Executive Summary

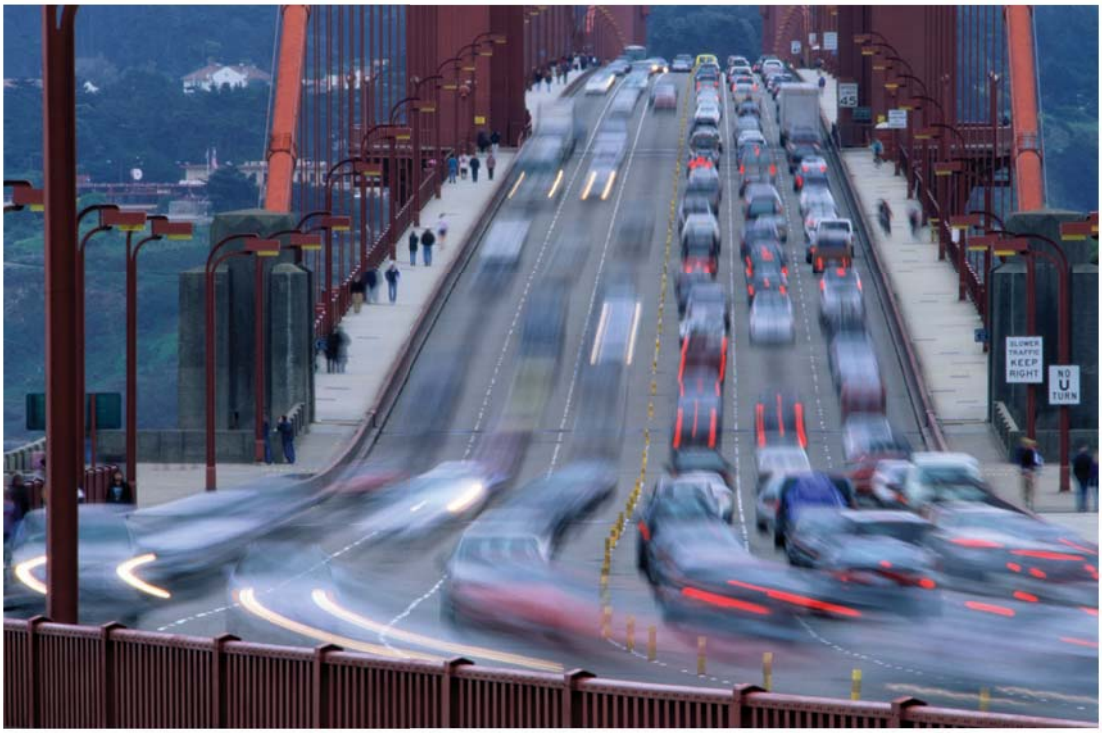
THE DEBATE ON HOW TO MEET the nation's climate change challenge is well underway, and ambitious goals for greenhouse gas (GHG) reductions are likely to be established. Proposals under discussion would set national targets for reductions in GHG emissions, from all sectors of the economy, of up to 83 percent 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 combinations 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.

- **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.
- **Capacity expansion and bottleneck relief.** Strategies expand highway capacity to reduce congestion and to improve the efficiency of travel.
- **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:

- **Expanded Current Practice,** which assumes the steady expansion of existing practices that could reduce GHG emissions focused predominately on major metropolitan areas;
- **Aggressive,** which assumes that the strategies are implemented sooner, more broadly geographically, and more aggressively than under the expanded current practice deployment; and
- **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 integrated 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.

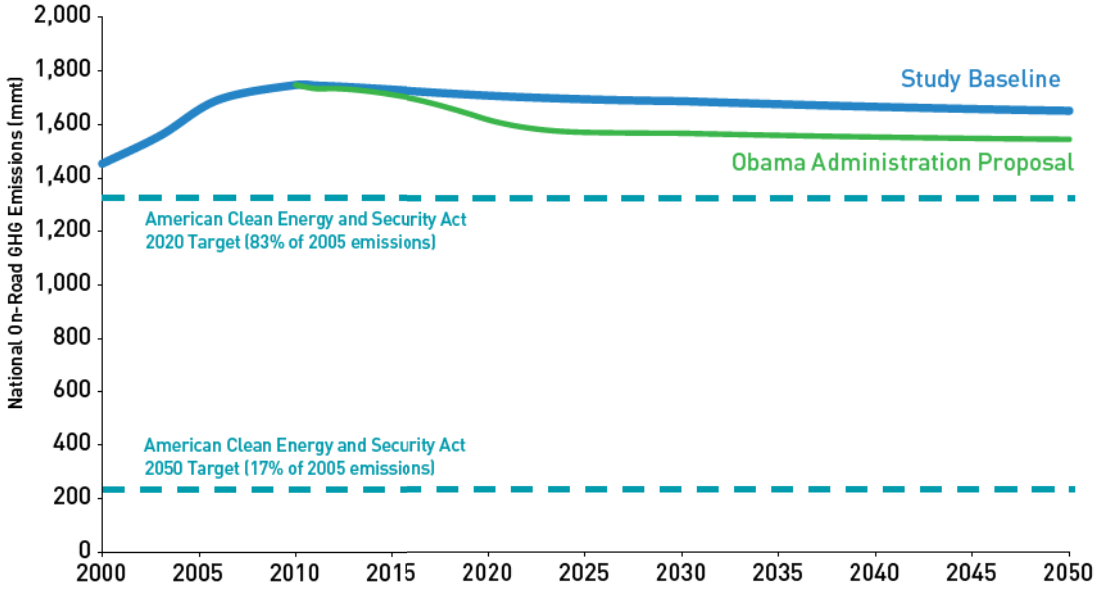
The reductions in GHG emissions estimated to result from implementation of the *Moving Cooler* strategies and bundles are expressed as a percentage reduction from this baseline.

