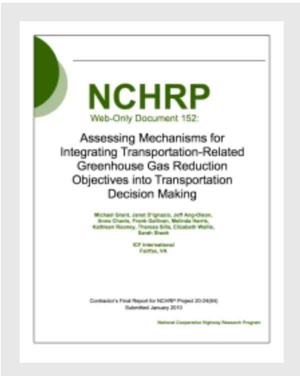
NCHRP
Web-Only Document 152:
Assessing Mechanisms for Integrating Transportation-Related Greenhouse Gas Reduction Objectives into Transportation Decision Making

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Assessing Mechanisms for Integrating Transportation-Related Greenhouse Gas Reduction Objectives into Transportation Decision Making

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ICF International
Fairfax, VA

Contractor's Final Report for NCHRP Project 20-24(64)
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National Cooperative Highway Research Program
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SUMMARY

This report is the product of research supported by the National Cooperative Highway Research Program. (NCHRP) The objective of NCHRP Project 20-24(64) was to provide a factual basis for judging the merits of alternative methods that state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) can use for managing GHG emissions from transportation. The project was undertaken to help policy makers to understand (a) how these alternative approaches to GHG emissions would affect states and metropolitan areas, (b) what approaches may be most effective for evaluating mobile-source GHG emission-management strategies, and (c) what particular tools are available to support implementation of these alternative approaches.

Policy efforts are advancing to integrate climate change considerations into transportation decision making.

New requirements for transportation agencies to integrate greenhouse gas (GHG) considerations into transportation decision making are currently being proposed and debated at both the national and state levels. Bills before the U.S. Senate and House of Representatives would require DOTs and MPOs to demonstrate effort to reduce GHG emissions as part of the statewide and metropolitan transportation planning process. Similar requirements have been proposed for the reauthorization of federal surface transportation legislation. Several states, including California, Washington, and New York, have already adopted requirements to address GHGs in transportation planning. These requirements are being considered in the context of a range of potential national climate change policy statements.

Exhibit ES-1: Examples of Proposed and Existing Requirements for Integrating GHG Objectives into Transportation

American Clean Energy and Security Act of 2009 (HR 2454, House-passed)	Amends existing transportation planning processes to require states and MPOs in transportation management areas (TMAs) to develop targets and strategies for GHG emissions reductions. State and MPO plans must "contribute" to the achievement of the national emissions reductions targets.
Clean Energy Jobs & American Power Act (Boxer/Kerry proposal)	Amends existing transportation planning processes to require states and MPOs in TMAs to develop targets and strategies for GHG emissions reductions. MPOs must demonstrate progress in stabilizing and reducing GHG emissions to achieve state targets.
Surface Transportation Authorization Act Of 2009 (Oberstar proposal)	Requires states and MPOs in TMAs to set targets for GHG emissions reductions from surface transportation and incorporate strategies to meet targets into their plans. U.S. DOT, through performance measures, will verify that states and MPOs achieve progress towards national GHG goals.
California's SB 375 (Signed 2008)	Requires the state to set GHG reduction targets for California's 18 MPOs. MPOs must prepare long range plans that demonstrate how they will achieve the targets.
Washington's HB 2815 (Signed 2008)	Requires the state to reduce light-duty vehicle miles traveled (VMT) per-capita 18% by 2020, 30% by 2035, and 50% by 2050.
New York's State Energy Plan (Adopted 2002)	Calls for analyzing the energy and GHG emissions impacts of long range transportation plans and transportation improvement programs (TIPs).

If enacted, any of the new federal requirements would have major implications for state DOTs and large MPOs. New requirements would likely necessitate enhancement to existing transportation analysis tools. The way the requirements are set could have equity implications, making it easier for some areas to comply than others. The nature of the requirements could also steer investment in GHG reduction measures toward some types of projects and programs over others.

Transportation agency executives need to understand the implications of these policy options. To provide that information, this study performed a comparative assessment of alternative policy mechanisms that would place requirements on transportation agencies to achieve GHG reductions in transportation planning and programming.

Greenhouse gases are different from other air pollutants in important ways.

Although the transportation community has had more than 15 years of experience addressing air quality issues within the transportation planning process, GHG emissions in several ways are different from the criteria air pollutants currently regulated under the Clean Air Act:

- The environmental impact of most GHG emissions is the same regardless of where or when they are released.
- GHGs encompass at least six different gases that generally have the same effect on climate, though some are more potent than others.
- There are no means of using air quality monitoring data to designate nonattainment areas that exceed safe levels.
- GHGs persist in the atmosphere for decades; thus cumulative emissions are important.

Due to the global nature of GHGs, there is not a clear health basis for setting limits of GHG emissions for specific regions or states. Consequently, climate change concerns will likely require new types of policy mechanisms to achieve environmental objectives.

Establishing GHG targets in transportation planning and programming involves decisions on several policy issues.

The assessment described in this report highlights five key dimensions of GHG management policy. (Exhibit ES-2)

Exhibit ES-2: Key Dimensions of Policies Associated with Integrating GHG Objectives into Transportation Planning and Programming

Geographic Level of Implementation	Target Metric	Sources Covered	Reduction Target based on	Regulatory Nature of Target
▪ States ▪ MPOs ▪ Subset of the largest MPOs ▪ Other (county, municipality, multi-state region)	▪ GHG emissions ▪ Vehicle miles of travel (VMT)	▪ Light-duty vehicles ▪ All on-road vehicles ▪ All transportation sources	What units? ▪ Total GHGs or VMT ▪ GHGs or VMT per capita What baseline? ▪ Base year (e.g., 1990) ▪ Business-as-usual scenario forecast	▪ Mandatory (with penalties) ▪ Voluntary (with incentives/ disincentives)

1. What is the Appropriate Geographic Level of Implementation?

There is no clearly effective approach to establishing boundaries for transportation GHG requirements. Unlike other air pollutants, where the geography of the air quality problem informs regulatory boundaries, GHG emissions have a global effect. The geographic level of implementation has implications for the amount of GHGs covered under the requirement, the available strategies for reducing emissions, and the modeling requirements and staffing demands placed on transportation agencies.[1]

- **State-level requirements would cover all areas and avoid placing an unfair burden on urban areas**. An advantage of a state-level requirement is that it would cover the entire geography of the U.S. An MPO-level requirement would cover a large portion of vehicle travel and transportation GHG emissions, but not the entire country. Approximately 70 percent of U.S. vehicle travel occurs in urbanized areas, and MPOs typically encompass these urbanized areas plus non-urbanized areas within the same county boundaries.
- **MPO-level requirements fit well with metropolitan transportation planning practices, but the large number and wide diversity of MPOs creates complexities**. An advantage of an MPO-level requirement is that metropolitan transportation plans are fiscally constrained plans that identify capital investments and other strategies and must be updated on a regular cycle. Therefore, these plans are better suited toward conducting a regional emissions analysis than statewide long range plans, which often are policy-oriented, do not identify specific investments, and are not required by federal law to be updated on a regular cycle. Because of the large number of MPOs (385 currently), a disadvantage of a requirement that applies to all MPOs is the complexity of establishing and tracking attainment of targets, if under the purview of a federal entity, compared to state-level requirements. An advantage of a requirement that applies to larger MPOs is that fewer entities are regulated, while accounting for a relatively large share of transportation GHG emissions.
- **Current analytic tools are inadequate for VMT and GHG analysis at the statewide level and for small MPOs**. Technical analysis capability is an important issue in determining the appropriate geographic level of implementation. Most state DOTs do not have statewide travel forecasting models capable of estimating vehicle travel or GHGs and evaluating reduction strategies. While a state-level requirement may benefit from the fact that state-level GHG inventories have been created for more than 30 states, these existing inventories are not highly detailed. A state-level requirement would place substantial resource demands on most DOTs to develop the necessary analytical tools; it also likely would require changes in the statewide transportation planning process. Upgrading analytical tools and changing the planning process could take several years. While an MPO-level requirement would also place resource demands on MPOs for modeling enhancements, many MPOs – particularly those in larger metropolitan areas – already have the basic building blocks for regional VMT and GHG analysis. The majority of MPOs, however, are small (with populations under 200,000) and have few staff and limited resources to handle new analytical requirements related to GHGs. In fact, the mean number of full time staff at MPOs with under 200,000 population is 3.2.[2]

2. Should a Requirement Focus on VMT or GHGs?

Reducing VMT is one strategy to reduce transportation GHGs. Focusing on VMT could simplify measurement of progress and monitoring of compliance with targets. Yet transportation GHGs emissions are affected by factors other than VMT – vehicle fuel economy, fuel carbon content, and the efficiency of the system operations – and the utility of VMT as a proxy for GHGs diminishes as vehicles and fuels become more efficient. The selection of a VMT or GHG metric has implications for the types of

[1] This study focused primarily on options of statewide or MPO-level implementation, and considered the option of requirements that would apply only to MPOs within Transportation Management Areas (TMAs). It did not evaluate other potential options such as a multi-state region.
[2] General Accounting Office (GAO) 09-868 *Metropolitan Planning Organizations, Options Exist to Enhance Transportation Planning and Capacity*. September 2009.

compliance strategies that would be emphasized and the effectiveness of the requirement at achieving desired climate change benefits.

- **A GHG metric focuses directly on the outcome of interest**. An advantage of using GHGs as a metric is that it is directly focused on the environmental outcome of interest – global climate change. In contrast, VMT is only one factor contributing to GHGs, and the link between VMT reduction and GHG reduction becomes weaker as fuel economy improves and low carbon fuels gain market share. For instance, the U.S. Department of Energy forecasts that between 2007 and 2035, light-duty VMT will grow by 53 percent while CO_2 emissions from light-duty vehicles will decline by nearly 5 percent.[3] A GHG metric accounts for all factors that affect GHG emissions from on-road vehicles – VMT, idling, vehicle fleets, and fuels. A GHG metric would encourage consideration of a wider range of reduction strategies to be implemented within the transportation planning process, and would allow better comparisons between different emissions sectors for an overall national climate strategy.
- **A VMT metric is more commonly used by transportation planners, but ignores the potential benefits associated with transportation system operations strategies and technologies**. An advantage of a VMT requirement is that VMT is more straightforward for transportation agencies to analyze, since it does not account for vehicle fleet characteristics and fuel carbon content. Since transportation planning agencies only have limited influence on vehicle technologies and fuels, a focus on VMT relates directly to a primary driver of GHG emissions that transportation planning decision can influence. It also avoids the potential that an unexpected improvement or slower than expected improvement in vehicle and fuel characteristics would significantly impact the ability to meet a GHG target. A VMT metric, however, will not capture the potential GHG benefits of transportation system management and operations strategies, such as lower speed limits, traffic signal improvements and incident management programs that reduce traffic delay, or technology strategies, such as truck stop electrification.
- **A VMT-based requirement would place more emphasis on strategies that reduce vehicle travel demand, such as land use strategies, transit investments, bicycle and pedestrian investments, and ridesharing programs**. A GHG-based requirement would enable reductions to be demonstrated through investments in improved system operations, and strategies that encourage the use of more efficient vehicle technologies and alternative fuels, as well as vehicle travel reduction. A GHG requirement can also account for reductions in non-road emissions.

3. What Emissions Sources Should Be Covered?

A GHG-related transportation planning requirement could focus only on travel by light-duty vehicles (automobiles and light trucks), all motor vehicles, or all transportation sources (including railroads, air travel, and marine vessels).

- **Light-duty vehicles make up a majority of transportation GHG emissions and can be influenced directly by transportation planning decisions**. Heavy truck travel is more difficult for DOTs and MPOs to influence, since it is closely tied to economic factors and much of it involves trips that extend beyond state or metropolitan area boundaries. In addition, transportation agencies have little influence over freight rail and commercial marine activity. Options available to DOTs and MPOs to reduce emissions from freight travel are largely restricted to reducing idling of vehicles, enabling more efficient movement of freight through specific corridors, and reducing emissions associated with specific port and intermodal facilities.

[3] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2010 Early Release,* December 2009. Summary Reference Case Tables A7 and A19. Available at: http://www.eia.doe.gov/oiaf/aeo/index.html.

- **Heavy-duty freight vehicles make up a disproportionately large share of GHG emissions compared to VMT**. An advantage of including heavy trucks in a planning requirement is that they account for a disproportionate share of GHG emissions. While freight trucks make up only 7.5 percent of VMT nationally, they produce 35 percent of on-road transportation CO_2 emissions.[4] Excluding this source would fail to account for an important component of transportation GHG emissions, and for strategies that improve heavy truck efficiency. However, freight could potentially be addressed through policies at a national level, in which case freight may not need to be included in state or metropolitan analyses.

- **Non-road sources are not typically incorporated into the metropolitan or statewide transportation planning process**. Including these sources would present challenges because non-road transportation is not part of most metropolitan transportation plans and programs. While state DOTs often help to plan and coordinate rail, marine, and air transportation, and some DOTs operate services, most DOTs do not invest in these systems.

4. How Might a Reduction Target be Set?

The way that the target is set would make it easier for some states or MPOs to comply and more difficult for others, depending on factors such as growth rates and the opportunities to implement reduction strategies. A target could be set as a total reduction in transportation GHG emissions or VMT, or as a per-capita reduction. The target could be set in relation to a historic baseline year (e.g., a 20 percent reduction from 1990 levels), a current year, or a projected future baseline (e.g., a build-no build comparison). Another option is not to set a specific target but to simply require VMT or GHG analysis, which in turn might lead to a greater recognition of and consideration of climate change implications in decision making.

- **An advantage of setting a fixed target (e.g., total VMT or GHGs) is that it provides more certainty and provides a common metric to compare the impact of transportation reduction strategies against those focused on other sectors**. However, uniform application of a VMT or GHG reduction target (e.g., a 20 percent reduction from 1990 levels is applied to all areas) may raise equity issues. It would be more challenging to meet this type of target in fast growing areas than slow growing ones.

- **An advantage of setting a per-capita target is that it would not penalize fast growing areas, and would provide more flexibility to DOTs and MPOs** if their actual population growth differs substantially from projections. However, the total GHG reductions achieved through this type of target are less certain, since robust growth could overwhelm actual emission reductions even if the targets are met. In addition, a uniform per-capita target could raise different equity issues, since some areas (e.g., rural areas or slow growing areas) have fewer opportunities to reduce transportation GHGs.

- **Flexibility to establish different targets for different areas is an important consideration in the design of requirements, given the wide diversity in population, economic growth, travel options, and freight movement across states and metropolitan areas**. An advantage of setting a target based on a historic year (e.g., in relation to 1990 levels) is that it would provide credit to states or regions that have taken early action to reduce GHG emissions. However, areas with high population growth would be more challenged to meet such an absolute target than areas with slower growth if uniform targets are established nationwide. The particular baseline year would determine how much targets account for historical trends. An advantage of setting a target in

[4] On-road sources include passenger cars, light-duty trucks, medium-and-heavy duty trucks, motorcycles, and buses. Sources: Federal Highway Administration, *Highway Statistics 2007*, Table VM-1; U.S. Environmental Protection Agency, *Inventory Of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table 2-15, April 15, 2009.

relation to a projected future baseline (e.g., in relation to forecast 2030 levels) is that it would help to level the playing field among states and MPOs, given their wide diversity in population and economic growth, as well as differences in opportunities to reduce motor vehicle emissions. This type of approach could be similar to a "build-no build" analysis that explores the impacts of a set of transportation investments in comparison to a scenario without these investments. Basing targets on forecasts, however, introduces some concerns about the legitimacy and reliability of forecasts used.

Under any approach, consideration needs to be given to the appropriate role and targets for transportation planning agencies in the context of all sectors of the economy.

5. Should a Requirement be Mandatory or Voluntary?

Emission reduction targets can be established to be mandatory or voluntary. A policy mechanism could mandate a certain level of reductions, with penalties for non-compliance (e.g., a VMT or emissions *budget*, similar to the emissions budgets established under the Clean Air Act requirement for transportation conformity) or it could encourage voluntary measures to achieve reductions, with incentives to motivate compliance (e.g., a VMT or emissions *performance standard)*.

- **A mandatory budget would likely require more substantial modeling analysis**. A mandatory budget would likely focus increased attention on strategies to achieve the target, just as the threat of not meeting conformity has been an impetus for some transportation agencies to invest in transportation demand management programs and other emissions reduction measures. It would necessitate greater care in setting realistic and achievable reductions, since failure to meet them would result in highway funding restrictions. As a result, a potential concern with a mandatory budget is that the target would be less ambitious than what some agencies could actually achieve. Given the pass-fail nature of a mandatory budget, it would likely require more effort to analyze the impacts of transportation strategies that have small impacts when close to meeting the target. Moreover, a fixed GHG budget would likely need to be revised on a rigorous schedule to accommodate changes in underlying assumptions regarding vehicle fuel efficiency or fuel carbon content. Performance standards may also need to be updated regularly, but there is less pressure to do so.
- **A performance standard would provide more flexibility to transportation agencies and might yield the same or more substantial GHG reductions as a mandatory budget**. A voluntary performance standard would provide more flexibility to transportation agencies. In some cases, such as if significant incentives were provided, performance standards might encourage agencies to reduce transportation emissions beyond what would be required of them under a budget. However, the total GHG benefits of a target involving performance standards would be less certain than under a budget.
- **A requirement could combine elements of both budgets and performance standards**. For example, a budget could establish minimum levels of reductions required of all DOTs or MPOs, and voluntary performance standards coupled with financial incentives could encourage additional reductions.

Other transportation GHG policy approaches could be considered instead of or in addition to setting targets.

In addition to establishing GHG-related targets for transportation plans, a number of other climate change-related policy mechanisms could be implemented that would directly affect transportation decision making. These mechanisms might be applied as a stand-alone requirement or could be included as a part of a target-based requirement.

- **States and/or MPOs could be required to develop climate action plans.** A climate action plan would identify GHG reduction strategies for all transportation sources, and potentially for all sectors of the economy. A multisector climate action plan could help to put transportation sources into context and enable better consideration and tradeoffs among sectors and modes of transportation, but some transportation strategies that emerge may be difficult to implement if they are not tied to transportation plans, programs, or funding, or if they are outside the control of transportation agencies.
- **Interagency consultation requirements** could be adopted to cover all federal, state, and local stakeholder agencies involved in efforts to reduce GHG emissions. Consultation processes could be similar to those incorporated in the transportation air quality conformity process or other consultation processes that occur in transportation planning. Consultation could include other agencies that may not be as involved in these processes, such as economic development and land use agencies.
- **A requirement for implementing transportation emissions reduction strategies or prioritizing funding toward these strategies** could replace or complement GHG target-based requirements. This approach could require implementation of specific types of transportation emissions reduction strategies or best management practices (BMPs). It could allow State DOTs or MPOs to select from a predetermined list of BMPs and receive credits or points for implementing specific measures in order to achieve a required number of points. This approach would be simpler to implement and less technically challenging than an approach requiring GHG or VMT forecasting, but it raises questions about the effectiveness of emissions reduction strategies in different contexts and applications and about the degree to which overall GHGs would be reduced. Alternatively, it could involve a requirement to prioritize funding for emissions reduction strategies before certain types of transportation investments (e.g., highway capacity improvements) could move forward, even if a target approach is implemented.
- **GHG analysis could be required at the transportation project level** in connection with the National Environmental Policy Act (NEPA) process. This could focus increased attention on the contribution of individual investment decisions on GHG emissions. It would also raise challenging analytical issues, since isolating the GHG impacts of an individual project is difficult, and the impacts are generally small.

