.

### Equity Effects

The direct costs of implementing strategy bundles will vary, with different costs incurred by government, consumers, and businesses. If properly designed, highway, public transportation, ride-sharing, and operations investments can be implemented to benefit all income groups and all user groups.

Without mitigating policies, the pricing strategies would potentially create serious equity issues, because of their disproportionate effects on lower-income groups and on those travelers with limited mobility options. Lower income groups spend as much as four times more than higher income groups of their income on transportation; implementation of pricing strategies would exacerbate this inequity.

One solution to this problem could involve taking the revenues from pricing strategies and reinvesting them in additional strategies that address equity concerns, particularly through investments

in public transportation and highway investments that benefit lower income and disadvantaged communities to reduce the effects of higher fees. Other income transfer approaches also could be used to address the effects on lower-income groups.

### **Future Research**

Ongoing research is needed in several areas, including further evaluation of the effectiveness of GHG measures in specific contexts, research and evaluation of effective means to develop and deploy new strategies and technologies, and research on the economic effects of different strategy approaches. The interactions of land use, urban form,

and transportation are complex, particularly when attempting to project the long-range effects of investment choices on travel behavior. Development of more refined modeling tools that combine GHG and economic analyses could help decision makers more effectively examine investment and planning scenarios, in terms of GHG effects and overall societal benefits and costs.

### **Note**

1 American Clean Energy and Security Act of 2009, HR 2454, 111th Cong., 1st sess., *Congressional Record* 155, no. 98, daily ed. [June 26, 2009]: H 7471.