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)[1] 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).

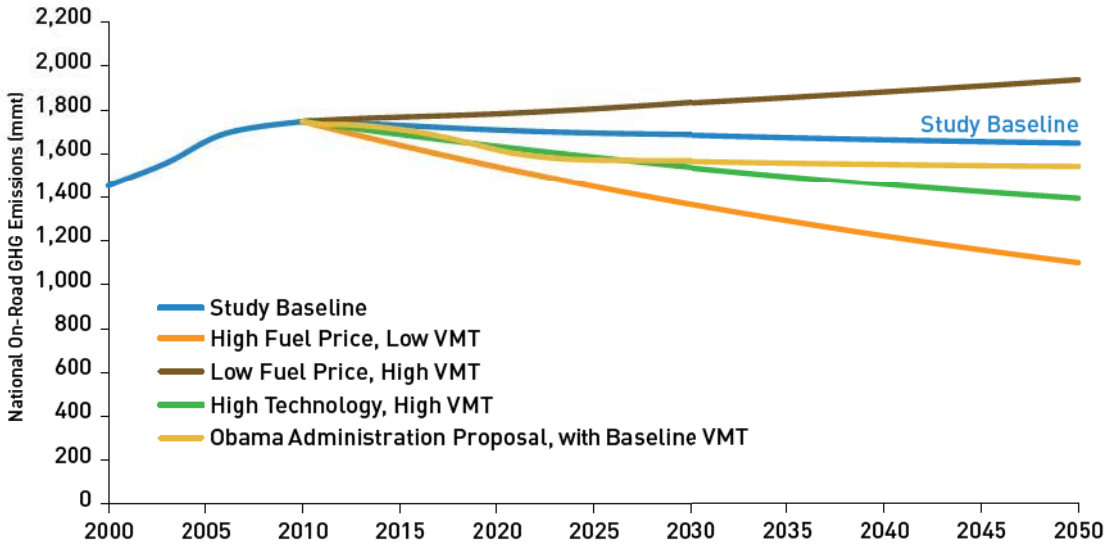
The recent national fuel efficiency standard proposal from President Obama was also extrapolated beyond 2016, assuming the same VMT growth

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 multimodal strategies that expand travel options.

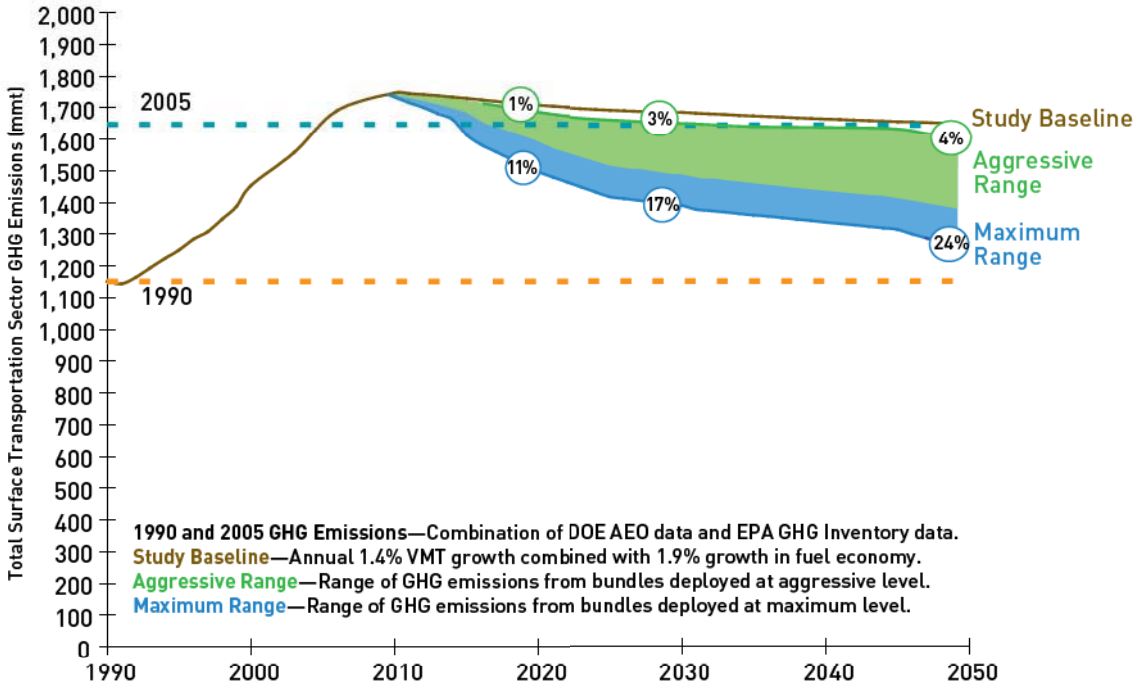
The analysis also shows that some combinations of strategies could create synergies that enhance the potential reductions of individual measures. In particular, land use changes combined with expanded transit services achieve stronger GHG reductions, than when only one option is implemented.