Other climate change policies could indirectly affect transportation planning decisions through effects on travel demand, transportation funding, or revenues.

Market-based mechanisms, such as carbon emissions trading and carbon taxes, are policy mechanisms that are being proposed at the national level and may be implemented along with transportation specific requirements. These mechanisms would indirectly affect transportation and could be implemented in conjunction with any of the policy mechanisms that are focused directly on transportation decision making. Policy makers should be aware of the potential indirect effects of these proposals on travel demand, funding, and revenues, and consider potential synergies of transportation requirements with these policies.

Other policy considerations will influence the effectiveness of any new GHG requirements.

The research described in this report was intended to assess advantages and disadvantages associated with different approaches to integrating GHG objectives into transportation decision making. The research demonstrates all approaches under consideration have both disadvantages and advantages; there is no one clearly optimal approach. In addition to their likely effectiveness in achieving GHG objectives, several other considerations will likely influence choices among the several approaches considered in this work:

- **Agencies' technical and staff capacity to fulfill requirements** – Any new requirements to analyze the GHG or VMT impacts of transportation plans and programs at the state or metropolitan level will likely require some improvements in transportation and land use modeling, either to account for better forecasts of VMT, congestion, and trips, or to better model the effects of land use and other strategies. Recognizing the large differences in forecasting capabilities among state DOTs and MPOs of different sizes suggests the need for some transition time and/or funding to ensure a minimum level of capability in forecasting, or an approach that does not require detailed modeling capabilities. This includes the consideration that it will take some time to build the necessary specialized technical skills within the numerous organizations for which these will be required. Transportation agencies have an interest in requirements that help to achieve GHG reductions while minimizing the burdens of having to conduct very time-consuming or complex analyses that only address very small or insignificant levels of emissions.
- **Planning as a means for influencing GHG reductions –** While transportation planning can play an important role in contributing to GHG reductions, transportation agencies have limited control over many of the factors that influence GHGs, including changes in vehicles and fuels. The role of transportation agencies, therefore, needs to be considered in the context of the various factors that affect GHGs.
- **Integration into existing processes** – Any new requirements should work in harmony with the existing transportation planning and project development requirements. New requirements might offer opportunities to better integrate transportation, land use (including housing and economic development considerations), and environmental planning, and should consider how they fit in with other climate change policies.
- **Equity considerations and unintended consequences** – Under an approach that involves targets, a key challenge is setting appropriate targets that are fair and do not unduly burden particular areas at the expense of others. A "one size fits all" type of target applied to all states or MPOs would likely be unworkable and create difficult equity issues, given the wide differences in population growth rates, travel and land use patterns, and the ability to implement effective transportation strategies. If targets are only set for a subset of areas, such as large MPOs this might create an unintended consequence of pushing growth outside of metropolitan areas with the greatest potential to reduce emissions per capita. At whatever level GHGs are regulated, transportation agencies would like to play a key role in establishing targets to ensure they are achievable and meaningful yet do not compromise the ability to meet transportation needs.
- **Flexibility to meet changing conditions** – Efforts to achieve GHG reductions should be flexible to respond to changing conditions, such as variations in population or economic growth and evolution in vehicle fleets. If specific targets are to be set (particularly under a mandatory budget), flexibility to adjust targets over time as necessary.

Transportation system planning and management policies designed to influence emissions and levels of GHG may have significant impact on DOTs and MPOs. If such policies are to be feasible and effective, their designers should consider carefully the policies' likely effectiveness and costs, the administrative burdens that compliance will place on agencies, and the equity of how costs and other burdens are distributed.

As policy makers work to craft global climate change and transportation policies that may affect state DOTs and MPOs, it is essential to consider the strengths and weaknesses of various approaches so that the selected approach works to achieve meaningful reductions in GHG emissions while minimizing compliance burdens, ensuring fairness, and supporting cost-effective strategies.

1. INTRODUCTION

This report is the product of research conducted by ICF International and supported by the National Cooperative Highway Research Program. (NCHRP) The objective of NCHRP Project 20-24(64) was to provide a factual basis for judging the merits of alternative methods that state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) can use for managing GHG emissions from transportation. The project was undertaken to help policy makers to understand (a) how these alternative approaches to GHG emissions would affect states and metropolitan areas, (b) what approaches may be most effective for evaluating mobile-source GHG emission-management strategies, and (c) what particular tools are available to support implementation of these alternative approaches.

1.1 Background

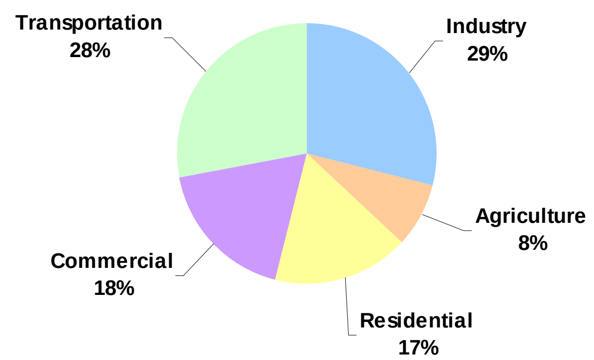
Given widespread concerns about the risks of climate change, momentum has been growing within the United States for policy actions to address greenhouse gases (GHGs), including reduction of GHG emissions from the transportation sector. At the state and local level, more than 30 states have developed climate action plans and more than 1,000 mayors have signed on to the U.S. Conference of Mayors Climate Change Protection Agreement pledging to reduce carbon dioxide (CO_2) emissions below 1990 levels by 2012.[5] At the federal level, legislative efforts are now underway in Congress and new initiatives being taken by the Obama Administration to tackle global climate change. The House of Representatives has passed legislation (Waxman-Markey HR-2454 *American Energy and Security Act of 2009 (ACES)*), and legislation was recently introduced in the Senate (Boxer-Kerry *Clean Energy Jobs & American Power Act*), which both include development of a national cap and trade program.

Since the transportation sector contributes 28 percent of U.S. GHG emissions (see Exhibit 1-1), serious attention is being given to the role that transportation might play in reducing GHGs. At the federal level, President Obama announced a new coordinated GHG and fuel economy program that would apply to light-duty vehicles and result in a combined fleet average standard of 35.5 miles by gallon by the 2016 model year. The U.S. Environmental Protection Agency (EPA) in May 2009 proposed new regulations for the National Renewable Fuel Standard Program in response to the Energy Independence and Security Act of 2007, which establishes new volume standards for renewable fuels that must be used in transportation fuels each year.

In addition to efforts that focus on vehicles and fuels, there has also been growing interest in policies to achieve GHG emission reductions through transportation decision making. For instance, the new House and Senate legislation both include provisions that would establish national GHG reduction goals and would establish criteria for DOTs and large MPOs to set GHG targets for metropolitan and statewide transportation planning. Policy changes such as these legislative proposals could become law as part of a national multi-sector policy to regulate GHGs, reauthorization of the federal surface transportation legislation, amendments to the Clean Air Act, or EPA rulemaking under the existing Clean Air Act. Numerous proposals have been put forth by environmental groups to address GHGs at the metropolitan and state level. Reauthorization discussions have included development of performance-based funding programs, including use of GHG reduction performance metrics.

[5] Center for Climate Strategies, http://www.climatestrategies.us/ and U.S. Conference of Mayors, http://www.usmayors.org/climateprotection/revised/. As of October 15, 2009.

Exhibit 1-1: U.S. Greenhouse Gas Emissions by Sector, 2007



Source: U.S. EPA, Inventory Of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, April 2009.

Already, several states have begun to develop policies to address the quantification and reduction of GHG emissions through transportation planning decisions (see Exhibit 1-2).[6] These include:

- **Quantification of Plan Impacts.** In New York State, the State Energy Plan, adopted in 2002, calls for the metropolitan planning organizations (MPOs), in conjunction with the state, to assess the energy use and GHG emissions expected to result from implementation of transportation plans and programs . Most MPOs in New York have now estimated energy use and CO_2 emissions from their long-range transportation plans and also from their transportation improvement programs (TIPs).[7] In California, several large MPOs have quantified the GHG impacts of their regional transportation plans as part of the environmental review required by the California Environmental Quality Act (CEQA).
- **Regional Transportation GHG Reduction Goals.** With the signing of SB 375 in September 2008, California became the first state to enact mandatory GHG reduction targets in regional transportation planning. The law directs the California Air Resources Board (CARB) to provide each of the state's 18 MPOs with GHG emissions reduction targets from the auto and light truck sector for 2020 and 2035 by June 30, 2010. MPOs will then be required to include measures in their long range plans to reach the GHG targets, either as part of a "sustainable communities strategy" within the plan or as part of an "alternative planning strategy" separate from the plan. Each MPO must have the approval of CARB for either of these strategies.
- **State VMT Reduction Goals.** In March 2008, the state of Washington enacted climate change framework legislation HB 2815, which includes a requirement to reduce light-duty vehicle miles traveled (VMT) per capita 18 percent by 2020, 30 percent by 2035, and 50 percent by 2050. This provision was a recommendation arising from the state's 2007 Climate Advisory Team.

[6] See ICF International, *Integrating Climate Change into the Transportation Planning Process: Final Report*, Prepared for FHWA, July 2008.
[7] See ICF International, *Estimating Transportation-Related Greenhouse Gas Emissions and Energy Use in New York State*, prepared for the U.S. DOT Center for Climate Change and Environmental Forecasting, March 2005.

Exhibit 1-2: Examples of Proposed and Existing Requirements for Integrating GHG Objectives into Transportation Planning and Programming

American Clean Energy and Security Act of 2009 (HR 2454, House-passed)	Amends existing transportation planning processes to require states and MPOs in transportation management areas (TMAs) to develop targets and strategies for GHG emissions reductions. State and MPO plans must "contribute" to the achievement of the national emissions reductions targets.
Clean Energy Jobs & American Power Act (Boxer/Kerry proposal)	Amends existing transportation planning processes to require states and MPOs in TMAs to develop targets and strategies for GHG emissions reductions. MPOs must demonstrate progress in stabilizing and reducing GHG emissions to achieve state targets.
Surface Transportation Authorization Act Of 2009 (Oberstar proposal)	Requires states and MPOs in TMAs to set targets for GHG emissions reductions from surface transportation and incorporate strategies to meet targets into their plans. U.S. DOT, through performance measures, will verify that states and MPOs achieve progress towards national GHG goals.
California's SB 375 (Signed 2008)	Requires the state to set GHG reduction targets for California's 18 MPOs. MPOs must prepare long range plans that demonstrate how they will achieve the targets.
Washington's HB 2815 (Signed 2008)	Requires the state to reduce light-duty VMT per-capita 18% by 2020, 30% by 2035, and 50% by 2050.
New York's State Energy Plan (Adopted 2002)	Calls for analyzing the energy and emissions impacts of long range transportation plans and transportation improvement programs (TIPs).

Transportation agency officials are understandably concerned about the effects new transportation GHG requirements on their agencies, in terms of analysis and decision making within statewide and metropolitan transportation planning and programming as well as project development. New requirements for managing GHG emissions from transportation sources may influence how DOTs and MPOs develop their long-range transportation plans and TIPs. New requirements may also change how DOTs, MPOs, and transit agencies must conduct project-level analyses, and affect their relationships with federal and state environmental agencies.

Some of the approaches being advocated are similar to a transportation conformity-style mechanism involving mandatory emissions budgets for on-road emissions sources, such as has been used for managing pollutants defined under federal law—what are termed criteria pollutants. The more than 15 years of experience with the transportation conformity process established under the Clean Air Act (CAA) Amendments provide a number of lessons learned about what has worked well and what has been less successful. Most observers agree that greater interagency consultation and emphasis on funding transportation strategies that improve air quality have been positive outcomes of the requirements. At the same time, many agencies believe that the conformity-based procedures are costly, time-consuming, and have only produced marginal improvements in air quality, due to limited ability of transportation agencies to influence the most significant factors that relate to motor vehicle emissions.

In the 1990s, dozens of MPOs went into a conformity "lapse" at one time or another, causing federal transportation funding to be restricted to a limited number of already approved or exempt projects (e.g., maintenance, safety, or air quality reduction projects). A number of technical issues with modeling and assumptions have also arisen due to the dynamic nature of transportation planning and mismatches between the tools and assumptions used to develop the State Implementation Plan (SIP) and transportation plans. For example, transportation plans and programs must demonstrate conformity at least every four years but there is no requirement to update the SIP on a regular basis. Thus, the tools and data used to develop the emissions budget can be different than those used to demonstrate conformity.

Although state air agencies have in many cases responded to these concerns (e.g., updating conformity budgets, trading mechanisms, or identifying additional strategies to assist in meeting conformity requirements), these issues have been challenging for many areas. Difficulties in analysis have also occurred in areas where nonattainment area boundaries did not match MPO travel demand model boundaries, and in rural areas with less resources and modeling experience.

The conformity experience and some of the recent state GHG initiatives raise questions about the incorporation of GHG objectives into the transportation decision making process. Perhaps the most significant of these is the concern that transportation agencies may be required to produce large reductions in transportation GHGs that will be unattainable, since these agencies have virtually no control over vehicle technology and fuels.[8] While there are a number of effective strategies to mitigate transportation emissions through demand management and system management, there is no clear evidence about how successful these strategies will be or what level of emissions reduction is appropriate to assign to transportation planning solutions in the context of state or national GHG reduction goals.

While many transportation agencies have had experience with integrating air quality considerations into transportation planning through the transportation conformity process, GHGs are distinct from the criteria air pollutants currently regulated under the Clean Air Act in several important ways:

- The environmental impact of most GHG emissions is the same regardless of where or when they are released. Issues such as localized "hot spots" and how atmospheric conditions, such as temperature, affect pollution are not relevant for most GHGs.[9]
- GHGs encompass at least six different gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorcarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) – all of which have the same general effect on the climate, though some are more potent than others. CO_2 accounts for the majority of GHG emissions from human activity and for about 95 percent of all GHGs emitted from transportation. Consequently, many analyses of transportation GHGs include only CO_2.
- There is no means of using air quality monitoring data to designate nonattainment areas that exceed safe levels.
- GHGs persist in the atmosphere for decades – thus cumulative emissions are important.

Criteria air pollutants, such as ozone and particulate matter, can be directly measured by means of air quality monitoring data, and geographic areas that exceed safe levels are designated by EPA as nonattainment areas. The geographic scale of requirements for reducing emissions is, therefore, based on atmospheric and meteorological data on air sheds using monitored air quality data as well as the location of emission sources. The target reductions are based on atmospheric modeling showing the pollutants of concern that contribute to poor ambient air quality and the level of reductions necessary to meet health-based air quality standards.

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[8] For example, modeling by the Metropolitan Transportation Commission, the MPO for the San Francisco Bay Area, for its 2035 plan found that a policy package of road pricing, smart growth, and telecommuting would reduce GHG emissions 17% from the baseline. Only with the addition of vehicle fuel efficiency improvements could the region reach its goal of a 40% reduction in on-road GHGs by 2035.

[9] Localized pollutants such as tropospheric ozone, carbon monoxide (CO), and aerosols also contribute to trapping heat in the atmosphere but their radiative forcing effects are difficult to quantify due to their short atmospheric lifetimes and concentrations that vary spatially and temporally.

In contrast, due to the global nature of GHGs, there is not a clear basis for setting limits to GHG emissions for specific regions or states within specific time frames. While climate scientists can identify a total level of GHG reduction necessary for climate stabilization, it is not clear how much of that reduction should come from the transportation sector, and how GHG reductions should be apportioned across states, metro areas, and rural areas, given vast differences in growth rates, economic base, and analytic capability. Consequently, any regulatory scheme for addressing GHG emissions in transportation planning will need to consider the unique aspects of GHG emissions if setting targets and establishing measurement techniques. Moreover, establishing GHG-related requirements in transportation planning will involve decisions on several policy issues that are not easily answered.

1.2 Purpose and Scope of the Study

The study reported here was intended to provide a factual basis for judging the merits of alternative policy mechanisms for managing GHG emissions from transportation. The research specifically explored how various approaches in place or proposed integrate with or impact transportation decision making at the state, regional and local levels. The primary audience for this research is intended to be federal, state, regional, and local policy-makers who are facing decisions about how best to integrate GHG reduction strategies with transportation and air quality planning. The analysis may also be useful to technical staff who support these policy makers and staff at state DOTs, MPOs, transit agencies, and environmental agencies that may play a role in advising upon and implementing new requirements.

The study is designed to provide information on (a) how alternative approaches to managing GHGs from transportation may affect states and metropolitan areas; (b) the strengths, limitations, and technical issues associated with implementation of alternative approaches; and (c) the capabilities of existing analysis tools to support implementation of alternative approaches.

This report is not intended to recommend any one regulatory approach over another, but is designed to help prepare policy and technical staff to contribute to and respond to regulatory proposals with a full understanding of their implications for transportation agencies.

The research focused on *policy mechanisms or approaches* that may affect transportation planning and investment decision making, such as those that may be included as part of new legislation, or regulations or rulemakings, and in particular on three policy approaches that might place requirements on state DOTs or MPOs involving setting specific targets for GHGs or VMT. These policy mechanisms are not mutually exclusive in that federal or state regulations or requirements could combine aspects from several of them. The three policy mechanisms and a brief description of each are shown in Exhibit 1-3.

In addition, this research analyzed four additional mechanisms that may place direct requirements on transportation agencies and may serve as components of the three approaches above or as stand-alone activities. The additional mechanisms are shown in Exhibit 1-4.

This report does not explore the effectiveness of specific transportation strategies (such as land use strategies, transit investment, transportation demand management programs, or operations strategies), or packages of strategies to reduce GHGs. A variety of other studies have examined and are examining such strategies.[10] In addition, this paper does not focus on regulatory approaches aimed directly at improving

[10] For instance, on-going projects or recently completed projects include: *Moving Cooler*, an effort co-sponsored by transportation and environmental groups and federal agencies, which examined strategies that could be implemented to reduce GHG emissions from personal travel; *NCHRP 20-24(59): Strategies for Reducing the Impacts of Surface Transportation on Global Climate Change*, which is preparing a synthesis of current research; *NCHRP 25-25 (45):*

vehicle efficiency (such as federal corporate average fuel economy (CAFE) or GHG emissions standards for vehicles) or increasing the use of low carbon fuels (such as a renewable fuel standard), or at economy-wide policies, such as cap-and-trade programs. While these approaches, and advances in technologies, are likely to be central components of the overall effort to reduce the transportation sector's contributions to climate change, they do not directly affect transportation agencies and therefore are considered outside the scope of this project.

Exhibit 1-3: Policy Mechanisms Analyzed Involving Target Setting

Policy Mechanism	Summary Description
Transportation GHG performance standard[11]	Involves establishment of GHG reduction targets with incentives for compliance or to assist in compliance.
Transportation GHG budget[12]	Establishes maximum levels of allowable GHG emissions with penalties for non-compliance. This approach is something similar to the process currently used in transportation conformity for areas not meeting the national ambient air quality standards.
Vehicle miles traveled (VMT) performance standard	Involves establishment of a VMT or VMT per capita target, with incentives provided for compliance or to assist in compliance.

Transportation Program Responses to GHG Reduction Initiatives and Energy Reduction Programs, which is documenting state DOT roles and practices to develop an estimate of GHG emissions reductions from on-going and potential actions; *TRB study: Potential Energy Savings and Greenhouse Gas Reductions from Transportation*, which is estimating the potential energy savings and GHG reductions that might be realized from transportation; and U.S. DOT's *Report to Congress on Transportation and Climate Change*, which is examining the GHG reduction effects of alternative transportation strategies, and the potential fuel savings and reductions in air pollution associated with these strategies.

[11] For purposes of this project, performance standards are defined as aspirational in nature. No penalties for non-compliance are assumed.

[12] For purposes of this project, budget assumes a fixed, numerical budget that cannot be exceeded for specific analysis years (e.g. 2020, 2050) and that penalties would apply for inability of a state DOT or MPO to reduce emissions to the allowable budget level.

Exhibit 1-4: Other Mechanisms Considered as Stand-Alone or Companion Policies

Climate Change Action Plan Requirement	This approach would require states to develop a GHG reduction plan for all sources, including both on-road and off-road transportation sources. This plan could involve setting targets for the transportation sector as a whole or specific components (e.g., on-road sources) and could identify specific GHG reduction strategies.
Interagency consultation requirements	Agencies involved in transportation planning / programming and air quality regulatory agencies would be required to consult on an on-going basis. This process could be somewhat similar to the current consultation requirements in transportation conformity, and depending on other requirements could address issues such as progress in meeting targets, revisions to targets, selection of strategies, or progress in implementing strategies, etc.
A requirement for implementation or prioritization of transportation emissions reduction strategies	This approach could require implementation of specific types of transportation emissions reduction strategies or best management practices (BMPs) within transportation plans and/or project development. It could involve credits or points that regulated areas would receive for implementing specific measures and allow State DOTs or MPOs to select from a predetermined list of BMPs in order to achieve a required number of points. It could also involve a requirement to prioritize funding for emissions reduction strategies before certain types of transportation investments (e.g., highway capacity improvements) could move forward.
Project level GHG analysis	Project-level emissions analysis is currently required only for hot-spot concentrations of certain pollutants. This would add GHG to the list of pollutants subject to a project-level analysis requirement which is usually carried out through the NEPA process.

1.3 Study Process

The identification and assessment of alternative policy mechanisms included in this study relied heavily on extensive input from practitioners from state DOTs, MPOs, transit agencies, and state environmental and air quality agencies, as well as federal agencies and national associations that represent transportation planning organizations. The research effort involved the following activities:

- Development of a background paper, based on research describing alternative possible policy mechanisms and their attributes;
- A workshop, held April 2-3, 2009 in Washington, DC, to engage participants in identifying alternative approaches and their perceived attributes, strengths and weaknesses, and implications;
- Two “virtual meetings” held via webinar on April 14 and 15, 2009 to bring in additional perspectives for other members of the transportation and environmental communities;
- A technical memo evaluating alternatives policy mechanisms for addressing transportation GHGs, comparing the alternative approaches, and assessing analysis tools and methods, based on additional research as well as interviews with selected transportation and environmental agencies with experience with GHG requirements;

- A second workshop held August 25-26, 2009 in Washington, DC, which invited back the initial group of workshop participants (plus a few additions) to validate the assessment of the alternative approaches and clearly define the pros and cons of each alternative.

In total, the workshops, virtual sessions, and interviews involved over 40 transportation and environmental professionals. These practitioners included staff with specific experience addressing state/local GHG requirements and experience with the transportation air quality conformity process, as well as some representing states with limited experience with current air quality requirements. The study also involved gathering input from national organizations, including the American Association of State Highway and Transportation Officials (AASHTO), the Association of Metropolitan Planning Organizations (AMPO), the American Public Transportation Association (APTA), and the National Association of Regional Councils (NARC). (See Appendix A for a list of all workshop participants.)

1.4 Report Organization

The remainder of this report is divided into four main sections:

- *Overarching Options for Establishing Transportation Requirements that Involve Targets.* Section 2 of this report discusses several overarching considerations associated with any requirement that involves setting targets to address GHG emissions in transportation planning/programming. It addresses the following key questions, and notes strengths and limitations of the primary options: 1) at what geographic level (e.g., state, metro area, other) should requirements be placed? 2) what should be measured (e.g., GHGs or VMT)? 3) what sources should be covered (e.g., light-duty vehicles, all on-road vehicles, all transportation)? 4) how should targets be defined? And 5) how should compliance be incentivized (e.g., penalties for non-compliance or incentives for compliance)?

- *Assessments of Alternative Policy Mechanisms for Reducing Transportation GHGs.* Section 3 identifies and describes several policy mechanisms that involve setting targets, along with requirements that might be implemented in addition to or instead of target-based requirements. It identifies key issues for policy makers to consider regarding each of these options, and includes a comparative assessment of the potential approaches focusing on the following assessment criteria: technical and staffing requirements, GHG reduction certainty and control, co-benefits/synergies, potential unintended consequences, flexibility/adaptability, equity, and public understanding.

- *Implications of Alternative Targets on Sample States and MPOs.* Setting targets is a particularly challenging and complex issue for any national-level policy mechanism addressing GHGs in transportation. Given differences in population growth, travel patterns, and economic activity, among other factors, the reductions required to meet a specific target will vary significantly across different states and metro areas. Section 4 of this report contains an analysis of a sample of states and metropolitan areas examining the estimated GHG emissions reductions that would be required to meet alternative targets. .

- *Analysis Tools and Techniques to Support Implementation of Policy Mechanisms.* Under policy mechanisms that include transportation planning/programming requirements, state DOTs or MPOs or both would need to conduct quantitative analyses to forecast GHG emissions or VMT associated with their transportation plans and programs. Section 5 of this report reviews the availability, strengths, and limitations of existing tools that may be needed to meet requirements, identifies gaps, and discusses the potential implications of these gaps.

2. Overarching Options for Establishing Transportation Requirements that Involve Targets

A transportation planning/programming requirement that involves setting targets to achieve GHG reduction objectives would likely entail several components:

- Setting a target reduction (e.g., through an emissions budget, a VMT performance standard, etc.) by federal or state authorities;
- Establishing administrative procedures;
- Establishing penalties and incentives for compliance; and
- Determining appropriate tools for analysis of transportation plans, programs, or investments.

Although this type of approach is sometimes thought of as a "conformity style" approach (referring to the transportation conformity process that is currently applied to criteria pollutants in air quality nonattainment and maintenance areas), there are a wide range of options for establishing GHG-related targets in transportation planning and programming, as identified in Exhibit 2-1.

Exhibit 2-1: Key Dimensions of Policies Associated with Integrating GHG Objectives into Transportation Planning and Programming

Geographic Level of Implementation	Target Metric	Sources Covered	Reduction Target based on	Regulatory Nature of Target
▪ States ▪ MPOs ▪ Subset of the largest MPOs ▪ Other (county, municipality, multi-state region)	▪ GHG emissions ▪ Vehicle miles of travel (VMT)	▪ Light-duty vehicles ▪ All on-road vehicles ▪ All transportation sources	What units? ▪ Total GHGs or VMT ▪ GHGs or VMT per capita What baseline? ▪ Base year (e.g., 1990) ▪ Business-as-usual scenario forecast	▪ Mandatory (with penalties) ▪ Voluntary (with incentives/ disincentives)

This section highlights five major policy issues associated with setting targets:

- What is the appropriate geographic level of implementation?
- What is the most appropriate target metric -- VMT or GHGs?
- What emissions sources should be covered?
- What are the most appropriate measurement benchmarks?
- Should a requirement be mandatory or voluntary?

In addition, other policy questions not directly addressed here will need to be addressed, such as what is the appropriate entity to establish targets and oversee compliance (for example, U.S. Department of Transportation, U.S. Environmental Protection Agency, state agencies.)

2.1 Geographic Level of Responsibility – State, MPO, or Local

GHG emission reduction programs can be applied at various geographical levels. At any level, responsibility for compliance could be assigned to a single agency or a group of agencies. There are four possible levels of application:

- States – Requirements would likely be applied to state DOTs, but could also involve other state agencies including departments of environment and departments of energy.[13]
- Metropolitan areas – Requirements would be applied at the level of metropolitan areas. MPOs are the most likely candidates, as the only regional agencies that currently perform a federally designated transportation role.[14]
- Transportation management areas (large metropolitan areas) – Requirements could be limited to a subset of larger metropolitan areas defined as transportation management areas (TMAs). TMAs, urbanized areas with more than 200,000 residents,[15] are subject to an additional set of federal requirements in metropolitan transportation planning.
- Local government units – Requirements could be set for county or city governments.

Responsibility could also be shared across geographic levels. For example, a state agency could serve as overall manager of a program, answering to U.S. DOT. But state agencies could also assign some responsibilities to local agencies. For example, California's SB 375 is a state-level requirement. The California Air Resources Board (CARB) is tasked with assigning GHG reduction targets to MPOs in the state. MPOs will then work with local governments to achieve required reductions. This study primarily focused on a statewide or MPO-level of implementation, and did not evaluate other potential jurisdictions or geographies such as multi-state regions.

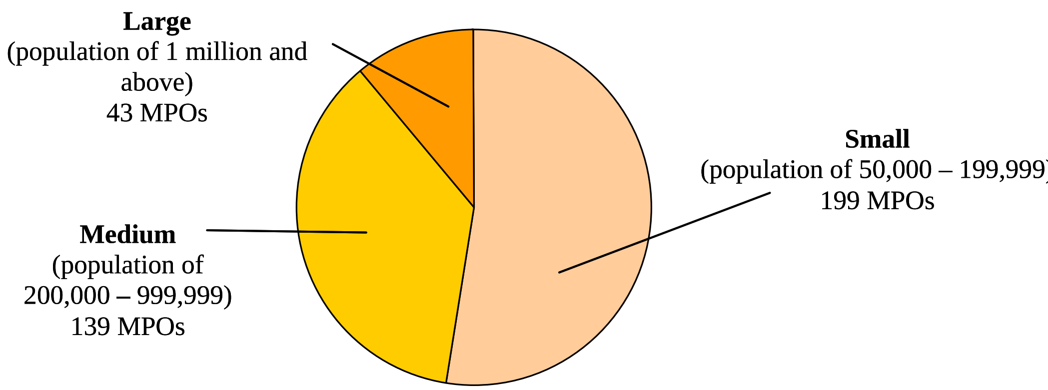
Requirements applied at the state level would provide the broadest coverage, but many state DOTs do not currently have the capacity to incorporate rigorous GHG emissions reduction programs in long range transportation planning. For example, statewide transportation plans must be developed for a minimum 20-year period but many are primarily policy-oriented plans and there is no federally required update schedule.[16] State DOTs may have to adopt a routine update schedule for plans to accommodate any GHG requirements. In addition, most DOTs have limited or no ability to forecast travel demand across the entire state roadway network. Statewide models would need to be created or significantly upgraded in order to forecast the impact of GHG reduction strategies. (See Section 5.3 for a more extensive discussion of state travel models.) Moreover, state DOTs control different proportions of roadway miles in each state, ranging from 6 percent in New Jersey to 89 percent in West Virginia.[17]

MPOs cover only part of the country, but GHG requirements could be more readily integrated into the current federally required metropolitan transportation planning process. MPO long range plans must be updated every five years, or four years in air quality non-attainment or maintenance areas. MPOs in non-attainment or maintenance areas already have experience conducting analyses of emissions related to their plans in response to the transportation conformity requirements of the Clean Air Act. Still, the majority of MPOs represent small urban areas, as shown in Exhibit 2-2. Many smaller MPOs have relatively simple or even no travel demand modeling capacity. Some small MPOs rely on their state DOTs, state air agencies, or outside consultants to provide model outputs and perform transportation or emissions

[13] Throughout the document the term "states" is used to apply to state governments generally, including executive offices and legislative bodies. The term "state DOTs" is used when departments of transportation are specifically intended.
[14] The boundaries of analysis could correspond with MPO boundaries, or could reflect some variation, such as the U.S. Census' combined statistical area (CSA) boundaries, which are used in air quality conformity and typically include an MPO(s) and surrounding communities.
[15] 23 USC 134(k)
[16] Federal regulations require each state to develop a long-range statewide transportation plan, with a minimum 20-year outlook, to be developed in consultation with state, tribal and local agencies. See 23 USC 135(f).
[17] Federal Highway Administration, *Highway Statistics 2007*, Table HM-10.

modeling. The mean number of full time staff at small MPOs (less than 200,000 population), according to responses from a recent GAO survey, is 3.2. The mean number of full time staff at medium MPOs (between 200,000 and 1 million population) is 8.2.[18]

Exhibit 2-2: Number of MPOs by Population Size



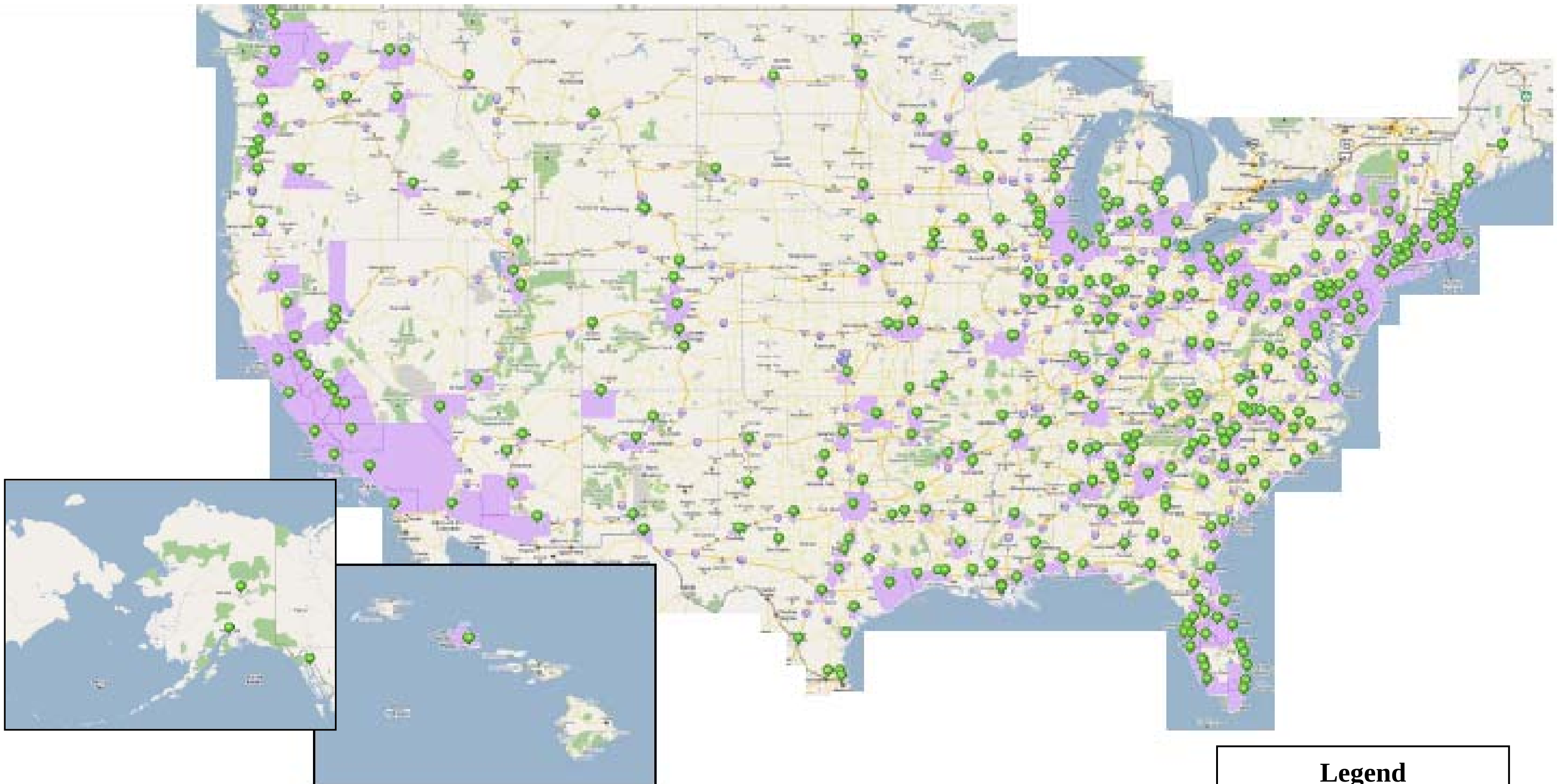
Source: General Accounting Office (GAO) 09-868 *Metropolitan Planning Organizations, Options Exist to Enhance Transportation Planning and Capacity*. September 2009.

Exhibit 2-3 displays MPOs and their boundaries nationwide. Some areas of the country are entirely covered by MPOs, including portions of California, Florida, and the northeast, but much of the country is not covered by an MPO. Still MPOs contain a majority of vehicle travel in the United States, with at least 70 percent of VMT occurring in urbanized areas with over 50,000 population in 2007.[19]

If only Transportation Management Areas (TMAs) were responsible for GHG reduction programs, coverage would be further reduced. TMAs still account for more than half of U.S. vehicle travel; at least 52 percent of VMT were in urbanized areas of over 200,000 population in 2007.[20] TMAs also tend to have more staff resources and more sophisticated travel demand models than smaller MPOs. In this regard the regulatory burden on TMAs would probably be the least of any agency type. Regulation at the level of MPOs or TMAs could inadvertently encourage development outside of the regulated metropolitan areas, depending on how the regulations are crafted and how stringent reduction targets are set.

[18] General Accounting Office (GAO) 09-868 *Metropolitan Planning Organizations, Options Exist to Enhance Transportation Planning and Capacity*. September 2009.
[19] MPO boundaries typically encompass a larger geographic area than the urbanized area boundaries, so the percentage of VMT in MPO areas is likely to be larger. Calculation based on data from Federal Highway Administration, *Highway Statistics 2007*, Tables HM-71 and VM-2. Daily VMT in Table HM-71 were multiplied by 365 to calculate annual VMT.
[20] MPO boundaries typically encompass a larger geographic area than the urbanized area boundaries, so the percentage of VMT in MPOs that are TMAs is likely to be larger. Calculation based on data from Federal Highway Administration, *Highway Statistics 2007*, Tables HM-71 and VM-2. Daily VMT for urbanized areas with population 200,000 or greater in Table HM-71 were multiplied by 365 to calculate annual VMT.

Exhibit 2-3: Map of Metropolitan Planning Organization (MPO) Areas in the United States



Legend

MPO Location

Source: Association of Metropolitan Planning Organizations (AMPO).

Counties and municipalities have planning powers that may be important in the implementation of any transportation GHG reduction program. Decisions about land use are typically made at the level of cities and counties. These agencies will need to be engaged in any efforts to integrate transportation planning and land use, which can help reduce VMT and GHG emissions. Regulation at the county level would also cover the entire U.S. On the other hand, travel patterns become increasingly difficult to track and to mitigate at smaller geographic levels. It may be impractical to expect cities and counties to meet GHG reduction requirements individually. Cities and counties would also need a substantial amount of support to conduct any detailed analyses of transportation GHG emissions

At any level of requirement, there are some complexities in analysis. For example, some MPOs span multiple states. Regulation at the state level could mean that some states deal with only portions of some urban areas. Regulation at the MPO level would require some MPOs to coordinate plans across multiple states. The air quality conformity process has demonstrated that the requirements for institutional coordination in such multi-state urban regions are highly complex but can be done to meet regulatory requirements. The interagency consultation process has assisted these large areas to coordinate together or implement certain flexibilities to allow separate states to work independently.

Exhibit 2-4 highlights key issues associated with the choice of geographic implementation.