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.

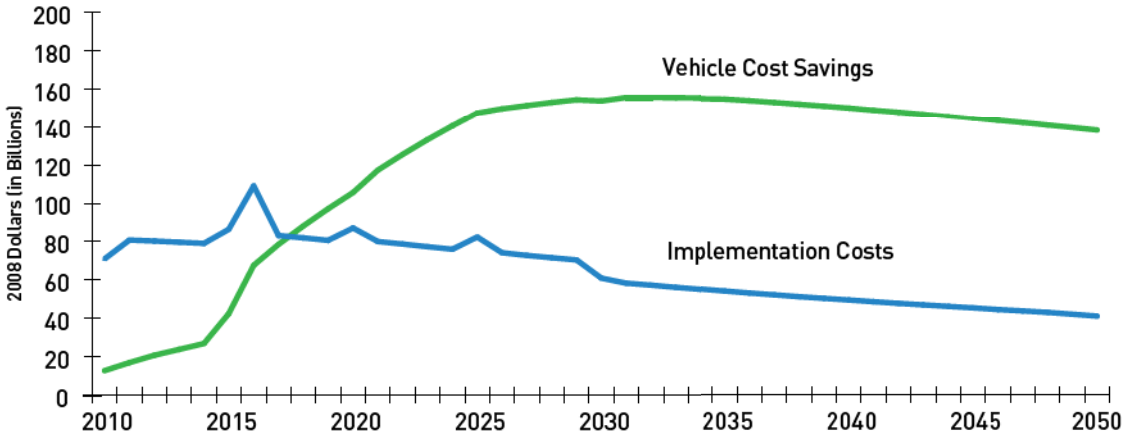
It is important to note that this comparison of implementation costs to vehicle cost savings is not a full assessment of costs and benefits, because the *Moving Cooler* analysis did not address other important benefits and costs, such as changes in mobility, travel time, safety, user fees, environmental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

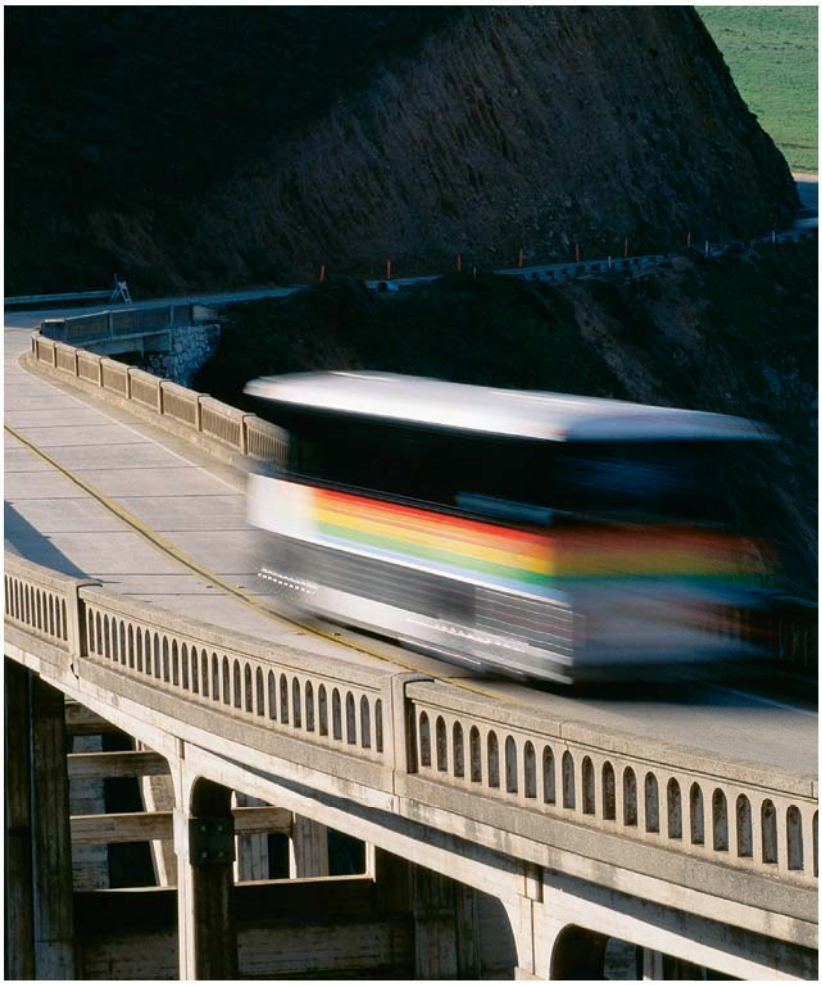
Transit capital investments, such as urban transit expansion and intercity and high-speed rail, could produce cumulative GHG reductions ranging from 0.4 to 1.1 percent of baseline emissions. This expansion of service requires sustained investment over and above the current levels of investment.

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.