Exhibit 2-4: Geographic Levels of Responsibility - Key Issues

Geographic Level Applied	Strengths	Limitations	Other Implications and Considerations
States	▪ Covers travel in all areas of the U.S., urban and rural.	▪ State Long Range Transportation Plans (LRTPs) often are policy plans; do not identify all investments over long time-frame. Would require a major shift in planning approach. ▪ Limited statewide travel model capabilities	▪ State LRTPs may need to be updated on a more frequent and regular schedule. ▪ Statewide models will likely need improvements ▪ State DOTs control different proportions of roadway miles in each state
All MPOs	▪ Major travel patterns are generally contained within MPO boundaries ▪ Would cover a significant portion of travel in the U.S.	▪ Does not provide full coverage of U.S. ▪ Many MPOs (e.g., smaller MPOs) have limited staff and modeling capabilities ▪ May inadvertently push growth outside of metro areas	▪ Need to consider how GHG requirements relate to air quality requirements to look for efficiencies ▪ MPO models may need improvements
TMAs	▪ TMAs generally have the most sophisticated travel models ▪ Would cover areas with the largest GHG emissions	▪ Does not provide full coverage of U.S. ▪ May inadvertently push growth outside of large metro areas	▪ Need to consider how GHG requirements relate to air quality requirements.
County or municipality	▪ Land use decisions are typically made at this level ▪ Could cover travel in all areas of the U.S.	▪ Difficult to assess and control GHGs at smaller geographic levels	▪ Local governments may need substantial resources for analysis

Any requirements for new long range planning or travel modeling activities would be easiest to implement for agencies that already have robust planning and modeling capabilities, particularly large MPOs. Many state DOTs would need to establish new long range planning practices if they were given primary responsibility for GHG reduction programs. Most state DOTs and smaller MPOs would need to upgrade or acquire travel forecasting models. However, easier implementation does not necessarily equate to better policy. If responsibility for GHG reductions were assigned just to MPOs, not all travel in the U.S. would be covered. Any regulatory scheme will have to consider existing geographical and political boundaries, and the best way to achieve coordination across agencies at different geographical levels.

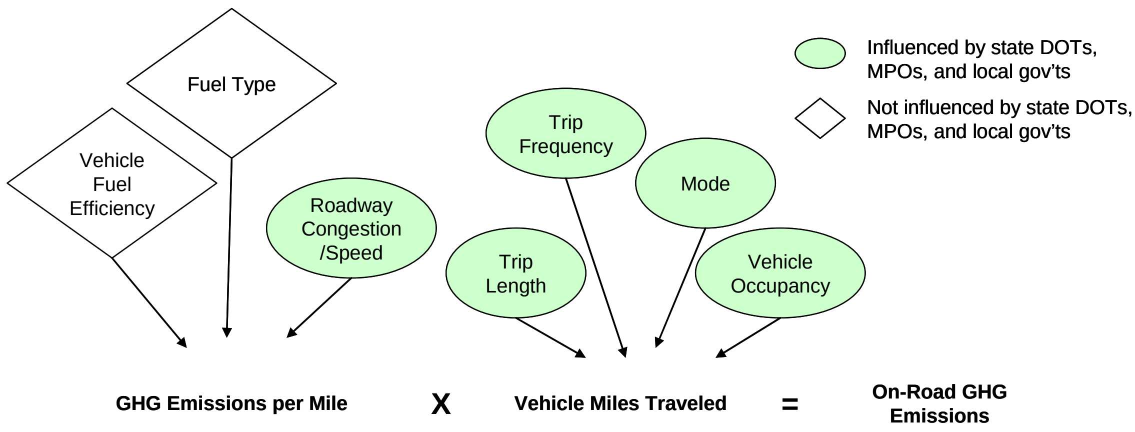
2.2 Target Metric – Vehicle Miles Traveled or Greenhouse Gas Emissions

The metric selected to be used as part of a target will ultimately affect what kinds of changes in the transportation system are promoted and how regulated agencies are evaluated. Two primary target metrics generally are considered: (a) GHG emissions, measured as tons of CO_2 emitted (or tons of CO_2 equivalent, incorporating other GHGs), understood as a direct measure of emissions from vehicle tailpipes;[21] and (b) vehicle-miles of travel, VMT, a proxy for tailpipe emissions.

A major potential challenge with the regulation of transportation GHGs through the planning process is the fact that the implementing agencies (DOTs and MPOs) have little or no control over some of the most important factors affecting on-road GHG emissions – namely, vehicle efficiency and fuel type. As illustrated in Exhibit 2-5 below, transportation agencies can influence the rate of GHG emissions per mile primarily through changes to roadway speeds and congestion levels.[22] In contrast, transportation agencies (together with local governments) can influence (although they do not control) the various factors that affect VMT. Thus, some have argued that regulation of GHGs through transportation planning should focus on VMT, not on-road GHGs. This type of approach, however, would be a significant departure from the existing transportation conformity approach that is in place for air quality. Under transportation conformity, the focus of analysis is on-road vehicle emissions, and reductions in emissions may be achieved through a wide range of strategies, including technology, fuels, and travel demand strategies.

[21] A very small percentage of transportation GHG emissions come from non-tailpipe sources, including primarily leakage of refrigerants from air conditioners and mobile refrigeration units, as well as lubricants used by vehicles.
[22] Transportation agencies may play a limited role in vehicle efficiency and fuels through investments in infrastructure, such as truck stop electrification, or creating incentives, such as allowing alternative fueled vehicles to use restricted (e.g., high occupancy vehicle) lanes. States can play a larger role through tax incentives or other policies.

Exhibit 2-5: Factors that Influence On-Road Vehicle Greenhouse Gas Emissions



Source: Figure adapted from: Salon, Deborah et al, "City carbon budgets: Aligning incentives for climate-friendly communities," Institute of Transportation Studies, University of California, Davis, June 11, 2008.

GHG emissions are a direct measure of the environmental outcome of interest – global climate change – and as such have some advantages as a metric. All types of strategies that can reduce transportation GHG emissions would be credited under a GHG metric, including strategies that reduce VMT, vehicle and fuel technology strategies, and operational strategies. Strategies that reduce emissions from transportation construction and maintenance activities also could be credited. A GHG metric can be used for non-road transportation (e.g., aircraft, rail, ships) and for other industry sectors, allowing comparison of these with on-road transportation.

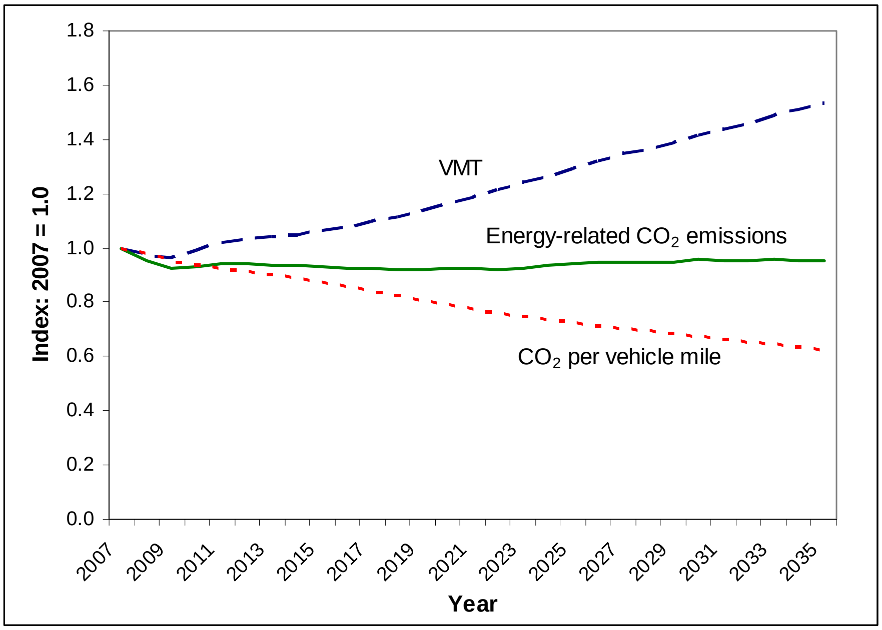
On the other hand, the estimation or forecasting of on-road GHG emissions can be complex. To estimate emissions at even a moderate level of accuracy and detail, inputs including VMT, fleet mix, and vehicle speeds are needed. EPA's MOVES2010 model, released in December 2009, provides significant improvements over previous emissions models for the estimation of GHG emissions addressing these various factors.[23] (See Section 5.4 for more detail about estimation and forecasting of GHG emissions.) There are no techniques to directly measure GHG emissions, although estimation is relatively simple when data on fuel sales are available. Moreover, state and federal policies on vehicle efficiency and alternative fuels affect GHG emissions as much as VMT does. Changes in such policies would affect the ability of states and regions to meet GHG targets, in conjunction with any changes in transportation investments.

VMT is a potential proxy for on-road GHG emissions that simplifies measurement and forecasting somewhat. Many transportation agencies have the capability to forecast VMT using existing travel demand models, albeit subject to some inaccuracies. VMT forecasting at the statewide level, for small metropolitan areas, and for freight movement is much less robust than forecasting in large metropolitan areas, however (see Section 5.3). Using VMT as a metric avoids the additional step and required inputs of estimating GHG emissions. There are also opportunities to improve the measurement of VMT through the use of odometer readings or advanced tracking technologies. On the other hand, VMT is not as good a proxy for GHG emissions if fleet mix and vehicle and fuel technologies change. As the vehicle fleet becomes more fuel efficient, emissions per mile of travel fall, and the benefit of eliminating a mile of vehicle travel is reduced.

[23] Information on MOVES2010 is available at http://www.epa.gov/otaq/models/moves/index.htm.

Exhibit 2-6 shows the expected relationship of VMT and CO_2 emissions in the United States for light-duty vehicles from 2007 to 2035, based on analysis by the U.S. Energy Information Administration. Annual VMT for light-duty vehicles is expected to grow from roughly 2.7 trillion in 2007 to about 4.2 trillion in 2035, an increase of 53 percent. However, with expected improvements in vehicle technologies (AEO2010 Reference Case), CO_2 emissions from light-duty vehicles are projected to drop by nearly 5 percent, from 1,150.4 to 1,097.2 million metric tons of CO_2 equivalent.

Exhibit 2-6: Light Duty Vehicle VMT and CO_2 Emissions Projections



Source: Index calculated from estimates of VMT and energy-related CO_2 emissions from light duty vehicles from U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2010 Early Release,* December 2009. Summary Reference Case Tables A7 and A19.

The divergence in VMT and CO_2 trends show that technology and fuel advancements are projected to offset VMT growth, but also point to the role of VMT in determining total emissions.

A VMT metric would likely focus more attention on travel demand management programs, like enhancing transit and bicycling options, and more effective integration of land use and transportation planning. Many agencies, however, are wary of placing too much emphasis on reducing VMT as a way to curb GHG emissions. Historically, the U.S. has seen tremendous success in reducing other air pollutant emissions through technology, as vehicle travel has grown.[24] While most regional travel patterns include some "unnecessary" VMT that can be reduced by providing better commute options and more attractive alternative mode options, some VMT is essential to economic activity and some efforts to reduce VMT could have adverse effects on mobility. There are also concerns about potential adverse public reaction and economic or equity impacts of some VMT reduction strategies (e.g., road pricing, parking pricing).

[24] Between 1970 and 2008, on-road vehicle emissions of carbon monoxide (CO) dropped by 76 percent, volatile organic compounds (VOC) dropped by 80 percent, and oxides of nitrogen (NOx) fell by 59 percent while VMT grew by 170 percent, from 1.11 trillion to 2.99 trillion vehicle miles. Sources: U.S. Environmental Protection Agency, *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data*, 1970-2008 Average annual emissions, all criteria pollutants, June 2009, available at: http://www.epa.gov/ttnchie1/trends/; Federal Highway Administration, *Highway Statistics to 1995*, Table VM-201 and *Highway Statistics 2008*, Table VM-2, available at: http://www.fhwa.dot.gov/policy/ohpi/hss/index.cfm.

The use of a VMT metric also does not provide credit for several strategy types, such as promoting operational strategies to improve traffic flow and more efficient driving techniques ("eco-driving"). Moreover, a VMT metric cannot apply to non-road transportation GHG emissions, and miles traveled by light-duty vehicles (mostly passenger travel) are not readily comparable to miles traveled by heavy-duty vehicles (mostly freight travel).

Exhibit 2-7 summarizes key issues associated with selection of the metric to be used in an analysis requirement. The choice of a VMT or a GHG metric will influence the types of strategies that transportation agencies implement and the technical requirements for implementation. VMT is an imperfect proxy for GHG emissions. While VMT is more commonly measured, improvements continue to be needed in transportation and land use modeling. Efforts to reduce VMT align well with other goals of sustainable development including improving the jobs-housing balance, increasing use of transit, and improving the coordination of land use and transportation planning. These VMT reductions could be reflected in either a GHG or a VMT metric. On the other hand, not all VMT is appropriately targeted for reduction and not all VMT is equal from a GHG perspective. A VMT metric does not account for the GHG emissions benefits of reductions in travel delay and changes to vehicle fleets and fuels.

Exhibit 2-7: Target Metric - Key Issues

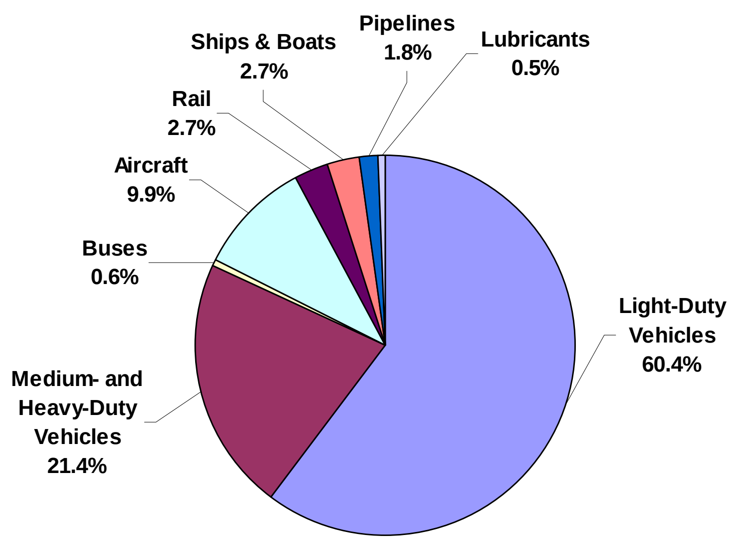
Metric	Strengths	Limitations	Other Implications / Considerations
GHGs (or CO_2)	▪ Directly measures the environmental outcome of interest ▪ At macro level, relatively easy to measure directly from fuel sales data ▪ Provides a common metric to compare the impact of on-road strategies to strategies that apply to other transportation modes and other sectors	▪ More difficult to forecast than VMT since more parameters to consider (e.g., vehicle technologies, speeds); may be more difficult to measure at finer levels of detail (e.g., project-level, locality) ▪ Changes in federal policies (e.g., CAFE standards or renewable fuel standards), or exogenous changes in technology and fuels, may have a significant impact on ability to meet targets, even without any change in transportation investments	▪ May need improved modeling tools to assess the GHG benefits of transportation operations ▪ May encourage investments in improved transportation operations and incentives to push vehicle technology (which might be implemented by states through tax incentives or other policies) ▪ Depending on how targets are set, may need VMT reductions to meet targets
VMT	▪ Extensively sampled and modeled by transportation agencies, although methods still need improvement ▪ Readily understandable to the public ▪ More closely related to some indicators of sustainability like jobs-housing balance and multimodal options	▪ Not a true measure of GHGs; relationship with GHG emissions affected by changes in fuel economy, fleet mix, and fuels ▪ Does not account for benefits of traffic operations improvements or other state or local technology strategies; may discourage states and MPOs from pursuing some strategies ▪ Does not apply to non-road travel	▪ May encourage greater transportation-land use planning integration, since land use is a driver of VMT ▪ VMT is correlated with economic activity and lifestyle decisions. Some VMT is "necessary" and some reduction strategies may have economic or equity implications ▪ Light-duty VMT and Heavy-duty VMT are not readily comparable

2.3 Emissions Sources Covered – Light Duty Vehicles, All On-Road Vehicles, or All Transportation Sources

Both a GHG- and VMT-focused requirement could apply to all motor vehicle travel, or just light-duty vehicles (automobiles and light trucks). A GHG requirement could also be established to apply to all transportation emission sources, including non-road sources such as trains, ships, and aircraft. It could also account for emissions associated with construction and maintenance of transportation infrastructure.

Light-duty vehicles are responsible for 63 percent of U.S. transportation sector CO_2 emissions (see Exhibit 2-8). A requirement focused on light-duty vehicle travel would be consistent with the emissions sources that transportation agencies can most easily influence. Nearly all of the demand management strategies implemented by DOTs and MPOs are intended to reduce light-duty VMT. This is a reason that Washington's HB 2815 VMT reduction requirement and California's SB 375 both apply only to light-duty vehicle travel. Heavy truck travel can be difficult for some DOTs and MPOs to influence, since it is closely tied to economic factors and much of it involves trips that extend beyond state or metropolitan area boundaries. While agencies can implement strategies locally to develop multi-modal facilities, limit idling, restrict speeds, and improve the flow of truck traffic, there are generally fewer strategies available to reduce heavy-duty emissions.

Exhibit 2-8: Transportation CO_2 Emissions by Source, 2007



Source: U.S. EPA, *Inventory Of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table 2-15, April 15, 2009.

Although their travel is more difficult for transportation agencies to influence, one reason to include heavy-duty vehicles in a planning requirement is that they account for a disproportionate share of GHG emissions. While freight trucks make up only 7.5 percent of VMT nationally, they produce over 21 percent of all transportation CO_2, and approximately 35 percent of on-road transportation CO_2 emissions.[25] Moreover, CO_2 emissions from freight trucks are growing and are projected to continue

[25] On-road sources include passenger cars, light-duty trucks, medium-and-heavy duty trucks, motorcycles, and buses. Sources: Federal Highway Administration, *Highway Statistics 2007*, Table VM-1; U.S. Environmental Protection Agency, *Inventory Of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*, Table 2-15, April 15, 2009.

growing as a share of transportation emissions.[26] Excluding this source would fail to account for an important component of transportation GHG emissions, and for strategies that improve heavy truck efficiency.

Non-road transportation sources of GHG emissions are not typically incorporated into the metropolitan or statewide transportation planning process. While state DOTs often help to plan and coordinate rail, marine, and air transportation, and some DOTs operate these services, most DOTs do not typically invest in these systems. One advantage of including at least some non-road sources in a new planning requirement is the ability to capture the net GHG benefits of investment in rail or ferry service improvements that reduce VMT or improve efficiency of these modes. Currently the impacts of non-road alternatives are recorded in conformity analyses as reduced VMT, but the pollutants emitted by trains and ferries are not included. Non-road transportation sources are included in state climate change action plans.

Exhibit 2-9 summarizes key issues associated with the sources covered by a planning requirement.