Additional Figures from the Report

Figure 1:

Table 2.1 **GHG Emission Reduction Strategies at Three Deployment Levels**

GHG Reduction Strategy	A. Expanded Current Practice	B. More Aggressive	C. Maximum Effort
Pricing Strategies			
Parking pricing	Price street parking starting in 2015, complete in 8 years.	Price street parking starting in 2010, complete in 6 years. Tax free private parking with >100 spaces. Require residential parking permit ($200).	Price street parking starting in 2010, complete in 4 years. Tax free private parking with >50 spaces. Require residential parking permit ($400).
Cordon pricing	Implement area pricing in large CBDs starting in 2015.	Implement area pricing in large and medium CBDs starting in 2015.	Implement area pricing in all CBDs starting in 2010.
Congestion pricing	Include all large regions by 2015; complete in 15 years. Average peak hour per mile price of $0.49 on congested segments	Include all large and medium regions by 2015; complete in 10 years. Average peak hour per mile price of $0.65 on congested segments.	Include all regions by 2015; complete in 10 years. Average peak hour per mile price of $0.65 on congested segments.
Intercity tolls	Toll all intercity interstate highways at a minimum of $0.02 per mile by 2020.	Toll all intercity interstate highways at a minimum of $0.03 per mile by 2015.	Toll all intercity interstate highways at a minimum of $0.05 per mile by 2010.
Pay-as-you-drive (PAYD) insurance	Require all states to permit the offering of per-mile insurance rates by 2010.	At least 50 percent of policies converted to PAYD by 2015, increasing to 75 percent by 2025.	At least 75 percent of policies converted to PAYD by 2015, increasing to 100 percent by 2025.
Vehicle-miles traveled (VMT) fee	$0.01 per mile ($0.21 per gallon indexed to fuel economy) VMT fee (2015).	$0.03 per mile ($0.63 per gallon indexed to fueleconomy) VMT fee (2015).	$0.12 per mile ($2.53 per gallon indexed to fuel economy) VMT fee (2015).
Motor fuel tax and carbon price	Increase fuel taxes or carbon price by $0.01 per mile (current $0.02 per mile) (new tax at $0.40 per gallon indexed to fuel economy).	Increase fuel taxes or carbon price by $0.03 per mile (current $0.02 per mile). (new tax at $0.62 per gallon indexed to fuel economy).	Increase fuel taxes or carbon price by $0.12 per mile (current $0.02 per mile). (new tax at $2.71 per gallon indexed to fuel economy)
Land Use and Smart Growth Strategies			
Combined land use strategies	At least 43 percent of new development in compact, pedestrian- and bicycle-friendly neighborhoods with high-quality transit.	At least 64 percent of new development in neighborhoods as described under (A).	At least 90 percent of new development in neighborhoods as described under (A).
Nonmotorized Transportation Strategies			
Combined strategies—pedestrian	"Complete streets" policies. Audit and retrofit for pedestrian accessibility.	Same as Level A, but with more extensive audits and retrofits.	Same as Level B, but with more extensive traffic calming.
Combined strategies—bicycling	Bike lanes and paths at one-mile intervals in high-density areas (> 2000 persons per sq. mi.)	Bike lanes and paths at one-half-mile intervals in high-density areas (> 2000 persons per sq. mi.)	Bike lanes and paths at one-quarter-mile intervals in high-density areas (> 2000 persons per sq. mi.)
Public Transportation Improvement Strategies			
Fare measures	Fares decreased by 25% in large regions by 2015.	Fares decreased by 33% in large and medium regions by 2015.	Fares decreased by 50% in all regions by 2010.
Increased levels of service and improved travel times	Increase transit level of service by 1.5 times current revenue mile growth rate, improve travel speeds by 10%.	Increase transit level of service by 2 times current revenue mile growth rate, improve travel speeds by 15%.	Increase transit level of service by 4 times current revenue mile growth rate, improve travel speeds by 30%.
Expanded Urban Public Transportation	Increase services proportional to 3% per year ridership growth by 2010.	Increase services proportional to 3.53% per year ridership growth by 2010.	Increase services proportional to 4.67% per year ridership growth by 2010.
Intercity Bus and Rail and High-Speed Rail	Increase funding over baseline by 5% per year for 20 years. High speed rail in 3–5 corridors implemented over 20 years.	Increase funding over baseline by 10% per year for 20 years. High-speed rail in 5–7 corridors implemented over 15 years.	Double funding over baseline in 2010 and increase by 10% per year for 20 years. High-speed rail in up to 12 corridors implemented over 15 years.
Regional Ride-Sharing, Car-Sharing, and Commuting Strategies			
High-Occupancy Vehicle (HOV) lanes	Initiate HOV expansion in all urban regions by 2020, with implementation during a 10 year period.	Initiate HOV expansion in all urban regions by 2020, with implementation during an 8 year period.	Initiate HOV expansion in all urban regions by 2015, with implementation during a 4 year period.
Car-sharing	Programs in all regions by 2020.	One car per 2,000 inhabitants in 10 years.	One car per 1,000 inhabitants in 5 years.
Employer-based telework and compressed work week programs	Provide employer goals and tax incentives.	Require employer-based travel demand management (TDM) programs; 4-day work weeks for government agencies.	Require employer-based TDM; 4-day work weeks for government agencies.
Employer-based TDM requirements, outreach, and support	Provide on-line ride matching and vanpool services.	Reduce single-occupancy vehicle (SOV) trips by 10% (employers with 50+ employees).	Add taxes on all commercial parking spaces combined with Level A and B strategies.
Regulatory Strategies			
Urban nonmotorized zones	In 10 years, convert 2% of CBD streets.	In 10 years, convert 4% of CBD streets.	In 10 years, convert 6% of CBD streets.
Urban parking restrictions	Parking freeze on new parking spaces by 2025.	Parking freeze on new parking spaces by 2020.	Parking freeze on new parking spaces by 2015.
Speed limit reductions	National speed limit of 60 mph by 2020.	National speed limit of 55 mph by 2020.	National speed limit of 55 mph by 2015.