Exhibit 2-9: Emissions Sources Covered by a Planning Requirement – Key Issues

Sources Covered	Strengths	Limitations	Other Implications / Considerations
Light Duty Vehicle Travel only	▪ Transportation planning tends to focus largely on light-duty vehicle travel demand and patterns	▪ Ignores the potential effects of transportation investments (e.g., new facilities, system operations improvements) on freight movement and efficiency. ▪ Ignores other potential heavy-duty and non-road vehicle-focused emissions reduction strategies	▪ Will focus attention on strategies that seek to manage passenger travel demand (e.g., land use-transportation integration, transit)
All On-Road Travel	▪ More fully accounts for the major sources of transportation emissions that are affected by transportation planning and investment decisions	▪ Heavy truck travel is difficult for DOTs and MPOs to influence, since it is closely tied to economic factors and much of it involves trips that extend beyond state or metropolitan area boundaries. May be more appropriately addressed at the national level.	▪ Including all on-road travel within a VMT metric creates some challenges since freight trucks make up a small portion of VMT but a much larger share of GHGs
All Transportation Sources	▪ Takes full account of the entire transportation sector	▪ Transportation agencies have limited planning control over non-road sources, such as aviation and rail ▪ Analysis is often very complex due to interstate and international travel, particularly in aviation and shipping, and the role of ports and airports that may serve goods movement and passenger travel over multiple states.	▪ Cannot account for all transportation sources using a VMT metric.

The choice of which emissions sources to include within a transportation planning/programming requirement is related to the question of what metric is selected. A GHG emissions metric can account for all on-road sources or all transportation sources, while a VMT metric focuses on light-duty vehicle

[26] Carbon dioxide emissions from freight trucks are forecasted to increase 26 percent between 2007 and 2035, while emissions from light-duty vehicles are forecasted to decline by 5 percent. Source: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2010 Early Release*, December 2009. Summary Reference Case Table A19.

travel. Including all on-road sources has the advantage of accounting for the important role of freight in GHG emissions, since heavy-duty vehicles make up about 35 percent of on-road transportation CO2 emissions and this share is growing. While investments can be made to help ease freight traffic congestion or shift freight from truck to rail, in general, heavy truck travel is more difficult for DOTs and MPOs to influence than passenger travel. Including all transportation sources would help to address additional strategies, but these sources present some challenges in terms of ability of transportation agencies to affect emissions and to analyze emissions, since non-road transportation is not part of most transportation plans and programs.

2.4 Measurement Benchmarks – Basis for Target Comparison

Benchmarks are needed for the measurement and monitoring of progress towards any numerical targets. The benchmarks chosen determine in large part the real-world implications of targets on transportation systems.

How targets are set for GHG emissions is an especially challenging issue, because impacts of GHG emissions are not related to their location of emission. Setting numerical targets for individual states or regions through a political process will account for regions' "fair shares" of emissions or reasonable level of effort. Factors that might be considered include emissions reduction potential, cost-effectiveness, economic effects, and social equity, among others.

Key elements in how targets are set include (a) the units for the target: whether targets are set in terms of total or per capita emissions (or VMT) and (b) the baseline against which targets are set: relative to a historical base year (e.g. 1990) or a business as usual forecast (e.g. 2020)

If total emissions are the benchmark, regulated areas would need to attain an absolute limit on GHG emissions, regardless of changes in population or economic activity. Total emissions relate to the magnitude of global warming impacts caused by a single area. As such, a total emissions target limits the impacts imposed by any one state or region. Share of impacts may be relatively unimportant at the scale of regions, but becomes increasingly more important at larger scales. On the other hand, total emissions targets can place an undue burden on areas with potentially high growth in population and/or economic activity, both of which generate VMT and therefore more GHG emissions. A uniform reduction target would be much harder to meet for areas seeing rapid growth.

Per capita emissions or VMT are measured relative to population (or potentially, population plus employees). A per capita target relates more directly to personal habits, since emissions limits are stated in terms such as pounds per person per year. Per capita targets also address the uncertainty of population growth. Regions are not penalized for adding population if a target relates to emissions or VMT per resident. Even with a per capita target though, uniform targets across geographical areas may disadvantage some areas. States or regions that add population more quickly have greater opportunities to shape personal travel habits of new households. In slow growing areas, agencies would have to focus more effort on changing the travel habits of existing residents.

Whether targets are set in terms of total figures or per capita figures a baseline year must be chosen as a benchmark. If a historical baseline year (e.g. 1990) is chosen, states and regions would be expected to reduce emissions to historical levels or perhaps below historical levels. For example, a target could be set at 80 percent of 1990 emissions levels. The particular baseline year chosen will have a variable effect on regions. Regions that have seen rapid growth in emissions since the baseline year will have more to reduce than regions than have seen little or no growth. On the other hand, regions that have taken steps to limit growth in VMT or GHG emissions since the baseline year would automatically receive credit for those actions. A more recent baseline year (e.g., 2005) would "forgive" any historical increases in emissions before the baseline year, but it would also not credit any actions to limit growth in emissions before the baseline year.

Setting a target relative to a future year, with emissions forecast using "business as usual" assumptions, would be more favorable to regions that have seen rapid growth in population or VMT per capita. A uniform target with a future year baseline would not provide any credit to regions that have limited growth in emissions, since all regions would be required to reduce the same percentage of emissions based on current trends. Still, there is substantial uncertainty in any forecast. A target based on forecast emissions or VMT can incorporate expected changes in fuel economy, carbon content of fuels, and population, but is only as accurate as the assumptions made. With a forecast baseline, there may need to be more rigorous procedures for updating and verifying forecasts periodically. In contrast, historical emissions and VMT are known quantities.

Exhibit 2-10 provides highlights of key issues associated with total or per capita metrics that could be used as part of an analysis requirement. Section 4 contains analysis of the impacts of different benchmarks on different states and regions.

Exhibit 2-10: Measurement Benchmarks - Key Issues

Metric	Strengths	Limitations	Other Implications / Considerations
Total GHGs or VMT	▪ Provides a fixed target	▪ May be difficult to meet target if population growth is substantially higher than initially projected.	▪ If targets are set uniformly, would be most challenging to meet in fast growing areas.
Per capita GHGs or VMT	▪ Offers flexibility to account for differences in population growth ▪ More directly related to personal habits	▪ Less certainty in total emissions levels than with a specified target in absolute terms.	▪ If targets are set uniformly, may be most challenging to meet in rural areas (given limited travel options) and slow growing areas.
Historical Year Baseline	▪ Historical values are known/measured ▪ Automatically credits areas that have taken steps to limit growth in emissions/VMT	▪ The specific baseline year selected could benefit some areas, and create challenges for others	▪ Disadvantages areas that have seen rapid growth in total or per capita emissions/VMT
Future Year Baseline	▪ Forecasts can account for expected changes in fuel economy, carbon content of fuels, and population	▪ Baseline depends on forecast assumptions, and is therefore less certain ▪ No credit for areas that have taken steps to limit growth in emissions/VMT	▪ More favorable to areas that have seen/are seeing rapid growth

Other variations in benchmarks are also feasible, and may help improve upon some of the limitations of benchmarks explored here. For example, one suggestion considered by California's SB 375 Regional Targets Advisory Committee (RTAC) was that reduction targets be set in terms of GHG emissions per *new* household. This benchmark allows that regions have a greater ability to shape the travel habits of new households rather than existing households. In strict per capita terms then, targets for slower growing regions would be less ambitious than targets for faster growing regions.

The shortcomings of uniform standards can be addressed by allowing for a process to create targets tailored to individual states and regions. It is unlikely that a single system for setting uniform standards would be viewed as fair by all regulated agencies. In California, the RTAC has recommended that initial targets be set by a centralized agency according to an established set of rules, but can then be individually adjusted based on feedback from regulated parties.

In summary, the benchmarks chosen for targets will influence the level of effort that individual states and regions must make, and could have major equity impacts. The choice of base year determines how recent and projected development trends are accounted for in targets. Because there will be winners and losers in any given scheme for the setting of targets, target setting is likely to be a highly politicized process. A uniform target across multiple geographical areas may not be feasible. Design of a GHG management scheme should take into account the particular circumstances of each area under management.

2.5 Regulatory Nature of Target – Mandatory or Voluntary

Emission reduction targets can be established through different regulatory mechanisms, ranging from those that mandate a certain level of reductions, with penalties for non-compliance, to those that encourage voluntary measures to achieve reductions, with incentives to motivate compliance. The word “target” refers to the desired change in VMT or GHG emissions. Different regulatory mechanisms give different levels of regulatory force to prescribed targets.

There are two main types of regulatory systems:

- VMT or emissions **budgets** are part an enforceable regulatory program. A budget is a fixed amount of emissions that cannot be exceeded. Compliance with a budget is mandatory. A budget might function similar to emissions budgets under the Clean Air Act requirement for transportation conformity; financial penalties, such as restricting federal transportation funding, would be a consequence of failure to comply with a budget.
- VMT or emissions **performance standards** are aspirational targets. Failure to comply with performance standards does not necessarily trigger penalties. Financial incentives might be available to assist in achieving performance standards. Financial rewards could be granted to areas that achieve their performance standards.

Because a VMT or emissions budget mandates a specific level of reductions, there is greater likelihood of achieving targets than under a voluntary system. But the added regulatory force of budgets also comes with additional pressure to set targets at fair and realistic levels, since agencies would be penalized for failure to comply. A budget would require extra attention to the statutory powers of regulated parties and the tools and models available to them for use in compliance. The target setting process is likely to be highly politically sensitive, given the consequences for agencies that fail to comply, and updating VMT or emissions budgets in a timely and consistent manner will be important. Any changes in assumptions that affect GHG emissions, such as federal regulation or exogenous changes of vehicle efficiency, carbon content of fuels, and VMT,, could change the ability of agencies to meet their budgets. Flexibility in defining and updating targets thus may be especially important with VMT or emissions budgets.

A system of performance standards would provide greater inherent flexibility to regulated agencies to define their level of effort, since attainment of targets is not mandatory. Financial incentives would motivate agencies to implement GHG reduction strategies. Agencies are likely to be more receptive to this approach. While some agencies would probably not attain their targets, the ultimate impact of the program is as likely to be determined by the level of funding support available and the structure of incentives as it is by the stringency of targets set. In fact, a performance standard approach could be more likely to achieve maximum feasible reductions than a budget system. Regulated parties are likely to accept more ambitious targets if there are no penalties associated with not meeting targets.

Individual mechanisms may combine elements of both budgets and performance standards. A single mechanism may be able to combine the greater certainty of a budgetary approach with the inherent flexibility of an incentive-based approach. Exhibit 2-11 summarizes the strengths and limitations of mandatory and voluntary systems. The possibility of mixed regulatory approaches is covered in more detail in Section 3.

Exhibit 2-11: Regulatory Approach – Key Issues

Regulatory Approach	Strengths	Limitations	Other Implications / Considerations
Mandatory (Budget)	▪ Greater regulatory force ▪ Reductions are more certain.	▪ Setting target reductions at realistic and achievable levels is crucial since penalties would take place if they are not met. The ability of regulated parties to achieve budgets using existing authorities is paramount. ▪ Changes in assumptions (e.g., due to changes in emissions models, prices of fuel, unexpected growth, new federal policies such as CAFE standards or renewable fuel standards) may have a significant impact on ability to meet targets; this will have more substantial implications under a mandate.	▪ May require or push additional improvements in modeling. Some uncertainties exist as to modeling/measuring deficiencies. ▪ Mandatory budgets may place unfair burdens or inequities on responsible agencies due to lack of current understanding of strategies and difficulty of assessing what is feasible. ▪ Heightened political sensitivity around the setting of any mandatory targets
Voluntary (Performance Standard)	▪ May be incentive-driven, and provide rewards for performance. ▪ Regulated parties may be more receptive ▪ Greater flexibility for areas to define their appropriate level of effort	▪ Lack of mandatory reductions may limit results. ▪ Relies on financial or other incentives to implement	▪ Enables more flexibility in investment decisions, but at the risk of not meeting targets. ▪ Regulated parties are likely to accept more ambitious targets if there are no penalties associated with not meeting targets.

Setting a budget would require areas to attain a specific level of GHG reductions, while setting a performance standard would allow areas greater flexibility to determine their appropriate levels of effort. The process of setting targets is likely to be controversial under either system, but the mandatory nature of a budget would make it especially important to consider the burden placed on regulated agencies. Ultimately, the outcome of a regulatory or voluntary approach may hinge upon the level of funding and the structure of incentives available to help agencies develop and apply GHG reductions strategies. It may be possible to combine both budgets and performance standards in a single mechanism to achieve greater GHG reductions while ensuring flexibility.

3. ASSESSMENTS OF ALTERNATIVE POLICY MECHANISMS FOR REDUCING TRANSPORTATION GHGS

The range of policy mechanisms that may be considered for reducing transportation GHS through planning and programming actions is potentially broad. However, a few principal dimensions characterize essential differences among mechanisms and their potential consequences for agencies responsible for policy implementation. This section describes policy mechanisms and key issues to be considered in developing a specific policy for achieving transportation GHG reduction.

3.1 Policy Mechanisms Considered

While the range of potential mechanisms is potentially broad, this research focused primarily on a set of options selected to be representative of current thinking in national and state-level policy forums. These options fall into three principal categories: (a) setting of regulatory targets (mandatory or otherwise) for emissions or other proxy measures, (b) other approaches based on government approval requirements, and market-based mechanisms.

Requirements that Involve Setting Targets

The analysis includes three transportation planning/programming-focused requirements, each of which may be applied as a state- or MPO-level requirement:

- Transportation GHG Performance Standard with Incentives
- Transportation GHG Budget with Penalties
- VMT Performance Standards with Incentives[27]

Each of these three possible requirements is described briefly below.

Transportation GHG Performance Standard with Incentives

This policy mechanism would include the establishment of GHG reduction targets with incentives for compliance and/or to reward compliance. States and/or MPOs that meet or exceed their reduction goals for identified future years would receive additional transportation funds or be granted more flexibility to use federal transportation funds. Incentives may also be available to help states and/or MPOs meet their goals. The measure would likely cover all on-road emissions sources, and would apply to emissions associated with a statewide or metropolitan transportation plan.

Targets could be set at the state-level or at the MPO-level. If federal regulations set targets at the state-level, states could then set targets for MPOs within their borders based on local feasibility to reduce transportation GHG emissions.

California's SB 375 is a statewide reduction target with sub-allocation targets for 18 MPOs, applying to the emissions from cars and light-trucks only. MPOs must prepare strategies (land use and VMT reduction) to identify how they will meet established regional targets. There is no requirement for local

[27] A VMT budget with penalties was considered but is not discussed in this report, because its characteristics would be very similar to those of other mechanisms examined.

governments, who hold land use authority, to comply with the MPOs' plans. SB 375 does not include a penalty for MPOs that fail to meet their targets.

The San Francisco Metropolitan Transportation Commission's (MTC) 2035 Plan establishes a CO_2 emissions reduction target as part of a combination of strategies to achieve goals mandated by CA AB 32. The Plan includes packages of investments combined with demand management policies. Even with an aggressive effort to reduce GHG emissions, MTC found only slight reductions are feasible within the scope of the Regional Transportation Plan.

The *American Clean Energy and Security Act (ACES) of 2009*, which recently passed in the U.S. House of Representatives, requires state and MPO plans (for MPOs over 200,000 population or Transportation Management Areas (TMAs)) to include GHG emission goals and targets, and strategies to achieve them. Additionally, ACES would add reducing GHG emissions to the current list of eight federal transportation planning factors. DOTs and MPOs must consider each factor in their long range plans, but plans cannot be legally challenged on the basis that factors were not adequately considered.[28] The U.S. DOT would establish requirements and performance measures to assure progress toward meeting GHG reduction goals. The U.S. EPA would also play a role in establishing national transportation GHG targets, and in establishing standardized models and methodologies for DOTs and MPOs to use in complying with targets.

Transportation GHG Budget with Penalties

This measure would establish maximum levels of allowable GHG emissions from the transportation sector with penalties for non-compliance. It could be implemented at either the state DOT or MPO level. Penalties would likely include restrictions on federal transportation funding. The budget would be set by a federal agency, or by state agencies in accordance with federal guidelines, and would generally be a declining amount of GHG emissions from transportation sources over a twenty year or more timeframe. The measure would likely cover all on-road emissions sources, and would apply to emissions associated with a statewide or metropolitan transportation plan.

There are two main options for how a GHG budget could be applied to the transportation sector. Each state could receive a multi-sector GHG budget. States would then have the flexibility to allocate emission reductions to individual sectors. States could choose to allocate more or less reductions to the transportation sector. Alternatively, a national transportation budget could be established, and sub-allocated to states and metropolitan areas. Budgeting authority in this scenario could fall entirely to the federal government, or to a mix of federal and state agencies.

This policy mechanism is somewhat similar to the transportation conformity process under the Clean Air Act, where an emissions budget is set and there is a penalty (restriction on funding non-exempt projects) for failure to meet the budget. In the conformity process, budgets for metropolitan areas are set by state air quality agencies, in accordance with federal requirements, based on standards of human health. The process of setting GHG budgets for individual states and regions would be less straightforward. Since there is no localized impact from GHGs emitted in a particular area, the basis for setting targets is less well understood.

[28] Planning factors are listed in Title 23 of the United States Code, Sections 134 and 135.

VMT Performance Standards with Incentives

This measure would target reductions in vehicle miles traveled (VMT) as a surrogate for GHG emissions. It would focus on on-road vehicles only, or perhaps light-duty vehicles only. States and/or MPOs that meet or exceed their reduction goals for identified future years would receive additional transportation funds or be granted more flexibility to use federal transportation funds. Incentives may also be available to help states and/or MPOs meet their goals.

Targets could be set at the state-level or at the MPO-level. If federal regulations set targets at the state-level, states could then set targets for MPOs within their borders based on local feasibility to reduce VMT. MPOs might also sub-allocate VMT reduction targets to individual local jurisdictions.

Mandatory VMT reductions have already been explored in a few states. In Washington State, House Bill 2815 requires that the state's annual per capita light duty vehicle VMT be reduced by 18 percent by 2020, 30 percent by 2035, and 50 percent by 2050, compared to a business-as-usual baseline forecast. As directed by Governor's Executive Order 09-05, Washington State DOT will recommend compliance actions and work with the state's largest MPOs to incorporate GHG and per capita VMT reduction strategies into their regional transportation plans.

In Maryland, House Bill 1116, which did not pass, proposed to establish a VMT reduction target for all local comprehensive plans in the state. The bill proposed to reduce per capita VMT by 11.2 percent below 2005 levels by 2018. The legislation would not have affected the state DOT or MPOs directly. Instead, counties and cities would be required to develop comprehensive land use plans for areas within their jurisdictions that demonstrated compliance with established goals. Local jurisdiction goals would also have been related to the location of housing, transit, and jobs.

Additional Policy Mechanisms

In addition to the three mechanisms above, this analysis includes four mechanisms that may serve as components of planning/programming-focused mechanisms. They could also serve as stand-alone mechanisms:

- Climate Change Action Plan Requirement
- Interagency Consultation Requirements
- Emissions Reduction Strategy Implementation Requirements
- Project Level GHG Analysis with Penalties

Each of these is described briefly below.

Climate Change Action Plan Requirement

This policy mechanism would require states and/or regions to develop a GHG reduction plan for all transportation sources, and potentially for all sectors of the economy. The plan would include identification of cost effective strategies that could be implemented at the state or local level. Responsibilities for developing and certifying plans could be assigned at multiple levels, with state DOTs and MPOs playing either lead roles or key supporting roles. For example, state DOTs could be tasked with developing plans with the support of MPOs. Alternatively, MPOs or other regional bodies could be tasked with developing their own plans, to be certified by the state. A Climate Action Plan may not be linked to a specific reduction target, but can serve as one tool to explore what is a feasible target for a particular region. Individual DOTs and MPOs could incorporate measures from Climate Action Plans into their long range plans as they see fit.