GHG Reduction Strategy	A. Expanded Current Practice	B. More Aggressive	C. Maximum Effort
Operational and Intelligent Transportation System (ITS) Strategies[a]			
Eco-driving training programs	Implement program. 10% of population reached, 5% net adoption by drivers.	Implement program. 20% of population reached, 8% net adoption by drivers.	Implement program, and fund public awareness campaigns and new driver education. 50% of population reached, 20% net adoption by drivers.
Ramp metering (centrally controlled)	Implement in large urban areas where V/C > 1.05 by 2030 with new and expanded Traffic Management Centers (TMCs).	Implement in large and medium urban areas where V/C > 1.0 by 2025 with new and expanded TMCs.	Implement in all locations where V/C > 0.90 by 2020 with new and expanded TMCs.
Variable message signs (VMS)	Implement where V/C > 1.05 by 2030.	Implement where V/C > 1.0 by 2025.	Implement where V/C > 0.9 by 2020.
Active traffic management	Not deployed.	Implement in large and medium urban areas where V/C > 1.0.	Implement in all locations where V/C > 0.9.
Integrated corridor management	Not deployed.	Implement in large and medium urban areas where V/C > 1.0 by 2025.	Implement in all locations with V/C > 0.9 by 2020.
Incident management	Implement where V/C > 1.05 by 2030 with new and expanded TMCs.	Implement where V/C > 1.0 by 2025 with new and expanded TMCs.	Implement where V/C > 0.9 by 2020 with new and expanded TMCs.
Road weather management (snow, ice, and fog)	Fully deployed on freeways by 2030.	Fully deployed on freeways by 2025.	Fully deployed on freeways by 2020.
Arterial management	Upgrade when V/C > 1.0 by 2030.	Upgrade when V/C > 1.0 by 2025.	Upgrade when V/C > 0.9 by 2020.
Traveler Information (511 and DOT website)	Implement where V/C > 1.05 by 2030.	Implement where V/C > 1.0 by 2025.	Implement where V/C > 0.9 by 2020.
Vehicle infrastructure integration (VII)[b]	50 percent of light-duty vehicles equipped by 2025, 100 percent by 2040.	50 percent of light-duty vehicles equipped by 2020, 100 percent by 2030.	50 percent of light-duty vehicles equipped by 2015, 100 percent by 2020.
Bottleneck Relief and Capacity Expansion Strategies			
Bottleneck relief	Improve 25 percent of top 200 bottlenecks to Level of Service E by 2030.	Improve 50 percent of top 200 bottlenecks to Level of Service E by 2030.	Improve 100 percent of top 200 bottlenecks to Level of Service D by 2020.
Capacity expansions	25 percent of the economically justified investments increased over current funding levels.	50 percent of the economically justified investments increased over current funding levels.	100 percent of the economically justified investments increased over current funding levels.
Multimodal Freight Strategies—Modal Diversion			
Rail capacity improvements	Capacity restrictions are reduced by 20 percent by 2025.	Capacity restrictions are reduced by 30 percent by 2025.	Capacity restrictions are reduced by 50 percent by 2025.
Marine transportation system maintenance and improvement	Maintain the current state of the system.	Restore major components of the system to a state of good repair.	Restore the entire system to a state of good repair.
Multimodal Freight Strategies—Mode Optimization			
Overweight load permits for trucks carrying shipping containers	In all states, allow indivisible load permits for trucks carrying shipping containers for distances up to 250 miles by 2025.	In all states, allow indivisible load permits for trucks carrying shipping containers for distances up to 250 miles by 2020.	In all states, allow indivisible load permits for trucks carrying shipping containers for distances up to 250 miles by 2015
Overweight load permits for longer combination vehicles (LCVs).	In all states, allow divisible load permits for LCVs up to 105,500 lbs by 2020.	In all states, allow divisible load permits for LCVs up to 129,000 lbs by 2020.	In all states, allow divisible load permits for LCVs up to 129,000 lbs by 2010 and up to 138,000 lbs for 8-axle B-trains by 2020.
Weigh-in-motion (WIM) screening at weigh stations	Implement by 2025 at all 24-hour truck weigh stations.	Implement by 2020 at all 24-hour truck weigh stations.	Implement by 2015 at all truck weigh stations.
Electronic credentialing to allow vehicles to bypass weigh stations and safety inspections	Expand to cover all 49 mainland states by 2025.	Expand to cover all 49 mainland states by 2020.	Expand to cover all 49 mainland states by 2015.
Truck stop electrification	Allow truck drivers to plug in to local power at 1,500 (out of 5,000) truck stops by 2025.	Allow truck drivers to plug in to local power at 3,000 truck stops by 2020.	Allow truck drivers to plug in to local power at all truck stops by 2015.
Battery-operated heating and cooling systems for sleeper cabs (APUs)	Require installation in all sleeper cabs by 2025.	Require installation in all sleeper cabs by 2020.	Require installation in all sleeper cabs by 2015.
Truck-only toll lane networks	Complete by 2025; new facilities should cover 10 percent of large urban area interstate VMT.	Complete by 2025; new facilities should cover 25 percent of large urban area interstate VMT.	Complete by 2025; new facilities should cover 40 percent of large urban area interstate VMT.
Multimodal Freight Strategies—Logistics			
Urban consolidation centers	Establish in large urban areas by 2025.	Establish in large urban areas by 2020.	Establish in large urban areas by 2015.

Note: Where not otherwise indicated, all measures are cumulative with lower levels of implementation.

[a]Notes on Operational and ITS Strategies: (1) Different congestion thresholds are used to get distinction in the scenarios; (2) Deployment of strategies except for VII is assumed to occur continuously throughout the analysis period; and (3) V/C = Volume to capacity ratio, a measure of roadway congestion that compares the traffic volumes to the roadway capacity. [b] VII deployment is based on the deployment curve in Volpe VII BCA Report (http://www.intellidriveusa.org/documents/vii-benefit-cost-analysis-(Draft).pdf). Projected Phase-In of VII Equipped Vehicles in the U.S. Fleet. The "More Aggressive" scenario uses these forecasts and they are adjusted for the "Expanded Current Practice" and "Maximum Effort" scenarios.

Figure 2:

Table 4.1 *Moving Cooler* Cumulative GHG Reduction, Implementation Costs, and Change in Vehicle Costs by Strategy (at Expanded Current Practice, Aggressive, and Maximum Deployment Levels) by 2050

	Expanded Current Practice Deployment (2010 to 2050)			Aggressive Deployment (2010 to 2050)			Maximum Deployment (2010 to 2050)		
Strategy Description	GHG Reduction (mmt)[a]	Implementation Cost Estimate[b] ($B 2008)	Change in Vehicle Cost Estimate[c] ($B 2008)	GHG Reduction (mmt)[a]	Implementation Cost Estimate[b] ($B 2008)	Change in Vehicle Cost Estimate[c] ($B 2008)	GHG Reduction (mmt)[a]	Implementation Cost Estimate[b] ($B 2008)	Change in Vehicle Cost Estimate[c] ($B 2008)
Pricing Strategies									
CBD/Activity Center on-street parking	33	< $0.05	$(26.8)	41	< $0.05	$(36.2)	42	< $0.05	$(37.8)
Tax/higher tax on free private parking	N/A	N/A	N/A	18	< $0.05	$(14.7)	31	< $0.05	$(26.8)
Residential parking permits	N/A	N/A	N/A	20	< $0.05	$(15.9)	48	< $0.05	$(40.4)
Cordon Pricing	66	$24.2	$(66.0)	76	$36.1	$(76.3)	92	$39.3	$(97.9)
Congestion Pricing	510	$233.9	$(522.8)	1,021	$349.0	$(792.9)	1,241	$380.3	$(1,033.8)
Intercity Tolls	31	$33.6	$(27.4)	54	$44.7	$(52.1)	105	$58.5	$(107.8)
PAYD	789	$166.0	$(831.2)	1,677	$166.0	$(1,678.0)	2,233	$166.0	$(2,225.8)
VMT fee[d]	280	$166.0	$(252.5)	840	$166.0	$(757.6)	3,361	$166.0	$(3,030.4)
Carbon Pricing (VMT impact)	350	< $0.05	$(316.1)	1,067	< $0.05	$(962.8)	4,744	< $0.05	$(4,246.2)
Carbon Pricing (Fuel economy impact)	1,181	< $0.05	$(236.7)	3,343	< $0.05	$(671.7)	10,442	< $0.05	$(2,121.1)
Land Use and Smart Growth Strategies									
Combined Land Use	160	$1.5	$(118.0)	865	$1.5	$(655.5)	1,445	$1.5	$(1,098.5)
Nonmotorized Transportation Strategies									
Combined Pedestrian	74	$15.2	$(64.4)	171	$30.4	$(148.4)	227	$42.2	$(197.2)
Combined Bicycle	59	$4.6	$(47.6)	117	$20.6	$(95.2)	176	$37.7	$(142.9)
Public Transportation Strategies									
Transit Fare Measures	19	< $0.05	$(17.8)	34	< $0.05	$(31.3)	78	< $0.05	$(72.2)
Transit Frequency/LOS/Extent	45	$52.5	$(47.0)	72	$102.6	$(99.3)	168	$243.8	$(265.5)
Urban Transit Expansion	144	$255.0	$(135.5)	281	$503.0	$(281.7)	575	$1,197.3	$(611.6)
Intercity Passenger Rail	46	$19.3	$(46.5)	47	$35.6	$(49.6)	50	$76.1	$(58.0)
High-Speed Passenger Rail[e]	73	$99.6	$(24.7)	97	$108.2	$(29.5)	143	$144.2	$(40.2)
HOV/Carpool/Vanpool/Commute Strategies									
HOV Lanes	48	$171.8	$(10.2)	64	$231.9	$(13.4)	141	$569.1	$(31.0)
HOV Lanes (24-hour applicability)	1	< $0.05	$(0.2)	1	< $0.05	$(0.3)	2	< $0.05	$(0.4)
Car-Sharing	37	$0.2	$(31.9)	77	$0.3	$(67.5)	163	$0.3	$(147.6)
Employer-Based Commute Strategies	252	$106.0	$(217.4)	486	$120.8	$(419.9)	1,165	$135.6	$(1,013.4)