Many states have already developed Climate Action Plans or are in the process of developing them, but many states have been slow to implement the Plans. While, the transportation sector and transportation agencies (including state DOTs and state Environmental/Air Quality agencies) provided input to the process in many states, future plans may benefit from greater involvement of transportation agencies.

Interagency Consultation Requirements

This measure would require that all stakeholder agencies, federal, state, and local, be consulted in efforts to reduce GHG emissions. It would likely be part of compliance with a planning-based GHG emission reduction requirement, rather than serving as a stand-alone mechanism. The process could track and report progress in reducing GHG emissions at the state or MPO level. Interagency consultation can also help to build stakeholder support for GHG reduction strategies that require multi-agency collaboration.

Consultation processes could be modeled on those incorporated in air quality conformity processes. All MPOs conducting conformity analyses are required to conduct an interagency consultation process. This process generally has been viewed as a beneficial part of the conformity requirements and has fostered good, on-going working relationships between key stakeholders. The conformity rule specifies that procedures be developed and implemented to ensure effective interagency consultation.

Requirement for Emissions Reduction Strategy Implementation or Prioritization

This approach could require implementation of specific types of transportation emissions reduction strategies or best management practices (BMPs) within transportation plans and/or project development. A range of strategies could be included: land use measures, transit measures, travel demand management, operations improvements, bicycle and pedestrian measures, and measures that encourage the use of more efficient vehicles and alternative fuels. The policy mechanism could involve a system of credits or points that regulated areas would receive for implementing specific strategies. In this case, State DOTs or MPOs could select from a predetermined list of BMPs in order to achieve a required number of points. BMPs, and the number of points that each receives, would be determined by a central regulatory authority. The California Air Resources Board's Regional Targets Advisory Committee (RTAC) recommended that a system of BMPs be incorporated in the implementation of SB 375. The RTAC concluded that BMPs should be used as an interim alternative for some MPOs that avoids complex travel demand modeling. The potential of various BMPs should also be considered in setting targets for individual MPOs.[29]

Another related option would be a requirement to prioritize funding for emissions reduction strategies before certain types of transportation investments (e.g., highway capacity improvements) could move forward.

Project Level GHG Analysis with Penalties

This measure would require energy and/or GHG analysis for individual projects or specific types of projects. Such analyses would likely be included in the environmental review process specified by the

[29] California Air Resources Board, Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375, September 29, 2009. Available at: www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf

National Environmental Policy Act (NEPA). Analysis of emissions from construction could also be required for major projects with long construction periods.

Several states and regions have already developed requirements or guidelines for analysis of GHG emissions from transportation projects. The New York State Energy Plan requires project level analysis of regionally significant projects listed in Transportation Improvement Programs (TIPs) and Long Range Transportation Plans (LRTPs), or projects that may lead to large increases in VMT. The environmental review must include an analysis of projected CO_2 emissions associated with construction and operation of build and no-build alternatives. Puget Sound Regional Council has issued guidance, along with regional partners, advising local jurisdictions on how and when to conduct project-level analyses of GHG emissions. In both the NY State Energy Plan requirement and in Puget Sound Regional Council's guidance, project-level analysis applies when alternatives are vetted.

In California, state law requires that impacts on GHG emissions be considered in the environmental review process for projects subject to the California Environmental Quality Act (CEQA). These include most large transportation projects. While formal guidelines for the analysis of GHG emissions from transportation projects have not been released, the California Air Pollution Control Officers Association (CAPCOA) has issued a white paper that suggests ways that such analyses could be conducted.[30] The possibility of a tiered approach to analysis of GHG emissions from projects is proposed in the white paper, and has also been proposed by the California Air Resources Board and the Sacramento Air Quality Management District. A tiered approach allows multiple options for a project to demonstrate compliance with requirements. For example, some projects might be exempted based on their basic characteristics or on the use of Best Management Practices. Other projects might demonstrate compliance by inclusion in a conforming transportation plan. Only the largest and most complex projects would need to conduct a full analysis of GHG emissions.

Market-Based Mechanisms

Market-based mechanisms, such as carbon emissions trading and carbon taxes, are policy mechanisms that may be implemented along with transportation specific requirements. These mechanisms would indirectly affect transportation and could be implemented in conjunction with any of the policy mechanisms that are focused directly on transportation decision making. A cap and trade program would likely include a ceiling on GHG emissions at the level of fuel producers (oil refineries and fuel importers), which in turn would increase the costs of transportation fuels. This change in fuel prices may cause a reduction in vehicle travel demand and reduce Highway Trust Fund revenues by lowering fuel consumption.[31] At the same time, a cap and trade program offers potential revenues from the sale of emissions allowances that could be allocated to transportation programs to reduce GHG emissions. In the case of a regulatory cap and trade system that does not cover transportation sources, GHG emissions offsets could be awarded for transportation projects, and offsets could be a source of revenue for transportation projects. These mechanisms are briefly described in Appendix B, as a reference, since it will be useful for policy makers to consider the potential indirect effects of these policies on the transportation system.

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[30] California Air Pollution Control Officers Association (CAPCOA), CEQA and Climate Change, January 2008.
[31] Analysis by U.S. EPA of the cap-and-trade program in the Waxman-Markey bill suggests that the increase in gasoline prices that result from the carbon price ($0.19 per gallon in 2015, $0.33 in 2030) is not sufficient to substantially change consumer behavior in regards to VMT or vehicle purchases. U.S. Environmental Protection Agency, "Analysis of the Waxman-Markey Discussion Draft – Appendix," p. 50. Available at: http://www.epa.gov/climatechange/economics/economicanalyses.html#wax.

3.2 Criteria for Assessing Mechanisms

A set of eight criteria were selected in this research to analyze the various policy mechanisms for integrating GHG objectives into transportation decision making, based on input from transportation and environmental agency stakeholders:

Technical Requirements – Requirements associated with data collection, modeling, and measurement, including the ability of existing and in-development analysis tools to meet needs associated with the mechanism.

Staff Requirements – Staffing needs to carry out requirements imposed by the policy mechanism, as well as staff capabilities and training needs.

GHG Reduction Certainty - The certainty of achieving GHG reductions under each approach.

GHG Reduction Control – The authority of the transportation agencies to achieve GHG reductions as required under each approach.

Co-benefits/Synergy – The likelihood of achieving co-benefits, such as air quality improvements, as well as integration or synergies with other planning processes (e.g., land use planning, air quality planning, other environmental planning) or other GHG reduction policy mechanisms (e.g., cap-and-trade, vehicle GHG standards).

Potential Unintended Consequences – The potential to produce negative or unintended side-effects (e.g., effective on economic activity, mobility, other environmental concerns).

Flexibility/Adaptability- Flexibility for transportation agencies to work within the policy mechanism framework as new technical, scientific, and policy information becomes available.

Equity – Consideration of the possible distribution of burdens of new requirements among different states, regions, or population groups.

Public Understanding – The ability to communicate the link between the mechanism and GHG reduction to the general public.

3.3 Assessment of Mechanisms

Exhibit 3-1 presents a high-level summary of the considered policy mechanisms across the comparison criteria. The summary table is followed by other more detailed tables addressing individual criteria. These tables show the research team's assessment of each of the seven policy mechanisms identified in Section 3.1. Separate implications associated with state-level and MPO-level requirements are noted where relevant.

Exhibit 3-1: Assessments Across Eight Specified Criteria

Criteria	Options that Perform Relatively Well	Options that Perform Relatively Poorly	Options to Consider to Address Weaknesses
Ability to Meet Technical Requirements	Requirements that do not involve complex travel demand modeling (e.g., scoring of emissions reduction strategies, interagency consultation requirements). Requirements for modeling placed only on larger MPOs, which tend to have the most sophisticated travel models	Options that require travel and GHG emissions forecasting at the statewide level, since state DOTs generally have limited tools to forecast statewide VMT and GHGs Options that require small MPOs to conduct VMT and/or GHG emissions analysis, since these MPOs typically have limited modeling capabilities.	Phase in modeling requirements and provide funding for travel model improvements to help states and MPOs without the necessary travel demand forecasting tools.
Ability to Meet Staff Requirements	Policy mechanisms that do not involve complex modeling, analysis, or changes in the transportation planning process (e.g., interagency consultation requirements)	Requirements for state DOTs to analyze the GHG implications of their plans, since this might require changes to the planning process and new modeling capabilities. Mandatory VMT or GHG emissions budgets, which may place a burden on small MPOs that have limited staff.	Provide training, technical assistance, and/or funding to help support technical capabilities and advances
GHG Reduction Certainty	A GHG budget with penalties (likely to have greater certainty of achieving specified reductions in GHG emissions than approaches without a penalty)	Purely voluntary approaches (e.g., performance standards are less certain to result to GHG reductions). A VMT per capita metric (since VMT is only one factor in GHGs and a per capita metric means that total GHG emissions might be larger if population growth is higher than expected).	Build in incentives and/or funding to help ensure attainment of targets. Build in tracking of progress at reducing GHG emissions into process.
GHG Reduction Control	Requirements to implement GHG emission reduction strategies that are under the control of transportation agencies (e.g., best management practices)	Requirements that include non-road sources, such as aviation and rail.	Consider programs and incentives to support non-road GHG reduction outside of the transportation planning process.
Maximize Co-benefits / Synergies	Requirements that encourage interagency coordination, including integration of transportation and land use planning and other strategies that also improve air quality and reduce congestion	Options that allow GHG reductions to be met entirely through technology and fuels and do not meaningfully help to integrate GHG considerations into transportation planning decisions	Include some form of interagency consultation to ensure meaningful development of targets and/or implementation of strategies
Minimize Potential Unintended Consequences	Interagency consultation (likely to help avoid negative consequences)	Requirements for only larger MPOs, since they might encourage growth outside of these areas. VMT performance standards, since they might discourage investments in operational strategies and clean	Consider options that cover all geographic areas but provide flexibility to address requirements differently in different types of areas.

Criteria	Options that Perform Relatively Well	Options that Perform Relatively Poorly	Options to Consider to Address Weaknesses
		technologies by DOTs	VMT performance standards might build in potential credits for other types of measures that reduce GHG emissions.
Maximize Flexibility	Performance standards (generally provide more flexibility than mandatory budgets).	A GHG budget with penalties (generally provides the least flexibility)	Build in mechanisms to adjust budgets or targets over time, based on changes in population or other factors.
Maximize Equity	Requirements that apply to all parts of the country, and where targets are set with recognition of the unique attributes of each area.	Requirements that only apply to a subset of MPOs (could disadvantage these areas). Targets that are set uniformly for transportation across all geographic areas (e.g., a 20% reduction below 1990 levels for all metro areas).	Provide flexibility in setting targets appropriate to the conditions of the regulated area, including consideration of population growth, economic base, and the availability of non-transportation reduction strategies.
Maximize Public Understanding	Requirements for implementing emissions reduction strategies (likely are easier for the public to understand than budgets and performance standards).	Requirements that involve modeling and technical analyses (may be less well understood or transparent to the public).	Recognize the public may be more supportive of incentive-based policies than mandates. Recognize that VMT is a simple, accessible measure, but the public may be skeptical of some strategies to reduce VMT.

Technical Requirements

Technical requirements for the mechanisms examined vary based on the sophistication of tools required to estimate VMT or GHG emissions, relative to currently available tools. Some mechanisms would require the development of new or enhanced models. The accuracy of estimation techniques is a concern for all mechanisms. Models that under-predict the impact of a given strategy will tend to discourage the implementation of that strategy. New standardized analytical techniques may be needed to accurately estimate GHG emissions.

The exhibit below provides specific findings on the technical requirements associated with each mechanism. A more extensive description of many of the challenges included in the exhibit is provided in Section 5.

Exhibit 3-2: Assessment of Technical Requirements

Mechanism	Findings
GHG Performance Standards with Incentives	▪ GHG analysis depends on two types of models (travel demand models and emissions models) and includes their inherent limitations. o Travel demand models—used by both DOTs and MPOs to forecast VMT, but commonly used models are limited in ability to capture the effects of many emission reduction strategies (e.g. land use strategies). Newer models (e.g., activity-based, simulation models) are more sophisticated. Individual DOTs and MPOs have a wide range of forecasting abilities. o Emissions Models—previous models (MOBILE6 and EMFAC2007) limited in ability to accurately model GHG emissions, especially in their ability to capture the effect of vehicle speed on GHG emissions. EPA's new MOVES2010 model (released December 2009) improves the estimation of GHG emissions and can be run with different levels of data depending on the capabilities and needs of users.
With state-level requirements	▪ Tools to forecast statewide VMT are not well developed. Most states do not have statewide travel demand models. o Most DOTs do not forecast VMT for planning purposes (VMT forecasts are only produced for fuel tax revenue estimation). (See Section 5.3) o Statewide VMT forecasts often do not have geographic or vehicle type detail needed to evaluate statewide strategies. ▪ In some locations, state boundaries will cross metro areas (where many VMT reduction strategies are most properly evaluated and implemented). ▪ State-level requirements may require development of new statewide travel models, or require combining state-level modeling with MPO-based modeling. (See Section 5)
With MPO-level requirements	▪ Robust MPO travel models are well geared toward analyzing VMT, and many metro area VMT reduction strategies can be evaluated using MPO models. However, there is a wide range of technical capacity among MPOs. Many MPOs, particularly small ones, do not have models that can forecast regional VMT. (See Section 5.3) ▪ Even at the MPO level, models often do not effectively account for the benefits of land use strategies on VMT. (See Section 5.3) ▪ Many MPOs would need to conduct some analyses outside of their current travel demand models (e.g., certain travel demand management strategies, or operational strategies); this is similar to how certain strategies are often treated in examining emissions reductions for transportation conformity. (See Section 5.5) ▪ Current models do not easily separate traffic generated by specific geographic areas versus traffic passing through areas. The distinction is important when attributing responsibility for VMT to various local areas.
Transportation GHG Budgets with Penalties	▪ All findings for a Transportation GHG Performance Standard also apply here, but the threat of penalties means that a higher level of sophistication is likely necessary.

VMT Performance Standards with Incentives	▪ All requirements related to travel demand models and the forecasting of VMT, as detailed above under Transportation GHG Performance Standard, also apply here. However, travel demand models may not need to incorporate the same level of detail about vehicle types as they would under a GHG Standard, since vehicle type is only relevant to emissions ▪ Requirements related to emissions modeling do not apply here.
Climate Change Action Planning Requirement	▪ As with the mechanisms above, the accuracy of GHG inventories and baseline forecasts is largely limited by the accuracy of VMT data and forecasts within specific geographic areas. ▪ Evaluation of strategies would likely depend on post-processor tools and simple analytical techniques. Plans would most likely analyze policies at a high level, rather than analyzing specific programs and investments. Therefore existing tools may be adequate. ▪ Limited data and modeling capabilities exist to address non-road modes of transportation, including rail and aviation.
Requirement to Implement Emissions Reduction Strategies	▪ A point system based on certified BMPs would eliminate the need for upgraded models at state DOTs and MPOs. ▪ A simple standardized spreadsheet tool may be needed to estimate points received for BMPs in different contexts. Development of such a tool could be coordinated by U.S. DOT or EPA. However, such a tool would not be as sensitive to certain policies as more sophisticated transportation/land-use models would be, and variations between different regions may not be adequately tailored. ▪ Effectiveness of BMP options would have to rely on limited data on responses to existing programs.
Interagency Consultation	▪ An interagency consultation requirement would not imply any new technical requirements on its own, but partner agencies may need to be consulted as part of the modeling process.
Project Level GHG Analysis	▪ A central regulatory authority would need to establish guidelines for the level of significance of GHG emissions and level of detail required in analyses. ▪ Some projects could be exempted from a full GHG analysis. ▪ For those projects conducting a full analysis, technical challenges include: o Defining the scope of the project. It can be conceptually difficult to separate the impacts of a single transportation project on GHG emissions from those of the entire system. o Defining the base case alternative for comparison. o Calculating emissions from the operation, construction, and maintenance of a facility. Methods to calculate these emissions for individual projects are not well established. Many jurisdictions do not have adequate inputs, e.g. data on current vehicle speeds and operational data for current construction equipment.

Staff Requirements

Staff requirements are greater for mechanisms that require a higher level of technical capacity. The staffing impact of a mechanism will vary from region to region; smaller agencies and agencies with less existing modeling capacity will feel more staffing pressure. If mechanisms include outreach or consultation processes, those can also consume substantial staff resources. In some cases, agencies may need to expand the abilities of their staff to include skills such as familiarity with more complex travel demand models and emissions models. The distribution of responsibilities across federal, state, and local agencies will determine specific staff requirements for each agency.

The exhibit below provides specific findings on the staff requirements associated with each mechanism.

Exhibit 3-3: Assessment of Staff Requirements

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ Staffing requirements depend upon both travel demand forecasting and emissions modeling components. Specific needs will vary from region to region based on level of application and current modeling techniques.
With state-level requirements	▪ Most state DOTs would need to make a substantial effort to develop state travel demand models, to develop updates to statewide transportation plans and develop more specific long-range plans identifying all investments. Staffing requirements for these efforts are likely to be large. ▪ Staff requirements would also include running GHG emissions models. Many state DOT and air quality agency staff have experience with such models under the conformity program. ▪ If the state passed requirements down to MPOs, there would be a need for state staff to monitor MPO progress and administer any incentives, and to support rural areas outside of MPOs.
With MPO-level requirements	▪ May require additional staff to acquire and run improved travel demand models. Requirements would be greatest for small MPOs that do not currently forecast VMT or emissions. ▪ Many MPOs already conduct regional emissions analysis for conformity, and thus may not require additional staff for GHG analyses. Large, sophisticated MPOs may be able to incorporate the additional work without hiring new staff or obtaining new skills. For instance, o San Francisco MTC did not need additional staff to incorporate targets and GHG analysis in its 2035 Plan. o NY MPOs report conducting GHG analyses using existing staff and skill sets. They were supported by NYSDOT and the standardized forms and models developed for the Congestion Mitigation and Air Quality (CMAQ) Program and for conformity. o On the other hand, MPOs in Seattle and Portland hope to hire additional staff for GHG modeling applications in the coming years.
Transportation GHG Budgets with Penalties	▪ All findings for a Transportation GHG Performance Standard also apply here, but staff requirements associated with documenting assumptions and conducting detailed analyses to demonstrate meeting the budget would likely be larger than under a purely aspirational target or performance standard.
VMT Performance Standards with Incentives	▪ All requirements related to travel demand models and the forecasting of VMT, long range plans, and monitoring requirements, as detailed above under Transportation GHG Performance Standard, also apply here. ▪ Staff requirements related to emissions modeling would not apply.
Climate Change Action Planning	▪ Agencies may be able to incorporate the additional workload without hiring new staff or acquiring new skill sets/models. However, developing effective multi-sector

Requirement	plans that address all modes of transportation may require new, and on-going coordination and analysis among multiple modes and sectors. ▪ The development of plans alone may not be very difficult. Staff requirements depend more on expectations and requirements regarding evaluation, implementation and compliance/monitoring.
Requirement to Implement Emissions Reduction Strategies	▪ Would require far fewer staff resources than more complex modeling. ▪ Would also streamline the selection of a strategy package, since regulated parties would pick from a limited range of predetermined strategies.
Interagency Consultation	▪ Additional staff resources needed to carry out interagency consultation could range from negligible, if consultation processes piggy-back on existing conformity processes, to substantial, if consultation processes must educate and achieve buy-in from stakeholders on an entirely new regulatory process.
Project Level GHG Analysis	▪ Could require individual analyses of each transportation project, which would add to staff time and potentially to time for project approvals. ▪ New modeling techniques can require significant staff resources.

GHG Reduction Certainty

The certainty of achieving real reductions in GHG emissions from a given mechanism depends on the effectiveness and enforceability of the mechanism. Mechanisms that mandate meeting a specific target (e.g., an emissions budget) are more certain to achieve some GHG reductions than those without any penalties for non-compliance. However, they may not necessarily yield the most reductions or be the most cost-effective approach. The pass-fail nature of a budget and threat of penalties may mean that transportation agencies negotiate less ambitious targets and focus more attention on modeling to demonstrate a target is met. Mechanisms that rely on simplified assumptions or rules of thumb (e.g., assigning points to various types of GHG reduction strategies) may leave more uncertainty around the scale of reductions that will be achieved by specific reduction strategies. On the other hand, even sophisticated models may not accurately predict the impact of every strategy.

The exhibit below provides specific findings on the GHG reduction certainty associated with each mechanism.

Exhibit 3-4: Assessment of GHG Reduction Certainty

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ Without a regulatory mandate or penalties for failure to achieve targeted reductions, there is less certainty of attaining specific targets. ▪ On the other hand, incentive-driven targets could be more likely to achieve maximum potential GHG reductions, if the incentives and funding are well designed. Penalty-driven targets may motivate regulated parties to focus on nominal compliance.
Transportation GHG Budgets with Penalties	▪ With mandatory budgets, there would be a higher level of certainty of attaining specific targets. But the budget established may not achieve maximum potential reductions if it is less ambitious.
VMT Performance Standards with Incentives	▪ All findings for a Transportation GHG Performance Standard with Incentives also apply here. ▪ But a VMT standard provides less certainty of reductions in GHG emissions, since VMT reduction may not translate directly into corresponding GHG reductions. For instance, shorter trips have slower speeds and sometimes higher per-mile emissions. Also, shifting from auto to bus transit reduces VMT more than GHG emissions, since buses have higher emissions per mile than automobiles.
Climate Change Action Planning Requirement	▪ May not yield any real reduction in GHG emissions without other process-based requirements or incentives. Implementation of plans would be voluntary. ▪ Enforcement mechanisms may be limited for non-compliance.
Requirement to Implement Emissions Reduction Strategies	▪ The certainty of achieving any targeted reductions would be less than under a mechanism that involved modeling of strategies. ▪ On the other hand, the standardization of reduction measures would make implementation of measures easy for a monitoring agency to track.
Interagency Consultation	▪ May not yield any real reduction in GHG emissions without other process-based requirements or incentives.
Project Level GHG Analysis	▪ A penalty system would likely produce some reductions in GHG emissions from the operation and/or construction of projects, but the scale of reductions feasible at the level of projects is likely to be small. ▪ There is some disagreement among transportation agencies about whether project-level requirements are an effective mechanism to achieve GHG reductions.

GHG Reduction Control

The ability of regulated agencies to control GHG emissions is crucial to the successful implementation of any mechanism. Different mechanisms imply the use of different strategies. Mechanisms that depend upon strategies outside the immediate purview of regulated agencies will not produce results unless they include robust provisions for coordination between agencies. Agencies' control over GHG emissions depends upon their statutory powers and geographic reach. Level of control also hinges on the point in the decision making process at which regulation takes place. Agencies have less control over the emissions impacts of investments when projects are in the advanced stages of planning.

Although this study does not focus on specific transportation strategies, it is important to understand the range of strategies that could be applied to surface transportation, and in particular, what strategies state DOTs and MPOs have jurisdiction over. Any regulatory or incentive-based approach will need to consider the ability of transportation agencies to affect GHG emissions in this context. Exhibit 3-5 shows the four main ways to reduce GHG emissions from on-road transportation, examples of public investments or strategies, and the level of DOT or MPO authority. State DOTs and MPOs have substantial authority over several types (though not all types) of investments to improve transportation system efficiency and reduce vehicle miles traveled (VMT). They have limited or no direct control over land use and the investments and programs to improve vehicle efficiency and increase use of low carbon fuels.

Exhibit 3-5: Ways that State DOTs and MPOs Can Reduce Transportation GHG Emissions

Strategy Focus	Investment or Program Type (example)	State DOT or MPO Authority
Improve Transportation System Efficiency	Transportation systems management (TSM) and operations (e.g., signal synchronization, incident management)	Substantial
	Speed limits	Substantial
	Driver training / "EcoDriving" programs	Limited
	Congestion pricing	Substantial
Reduce Vehicle Activity (VMT)	Infrastructure and programs for transit, walking, bicycling, ridesharing	Substantial
	Road pricing	Substantial
	Fuel pricing	No control
	Efficient land use patterns (infill, TOD)	Limited ability to affect through indirect means; local governments generally hold the direct authority over land use decisions
Increase Vehicle Efficiency	Incentives for efficient vehicles	Limited (can provide incentives based on roadway access)
	Fuel pricing	No control
	Regulation of vehicle efficiency	No control
Low Carbon Fuels	Refueling infrastructure for hydrogen, biodiesel, and ethanol	Limited (can support refueling infrastructure)
	Regulation of fuel type	No control

Although transportation agencies do not have control over some of these strategies, it is important to note that states may play a role in many of these strategies through legislation or implementation by other departments. For instance, states could implement increases in fuel prices (e.g., gas tax increases) and implement Smart Growth policies, guidance, or tax incentives to shape land use planning. Therefore, these approaches could be considered as part of a package of transportation strategies to reduce GHGs, recognizing that transportation planning decisions are not the primary driver of these strategies.

It should also be noted that even in cases where transportation agencies have substantial authority to implement strategies, their ability to reduce GHG emissions through these strategies may be somewhat limited due to external factors. For instance, there are many factors that influence vehicle travel demand and system operations – such as fuel prices, demographic/economic factors, and housing and educational policy – that are beyond the control of transportation agencies. The exhibit below provides specific findings on the GHG reduction control associated with each policy mechanism.

Exhibit 3-6: Assessment of GHG Reduction Control

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ Control over on-road GHG emissions is determined by agencies' ability to influence vehicle fuels/technology, system performance, and VMT. ▪ Policies related to vehicles and fuels (e.g., CAFE standards, renewable fuels standards) are largely outside the control of state DOTs and MPOs. However, partner agencies can influence these vehicles and fuels to some extent, largely at the state level (e.g., fuel economy based registration fees, state fuel taxes). ▪ Strategies that reduce VMT require changes in travel behavior, which can be difficult because of personal preferences, entrenched patterns of travel, and lack of access to alternative modes of transportation.
With state-level requirements	▪ States do not directly control land use, which can affect their ability to meet specified targets, although many have the capacity to influence land use through state planning/economic development agencies; state DOTs often play a limited role. ▪ Some metropolitan areas cross state-boundaries, making state-level requirements potentially more challenging (e.g., dealing with segments of a regional model; multi-state commute patterns). ▪ Interstate travel could be a source of emissions that is difficult to address.
With MPO-level requirements	▪ Some MPOs span multiple states, which can make region-wide policies and programs challenging to implement. ▪ Most MPOs do not have direct control over land use, although many have the capacity to influence land use by working with partner agencies. ▪ An MPO-level requirement would not cover travel in rural areas. Travel between metro areas could be a source of emissions difficult to address at the MPO level.
Transportation GHG Budgets with Penalties	▪ All findings for a Transportation GHG Performance Standard also apply here.
VMT Performance Standards with Incentives	▪ Credits only transportation demand management (TDM) strategies without addressing strategies related to vehicle technologies, fuels, and systems operations, which are viable strategies to reduce GHG emissions. ▪ All findings above related to strategies that reduce VMT and to the planning powers of MPOs and DOTs also apply here.
Climate Change Action Planning Requirement	▪ State DOTs and MPOs have limited control over non-road sources, which may be included in sector-wide transportation climate plans. ▪ DOTs and MPOs would rely on partner agencies to help implement many types of on-road GHG reduction measures, especially land use measures.
Requirement to Implement Emissions Reduction Strategies	▪ Transportation emissions reduction strategies should be defined such that regulated agencies have the capacity necessary to implement them.
Interagency Consultation	▪ Not applicable
Project Level GHG Analysis	▪ GHGs do not have a localized impact. Several MPOs and state DOTs in the early stages of developing GHG-related performance measures have concluded that project level comparisons of GHG emissions are not useful because the travel patterns that determine GHG emissions are determined at the system level. However, some agencies feel project-level analysis is useful to bring attention to the effects of investment decisions, and there may be opportunities for mitigation.

Co-benefits and Synergy

One consideration in examining policy mechanisms is the extent to which they support multiple objectives and relate to other planning processes. Potential co-benefits of requirements to reduce transportation GHG emissions may include improved air quality, multimodal connections, and quality of life, among other benefits. These co-benefits are common across most of the policy mechanisms. Synergies may occur with the existing transportation planning process (e.g., the extent to which requirements support or enhance the existing process), with other planning processes (e.g., the extent to which requirements help to integrate land use, economic development, and environmental planning with transportation decision making), or with other GHG reduction policies (e.g., cap and trade policies, CAFE standards, etc.).

The following exhibit provides a summary by policy mechanism.

Exhibit 3-7: Assessment of Co-Benefits/Synergy

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ Could be integrated into the long-range transportation planning process, along with other performance standards or targets. o Many state DOTs and MPOs are integrating performance measures into their planning. For instance, the San Francisco Metropolitan Transportation Commission 2035 Plan includes a range of regional targets (e.g., 10% VMT reduction per capita by 2035 and 20% reduction in person hours of delay below 2008 levels) o Can include and capture all types of strategies including those related to vehicle fuels and technologies, and operational measures. ▪ Provides a common metric to compare reductions from transportation with reductions from other sectors. ▪ May mean that conducting a separate project-level GHG analysis is unnecessary since projects are included in the plan's analysis. ▪ Could work in concert with a cap and trade policy. National and state transportation emissions reduction policies, e.g., CAFE standards, renewable fuels standards, would contribute toward meeting the performance standard.
With state-level requirements	▪ May not necessarily integrate well with the existing statewide transportation planning process. Since statewide long range transportation plans often are policy plans, do not identify all planned investments, and are not always updated on a regular cycle, forecasting transportation system-wide emissions will require some changes in process; however, these changes may also help to ensure stronger connections between state, regional, and local transportation decisions. ▪ States may need to work together with other states where metro areas cross state boundaries, which is done in air quality planning and conformity determinations.
With MPO-level requirements	▪ Would integrate with the existing metropolitan transportation planning process and transportation conformity process. In areas subject to transportation conformity, there likely would be benefits to coordinating emissions reduction strategies across greenhouse gases and criteria pollutants.
Transportation GHG Budgets with Penalties	▪ Compliance with the budgets could be included in transportation planning requirements much like transportation conformity requirements are implemented. Transportation agencies would need to demonstrate that on-road emissions associated with their plans and TIPs would be reduced to meet the budget for specific future years. ▪ Provides a common metric to compare reductions from transportation with reductions from other sectors. ▪ Can include and capture all types of strategies including those related to vehicle fuels and technologies, and operational measures.

	▪ May mean that conducting a separate project-level GHG analysis is unnecessary since projects are included in the plan's analysis. ▪ Could work with a cap and trade policy but if the cap includes transportation sources, then there would essentially be a cap on emissions at the national level and individual budgets for on-road transportation sources for states or metro areas.
With state-level requirements	▪ May not necessarily integrate well with existing statewide transportation plans, which often are policy plans, do not identify all planned investments, and are not always updated on a regular cycle. However, changes in statewide planning could help to ensure stronger connections between state, regional, and local transportation decisions.
With MPO-level requirements	▪ Would integrate with existing transportation planning process and transportation conformity process.
VMT Performance Standards with Incentives	▪ Emphasis on investing in alternatives to driving (transit, ridesharing, walking, bicycling) and integrating transportation and land use planning has multiple co-benefits: mobility, accessibility, public health. o Many of these strategies are already being used to reduce criteria pollutants and as part of transportation systems investments. o While GHG-based targets also might encourage these approaches, VMT standards would likely focus more attention on these strategies. ▪ Can be combined with cap and trade and other policies.
Climate Change Action Planning Requirement	▪ Could catalyze GHG reduction planning across sectors and different modes of transportation (including aircraft, rail, and water), which could help in assessing the most effective, and cost-effective, strategies. ▪ Can be combined with cap and trade and other policies, and may help states to identify strategies to reduce transportation GHG emissions outside of the traditional transportation planning process, such as alternative fuel vehicle fleets, land use planning, etc.
Requirement to Implement Emissions Reduction Strategies	▪ Would integrate with existing transportation planning process at both the state and MPO levels. ▪ Can be combined with cap and trade and other policies. ▪ May help transportation agencies to consider a range of effective land use and transportation strategies that can also have co-benefits in terms of air quality improvement and multimodal options.
Interagency Consultation	▪ Would integrate with existing transportation planning and conformity processes at both the state and MPO levels. ▪ Could bring an additional set of stakeholders into the transportation planning process, which may yield benefits in terms of improved integrated decision making and better plans and projects.
Project Level GHG Analysis	▪ Can be modified so that project level analysis is incorporated as a component of another policy mechanism such as NEPA compliance. ▪ Might encourage transportation agencies to consider changes in transportation investments and/or design to incorporate features that reduce GHGs; may also encourage more efforts to mitigate GHGs from construction and maintenance. o Agencies have more direct control over construction and maintenance-related emissions than emissions associated with the operation of vehicles on the completed facility ▪ In rural areas, construction and maintenance related emissions may be the only opportunity for reducing GHG emissions.

Potential Unintended Consequences

Potential unintended consequences are an important consideration in considering policy mechanisms. A key issue is the geographic coverage of requirements, since requirements that place burdens on only some areas to reduce emissions (e.g., only metropolitan areas) may inadvertently push growth outside of these areas, limiting the effectiveness of the approach and creating equity concerns. It is important to note that all approaches that are successful in reducing GHG emissions through reduced motor vehicle fuel consumption will result in lower motor fuel taxes and revenues for the Highway Trust Fund. Exhibit 3-8 summarizes the potential unintended consequences by policy mechanism.

Exhibit 3-8: Assessment of Potential Unintended Consequences

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ If funding is tied to meeting performance standards, could affect the ability of some states/regions to respond to transportation needs by diverting limited funding from system maintenance/repair or expansion needs to emission reduction efforts. ▪ Would encourage implementation of strategies to reduce motor vehicle fuel consumption, which would reduce motor vehicle fuel tax revenues.
With MPO-level requirements	▪ Might encourage growth outside of metro areas subject to requirements.
Transportation GHG Budgets with Penalties	▪ GHG budgets might not encourage the most cost-effective reductions to occur across the entire economy, since there is not assumed to be a market mechanism involved (unless states or MPOs could "trade" emissions reductions credits). ▪ Jurisdictions already tackling GHGs emissions may be disadvantaged compared to less ambitious jurisdictions, as they will have already captured emissions reductions from strategies that are easily implemented, and these might already be reflected in setting the budget. Jurisdictions with relatively low VMT per capita due to long-term approaches to land use and transportation investment could be similarly disadvantaged. ▪ Would encourage implementation of strategies to reduce motor vehicle fuel consumption, which would reduce motor vehicle fuel tax revenues
With MPO-level requirements	▪ Might encourage growth outside of metro areas subject to requirements.
VMT Performance Standards with Incentives	▪ DOTs and MPOs would not have any incentive to support technological advances that lower GHG emissions per mile. Limits transportation agencies to pursuing demand management strategies. Transportation strategies not related to VMT reductions, even if cost-effective, may not be promoted. Likely would not include strategies to affect freight movement. ▪ Under current financing structures, reducing VMT would also reduce gas tax revenues.
Climate Change Action Planning Requirement	▪ Unclear
Requirement to Implement Emissions Reduction Strategies	▪ Might result in some strategies being implemented that are not cost-effective in certain contexts.
Interagency Consultation	▪ Depending on how requirements are established, might create a source of delay in planning or project development or shift decision making authority to other entities (e.g., environmental agencies)
Project Level GHG Analysis	▪ Could delay the implementation of projects desired to meet expected growing travel demand, economic development needs, or other needs.

Flexibility to Adapt

Flexibility is an important consideration in the implementation of any of the policy mechanisms. It is very likely that emerging federal policies on energy and the environment, such as cap-and-trade and vehicle fuel economy standards, will have important implications on transportation GHG emissions. Changes in fuel prices and vehicle stock in response to these policies, as well as potential changes in consumer preferences, population growth, and economic growth will have important implications for the ability of transportation agencies to achieve GHG reduction through planning activities.

Performance-based and incentive-oriented mechanisms are generally considered more flexible than mandatory requirements. However, even with a regulatory requirement, such as a GHG budget with penalties, there is some potential to build in flexible mechanisms, such as the ability to adjust targets in response to changes in models, or assumptions. Building flexibility into any regulatory scheme is generally desired by transportation agencies.

Exhibit 3-9: Assessment of Flexibility/Adaptability

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ A performance standard would likely be more adaptable than a fixed budget. ▪ The GHG target presumably could be changed based on available emission and growth numbers, if desired.
Transportation GHG Budgets with Penalties	▪ A budget with penalties assumes a regulatory approach and therefore flexibility will be limited once the budget(s) is set and implementing regulations are in place. ▪ However, systems can be set up to allow some flexibility to adjust budgets over time, add new strategies, etc.
VMT Performance Standards with Incentives	▪ Limited strategies to reduce VMT other than individual changes in travel choices.
Climate Change Action Planning Requirement	▪ Transportation agencies could have a lot of flexibility as part of the process of developing the climate action plan. ▪ However, if a multisector climate action plan with targets for individual sectors is developed, this may make it difficult to adjust the transportation contribution over time as conditions change.
Requirement to Implement Emissions Reduction Strategies	▪ May allow a high level of flexibility to select strategies. ▪ On the other hand, may constrain choices to certain "approved" categories of strategies or limit ability to develop projects without implementing certain programs.
Interagency Consultation	▪ Could be very flexible; depends how prescriptive the consultation requirements are.
Project Level GHG Analysis	▪ If requirement simply calls for disclosure of GHG effects, this provides maximum flexibility. If mitigation must be conducted, there may be limited ability to address GHG emissions.

Equity

Equity is an important consideration, since policy mechanisms should not unduly burden certain geographic areas or populations. Since climate change is a global problem, transportation planning requirements that only apply to a subset of the U.S., such as only to metropolitan areas or a subset of metropolitan areas could disadvantage these areas. Under any approach that involves targets (particularly under a mandatory budget), a key challenge is setting appropriate targets that are fair and do not unduly burden particular areas at the expense of others. For instance, a target to reduce GHG emissions to 20% below 1990 levels would be much more challenging to meet in an area with high population growth than in one with slow population growth; Section 4 of this report explores this issue in further depth. Exhibit 3-10 presents a summary of potential unintended consequences by policy mechanism.