Regulatory Measures									
Nonmotorized Zones	2	$1.4	$(1.3)	4	$4.2	$(3.2)	6	$8.5	$(4.9)
Urban Parking Restrictions	80	< $0.05	$(55.5)	189	< $0.05	$(135.6)	359	< $0.05	$(276.1)
Speed Limit Reductions	1,236	$4.1	$(389.8)	2,320	$6.5	$(753.6)	2,428	$7.5	$(805.1)
System Operations and Management Strategies									
Eco-Driving	727	< $0.05	$(134.9)	1,170	< $0.05	$(221.8)	1,815	< $0.05	$(366.9)
Ramp Metering	27	$1.3	$(4.5)	78	$3.1	$(12.3)	83	$7.5	$(13.2)
Variable Message Signs	2	$0.8	$(0.3)	2	$2.0	$(0.4)	3	$4.8	$(0.4)
Active Traffic Management	N/A	N/A	N/A	46	$10.8	$(7.7)	80	$25.9	$(13.0)
Integrated Corridor Management	N/A	N/A	N/A	46	$10.8	$(7.7)	80	$26.0	$(13.0)
Incident Management	58	$2.2	$(9.4)	72	$5.4	$(11.8)	80	$12.9	$(13.2)
Road Weather Management	1	$2.0	$(0.1)	1	$4.9	$(0.2)	2	$11.8	$(0.4)
Signal Control Management	3	$2.5	$(0.5)	18	$6.1	$(3.0)	37	$16.9	$(6.1)
Traveler Information	4	$2.0	$(0.7)	30	$4.9	$(4.8)	31	$11.8	$(5.0)
Vehicle Infrastructure Integration	65	$42.6	$(9.9)	16	$42.6	$(2.2)	8	$42.6	$(1.0)
Bottleneck Relief and Capacity Expansion Strategies									
Bottleneck Relief[f]	(3)	$29.0	$124.7	(5)	$71.4	$218.7	(11)	$142.7	$481.1
Capacity Expansion[f]	(4)	$333.2	$175.3	(7)	$617.0	$324.6	(15)	$1,234.0	$650.5
Multimodal Freight Strategies									
Rail Capacity Improvements	44	$19.9	$(18.5)	66	$32.6	$(27.7)	131	$48.5	$(55.5)
Marine System Improvements	5	$4.0	$(1.0)	8	$8.0	$(1.4)	12	$17.7	$(2.1)
Shipping Container Permits	8	< $0.05	$(1.6)	8	< $0.05	$(1.7)	9	< $0.05	$(1.9)
LCV Permits	8	< $0.05	$(9.6)	12	< $0.05	$(15.8)	15	< $0.05	$(17.2)
WIM Screening	1	< $0.05	$(0.1)	1	< $0.05	$(0.1)	1	$0.1	$(0.1)
Weigh Station Bypass	1	< $0.05	$(0.2)	1	< $0.05	$(0.2)	2	$0.1	$(0.2)
Truck Stop Electrification	11	$0.6	$(2.9)	25	$1.3	$(6.2)	46	$2.2	$(10.5)
Truck APUs	133	$0.3	$(28.8)	148	$0.3	$(32.6)	162	$0.4	$(36.5)
Truck-Only Toll Lanes	24	$17.1	$(4.6)	59	$42.7	$(11.5)	107	$71.6	$(20.7)
Urban Consolidation Centers	6	$0.4	$(1.6)	8	$0.4	$(2.3)	9	$0.4	$(3.1)

Note: This table summarizes how well each strategy is expected to help reduce GHGs by 2050, as well as the direct implementation costs and vehicle costs and savings of implementing these strategies. It is important to note that the results shown in this table for the individual strategies cannot simply be added together to estimate the impacts of combining strategies; the synergistic impacts of bundling the strategies are discussed in Section 4.2. LOS = level of service.

[a] mmt = million metric tonnes greenhouse gases.

[b] Implementation cost is the estimated cumulative cost to implement each strategy, including capital, maintenance, operations, and administrative costs.

[c] Vehicle cost is the estimated cumulative reduction in the cost of owning and operating vehicles from a societal perspective, which would result with reductions in VMT and fuel consumption experienced with implementation of each bundle. Vehicle costs 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.

[d] An equivalent national VMT fee could accomplish the same VMT reductions, but not the fuel efficiency reductions of carbon pricing. The deployment costs of VMT based fees could be shared with required vehicle technology or odometer audits for PAYD if both of these strategies were implemented using consistent approaches.

[e] The evaluation of high-speed rail only takes into account the GHG emissions reduction associated with effects on surface transportation (and does not include air travel effects).

[f] GHG emission reductions use the FHWA methodology, as used for the Conditions and Performance (C&P) reports, to project the effect of capacity expansion on future VMT. This methodology addresses induced demand and diverted travel and also assumes that increased user fees will pay for capacity expansions. If the C&P methodology were to be applied absent the user fee assumption, the estimated GHG produced by these strategies would increase to between 440–560 mmt (which is less than 1 percent of the *Moving Cooler* baseline). This result underscores the importance of pricing strategies.

Figure 3:

Table 4.2 ***Moving Cooler*** **Yearly GHG Reduction in 2020, 2030, and 2050 by Strategy (at Expanded Current Practice, Aggressive, and Maximum Deployment Levels)**

	Expanded Current Practice Deployment GHG Reduction in Year (mmt)[a]			Aggressive Deployment GHG Reduction in Year (mmt)[a]			Maximum Deployment GHG Reduction in Year (mmt)[a]		
Strategy Description	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
Pricing Strategies									
CBD/Activity Center on-street parking	< .5	1	1	1	1	1	1	1	1
Tax/higher tax on free private parking	N/A	N/A	N/A	< .5	1	1	1	1	1
Residential parking permits	N/A	N/A	N/A	< .5	1	1	1	2	1
Cordon Pricing	1	1	3	1	2	3	1	3	3
Congestion Pricing	5	18	18	11	35	35	18	43	39
Intercity Tolls	< .5	1	1	2	2	2	3	3	2
PAYD	20	19	19	39	47	44	56	63	59
VMT fee	8	8	7	25	24	22	101	97	90
Carbon Pricing (VMT impact)[b]	11	10	10	32	31	28	136	138	132
Carbon Pricing (Fuel economy impact)	24	37	38	70	103	106	236	325	325
Land Use and Smart Growth Strategies/Nonmotorized Strategies									
Combined Land Use	1	3	10	7	22	45	12	38	73
Combined Pedestrian	2	2	2	5	5	5	6	7	6
Combined Bicycle	1	2	2	1	2	2	2	6	6
Public Transportation Strategies									
Transit Fare Measures	1	1	1	1	1	1	2	2	2
Transit Frequency/LOS/Extent	1	2	2	1	2	3	2	4	9
Urban Transit Expansion	2	4	7	4	7	12	8	14	26
Intercity Passenger Rail	1	1	1	1	1	1	2	2	2
High-Speed Passenger Rail	1	2	3	1	3	4	2	4	6
HOV/Carpool/Vanpool/Commute Strategies									
HOV Lanes	1	1	1	2	2	2	4	4	4
HOV Lanes (24-hour applicability)	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Car-Sharing	1	1	1	2	2	2	5	4	4
Employer-Based Commute Strategies	7	7	7	15	14	13	35	34	31
Regulatory Measures									
Nonmotorized Zones	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Urban Parking Restrictions	< .5	1	7	1	4	13	3	9	18
Speed Limit Reductions	12	44	41	40	75	71	51	76	72

Table 4.2 (continued)

	Expanded Current Practice Deployment GHG Reduction in Year (mmt)[a]			Aggressive Deployment GHG Reduction in Year (mmt)[a]			Maximum Deployment GHG Reduction in Year (mmt)[a]		
Strategy Description	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
System Operations and Management Strategies									
Eco-Driving	8	18	36	15	29	54	38	50	65
Ramp Metering	< .5	< .5	2	< .5	< .5	6	< .5	< .5	7
Variable Message Signs	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Active Traffic Management	N/A	N/A	N/A	< .5	< .5	4	< .5	< .5	7
Integrated Corridor Management	N/A	N/A	N/A	< .5	< .5	4	< .5	< .5	7
Incident Management	< .5	< .5	5	< .5	1	7	< .5	1	8
Road Weather Management	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Signal Control Management	< .5	< .5	< .5	< .5	< .5	1	< .5	< .5	3
Traveler Information	< .5	< .5	< .5	< .5	< .5	2	< .5	< .5	2
Vehicle Infrastructure Integration	< .5	< .5	6	< .5	< .5	2	< .5	< .5	1
Bottleneck Relief and Capacity Expansion Strategies									
Bottleneck Relief[c]	1	1	(4)	3	3	(7)	4	4	(10)
Capacity Expansion[c]	1	1	(2)	2	2	(4)	5	6	(13)
Multimodal Freight Strategies									
Rail Capacity Improvements	< .5	2	2	1	2	2	2	4	4
Marine System Improvements	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Shipping Container Permits	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
LCV Permits	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
WIM Screening	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Weigh Station Bypass	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Truck Stop Electrification	< .5	< .5	< .5	1	1	1	1	1	2
Truck APUs	3	5	4	4	5	4	5	5	4
Truck-Only Toll Lanes	< .5	1	1	1	2	2	1	3	5
Urban Consolidation Centers	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5

Note: This table summarizes the level of GHG reduction for each strategy in years 2020, 2030, and 2050. Annual GHG reductions of 16 to 17 mmt represent an annual reduction of 1 percent from the *Moving Cooler* study baseline. The study baseline estimates total national on-road GHG emissions based on VMT and fuel economy assumptions, as identified in Section 3.0. These estimates are: 1,712 mmt in 2020, 1,689 mmt in 2030, and 1,653 mmt in 2050.

[a] mmt = million metric tonnes greenhouse gases.

[b] Or an equivalent national VMT fee.

[c] Refer to Footnote e in Table 4.1 for additional explanation.