Exhibit 3-10: Assessment of Equity

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ Requirement to meet a target to reduce GHG emissions to a base year level by some future designated date would likely be more challenging for states and MPOs with fast growing populations than for slow growing states/MPOs. ▪ Existing transit and multimodal options in an area will likely improve that region's ability to meet a specified target.
Transportation GHG Budgets with Penalties	▪ Ability for states and metro areas to meet the budget would differ based on how the budget is defined. For fast growing states and jurisdictions, a target reduction to certain base-year levels would be more difficult to achieve than a per capita reduction. Areas with transit and multimodal infrastructure may be better able to reduce transportation GHG emissions. ▪ Base year choice could adversely affect regions that have been reducing emissions already.
VMT Performance Standards with Incentives	▪ Assumes all VMT of equal value (e.g., discretionary trip vs. work trip) ▪ Some areas – particularly those with limited transit availability, low population densities, and high pass through (long distance) travel – will have more difficulty in reducing VMT than other areas. ▪ If a VMT reduction focus encourages more investment in transit and options for non-motorized travel, this may improve accessibility and travel options for transit-dependent populations.
Climate Change Action Planning Requirement	▪ If a climate action plan covers multiple sectors, transportation might be assigned a disproportionate share of the burden to reduce emissions. Involvement of transportation agencies in the setting of targets and selecting strategies will be important to avoid potential equity concerns.
Requirement to Implement Emissions Reduction Strategies	▪ Depending on how the requirement is structured, it may not be feasible for certain metro areas or states to implement some types of strategies.
Interagency Consultation	▪ Not applicable.
Project Level GHG Analysis	▪ If project-level requirements limit the ability to build new highway capacity, this might disadvantage growing areas that are in more need of new transportation infrastructure.

Public Understanding

The ability of transportation agencies to communicate to the public and elected officials about how transportation decisions are affected by GHG requirements is important to transportation agencies. Complex requirements, such as the current transportation conformity process used to integrate air quality considerations in transportation planning, can be difficult for the public and decision-makers to understand. Many of the considered transportation GHG policy mechanisms also will be somewhat difficult for the general public to understand. However, it is important to note that the public may react more forcefully to the proposed strategies and investments in transportation plans, such as roadway pricing or land use changes, as well as highway and transit investments. Exhibit 3-11 summarizes the assessment.

Exhibit 3-11: Assessment of Public Understanding

Mechanism	Findings
Transportation GHG Performance Standard with Incentives	▪ The public may be more supportive of an incentive-based policy than a mandate. ▪ The target focuses directly on the desired outcome: GHG reduction (in contrast to VMT). Understanding and demand for climate change action has increased in the public eye. This is a policy that directly addresses the issue. ▪ Public support may be limited if implementing strategies to meet a target requires changes in travel behavior.
Transportation GHG Budgets with Penalties	▪ The target focuses directly on the desired outcome: GHG reduction (in contrast to VMT). Understanding and demand for climate change action has increased in the public eye. ▪ Communicating the penalties to the public may help them to understand why transportation investments and policies are being implemented. ▪ Public support may be limited if implementing strategies to meet a target requires changes in travel behavior.
VMT Performance Standards with Incentives	▪ VMT is a simple accessible measure, understandable to the general public. ▪ Proposals to reduce VMT may be met with skepticism by the public and are a sensitive issue with decision makers. Some perceive that reducing VMT is going to negatively affect growth, the economy, attractiveness of a region for business location, etc. Others are promoting VMT reduction efforts as enhancements to livability and sustainability. ▪ The link between VMT reduction and GHG reduction weakens as fuel efficiency improves, but the public may not understand the differences. ▪ Public support may be limited if implementing strategies to meet a target requires changes in travel behavior.
Climate Change Action Planning Requirement	▪ Unclear - Climate Action Plans have already been completed by over 30 states. However, the public may not understand how these plans are developed or implemented.
Requirement to Implement Emissions Reduction Strategies	▪ This is simpler for the public to understand than the complexities associated with VMT forecasting or emissions modeling.
Interagency Consultation	▪ The public likely will not be very aware of this type of process requirement.
Project Level GHG Analysis	▪ The public generally does not understand that project level emissions impacts of GHG are generally very small in the context of systemwide emissions. They do not understand some of the technical challenges associated with developing this information (e.g., short-term and long-term effects)

3.4 Regulatory Transitions

The policy mechanisms examined above are not necessarily mutually exclusive. Aspects from various mechanisms could be implemented simultaneously, in a complementary way. For example, a GHG performance standard could be enacted at the state level, with targets set for individual states to reduce GHG emissions. States could then establish VMT standards for MPOs within their borders, recognizing that MPOs are better equipped to oversee reductions in VMT at the level of urban areas, while state governments have more power to reduce GHG emissions through policies aimed at vehicle technologies and fuels statewide.

Likewise, legislation could transition from one mechanism to another over time, allowing time for regulated agencies to adjust to any new requirements. It is common practice in environmental regulation to announce new rules and regulations a few years before agencies will be required to comply. In

California, preliminary proposals for the implementation of SB 375 include a transition from the use of Best Management Practices to the use of travel demand modeling to select and verify GHG reduction strategies, as assumed under a Transportation GHG Performance Standard. The proposal by the RTAC is specifically meant to ease the significant new technical requirements that GHG targets will impose, especially on smaller MPOs. Allowing the use of BMPs as an alternative compliance mechanism for a period of several years would afford small MPOs a grace period in which to upgrade their modeling capabilities. Use of BMPs would not require substantial modeling on the part of MPOs, since the emissions reduction credits for BMPs would be established by the state of California.

New federal or state legislation could also establish targets that are initially voluntary, such as under a transportation GHG performance standard, but eventually become mandatory. Such a mechanism would allow a grace period for regulated agencies to increase their capacity to plan for reduced GHG emissions and familiarize themselves with the use of funding and incentives provided. Additional incentives could also be offered to state DOTs or MPOs that moved to reduce GHG emissions sooner rather than later. Meanwhile, the reality that compliance would eventually become mandatory, and that penalties would be imposed on non-complying agencies, would help motivate agencies to act sooner rather than later.

4. Implications of Alternative Targets on Sample States and MPOs

The appropriate setting of reduction targets is an important issue, particularly under regulatory approaches where reductions are mandatory. Setting targets for GHG emissions is also more challenging than for other types of pollutants. Unlike criteria pollutants, impacts of GHG emissions are not related to their location of emission. While there is some consensus among the scientific community about the total amount by which GHG emissions should be reduced globally, there is no consensus about how different economic sectors and regions can best contribute to an overall goal. A process for establishing reduction targets will be needed, with a regulatory agency or body either allocating specific reduction targets to individual states or regions or approving targets that are set by each state or MPO. Numerical targets for individual states or regions would likely be set through a regulatory process that considers several factors, including emission reduction potential, cost-effectiveness, economic effects, social equity, and feasibility.

Setting of targets has important equity issues for states and regions. If uniform targets were established for the transportation sector across all areas, the implications for various states and regions would be very different. The ability of areas to meet a target might depend on rates of population growth and economic activity and historical changes in travel patterns. For example, faster growing states and regions may find it more difficult to meet a reduction target than areas growing more slowly. Other factors related to demographics and urban development patterns may also affect the ability of areas to meet reduction targets. For example, some cities have physical patterns that are more conducive to non-auto modes of travel.

This section demonstrates the impact that uniform reduction targets would have on a sample of states and MPOs, given their historic and forecast growth patterns. The analysis is based on historical growth in population and VMT in each area, as well as future growth in population and VMT, as forecast by individual states and MPOs. Fuel consumption was calculated from VMT, using national average light-duty fuel economy, both historical and forecast. CO_2 emissions were calculated using standard factors per gallon of fuel. More information on the data sources used is provided in Appendix C.

The analysis considers the following scenarios for uniform targets:

Exhibit 4-1: Scenarios Analyzed for Sample States and MPOs

Target Type	Scenario Analyzed
Reduction in GHG emissions from base year	20% reduction in CO_2 emissions from 1990 levels by 2020
Reduction in per capita GHG emissions from base year	20% reduction in CO_2 per capita from 1990 level by 2020
Reduction in GHG emissions from BAU scenario	30% reduction in CO_2 emissions in comparison to BAU scenario for 2020
Reduction in per capita VMT from base year	20% reduction in VMT per capita from 1990 level by 2020

Without looking at the specific strategies available to states and MPOs to reduce GHG emissions, this analysis simply explores what level of reductions would be required in different areas under a standardized way of setting reduction targets. The analysis provides the following conclusions:

The way in which targets are set has major implications on the abilities of states and MPOs to meet them. Given wide differences in population growth, economic activity, and travel patterns in different areas, the establishment of one reduction target for all areas would place very different burdens on individual states and MPOs:

- States and MPOs that are experiencing high growth in population, economic activity, and travel per resident would be more challenged than others in meeting targets to reduce GHG emissions below a base year (e.g., 20 percent below 1990 levels) than those with slower growth. A more recent base year (e.g., 2005) may partially address this concern.
- While a reduction target set in relation to population would address the challenges of high growth areas, such a target (e.g., a per capita VMT reduction target) would be more challenging to meet for states and metro areas that have seen increases in VMT per capita, and may be most challenging to meet in areas with slow or no population growth.
- A target set in relation to a business as usual (BAU) scenario may be perceived as more equitable than a target set relative to a base year, but careful consideration of the validity of assumptions that go into the BAU scenario will be needed. Moreover, this approach does not reward states and MPOs that have already built VMT or GHG reductions into their transportation plans.
- A VMT target would affect some states and regions differently than a CO_2 target. A CO_2 target would credit areas that reduce CO_2 emissions per mile, such as through fuel economy standards. A VMT target might be more favorable to areas in which heavy-duty truck traffic is growing more rapidly than light-duty VMT, since heavy-duty trucks produce significantly more CO_2 per mile than light-duty vehicles.

Consequently, flexibility to establish different targets for different areas is an important consideration in the design of requirements. Establishing uniform targets creates equity issues. The ability of different states or MPOs to achieve GHG reductions will depend on a wide range of factors, and these need to be considered in establishing targets without unfairly disadvantaging some areas. Moreover, the share of total GHG emissions that are from transportation sources varies among states and MPOs, and in some areas it may be possible to achieve cost-effective emissions reductions from other sectors. The context of transportation within a state or MPO's total emissions inventory, therefore, also could be considered in the setting of targets.

4.1 Wide Diversity in State and MPO Characteristics

Across states and metropolitan areas, the characteristics of population size, population growth, urbanization, and travel patterns, among other factors, vary considerably. A sample of seven states and six MPOs was analyzed to determine the relative impacts of different targets in terms of GHG reductions necessary to meet these targets. Sample states and MPOs were selected to represent a range of geographies, population size, population growth rates, and urbanization, as shown in Exhibit 4-2 below.[32]

Among the sample states, 2005 populations ranged from 0.6 million (Vermont) to 6.3 million (Washington), and per capita VMT ranged from less than 9,000 per year (Washington) to a high of more than 12,000 per year (Vermont). There was significant variation in the proportion of vehicle travel that occurs in rural areas, from 26 percent (Maryland) to 77 percent (Montana). There was less variation in the

[32] Data and forecasts for each area were compiled from several different sources. While every effort was made to minimize discrepancies, the figures presented should be taken as representative rather than definitive of each area's travel patterns.

proportion of truck travel as a share of total vehicle travel, with most states ranging from 8 to 10 percent; however, truck travel was estimated as 15 percent of total VMT in Arizona. Among the sample MPOs, populations ranged from 2 million (Portland) to 7.1 million (San Francisco), and average VMT per resident ranged from below 8,000 per year (Seattle) to more than 10,000 per year (Dallas).

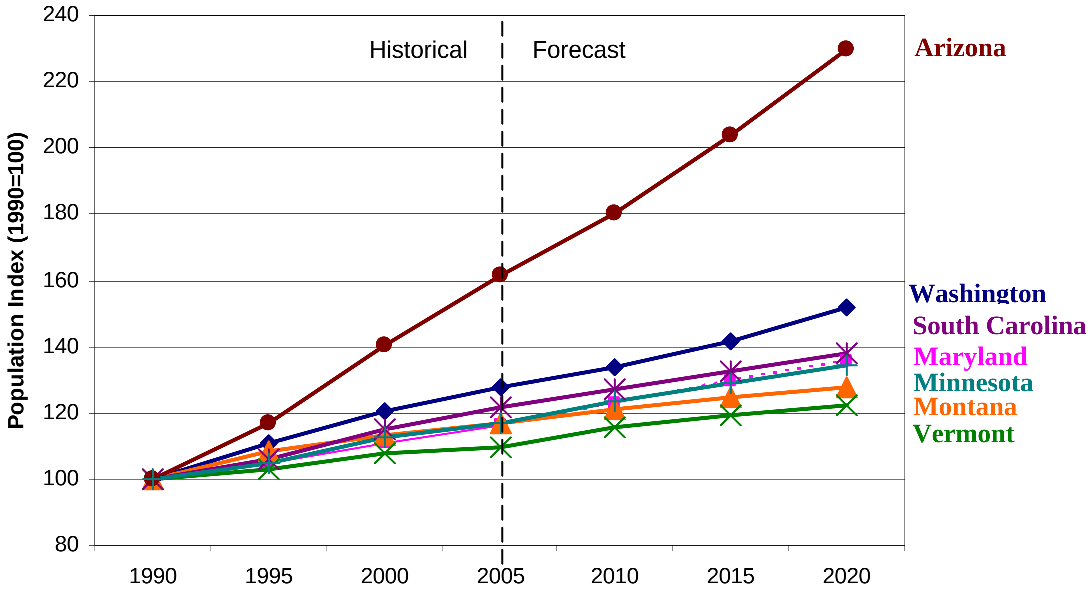
Exhibit 4-2: Population and Travel Characteristics of Sample States and MPOs: 2005

Area	Population (millions)	Annual VMT per capita	% Rural VMT*	% Truck VMT
States				
Washington	6.3	8,847	29%	10%
Arizona	6.0	10,047	29%	15%
Maryland	5.6	10,101	26%	8%
Minnesota	5.1	11,127	49%	7%
South Carolina	4.3	11,618	50%	10%
Montana	0.9	11,889	77%	10%
Vermont	0.6	12,446	76%	8%
MPOs				
San Francisco	7.1	8,596		
Washington, DC	5.9	9,395		
Dallas	5.6	10,376		
Seattle	3.5	7,844		
Sacramento	2.2	9,356		
Portland	1.4	8,937		

Sources: For states, population figures are drawn from the U.S. Census. Travel data is drawn from FHWA Highway Statistics. For MPOs, figures are drawn from data provided by the MPOs and from Highway Statistics. Share of rural VMT was not collected for MPOs. Share of truck VMT was estimated using a variety of techniques across MPOs, and is not considered comparable between areas.

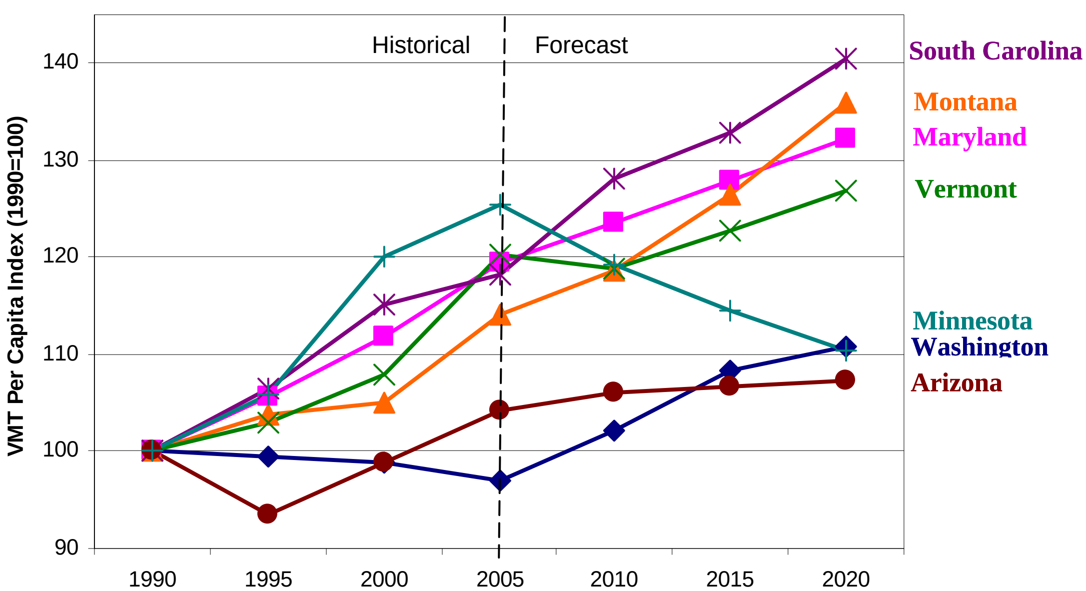
Population growth (historical and forecast) also varies significantly among the sample areas. Exhibits 4-3 to 4-6 show historical (1990-2005) and forecast (2005-2020) trends in population and travel patterns within the sample states. Forecast figures are shown beyond the dashed line. Among the sample, Arizona has shown the highest rate of population growth from 1990 to 2005, and is forecast to continue growing at the highest rate, with its 2020 population about 2.3 times as large as its population in 1990 (Exhibit 4-3). VMT per capita has generally grown since 1990, but by significantly more in some states than others, and actually declined slightly in Washington State (Exhibit 4-4). It should be noted that the quality of VMT forecasts beyond 2005 is uncertain, and may reflect different levels of sophistication in projection methods among states. South Carolina has seen by far the highest rate of growth in truck traffic of the sample states, and is expected to continue to see very high growth in truck traffic (Exhibit 4-5).

Exhibit 4-3: State Population Growth, 1990-2020



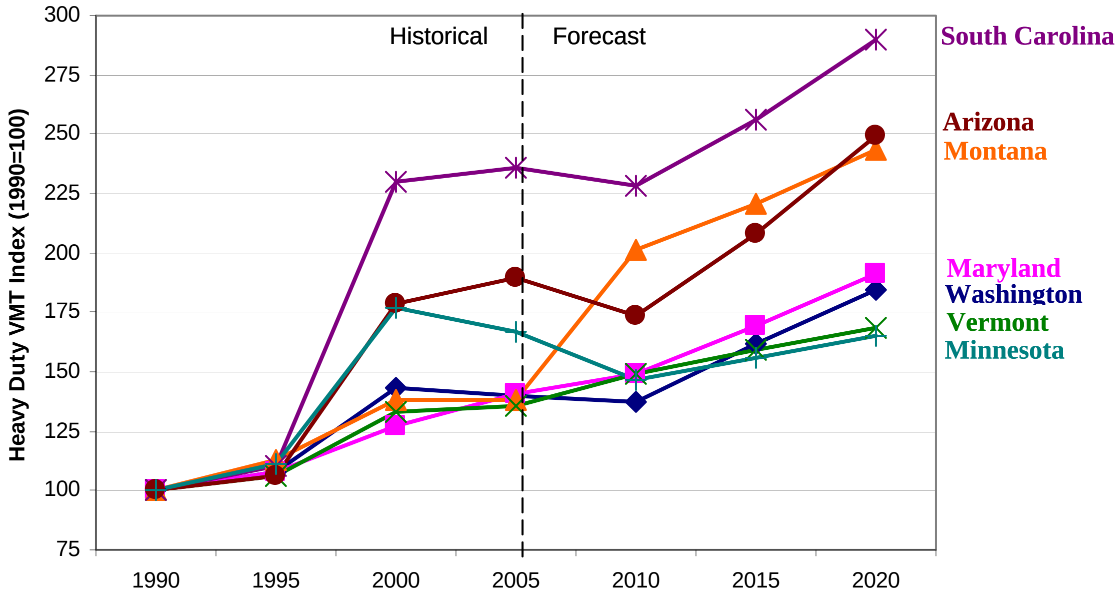
Source: U.S. Census data and forecasts.

Exhibit 4-4: State VMT per capita, 1990-2020



Source: Historical VMT from Highway Statistics. Forecast VMT from state climate action plans.

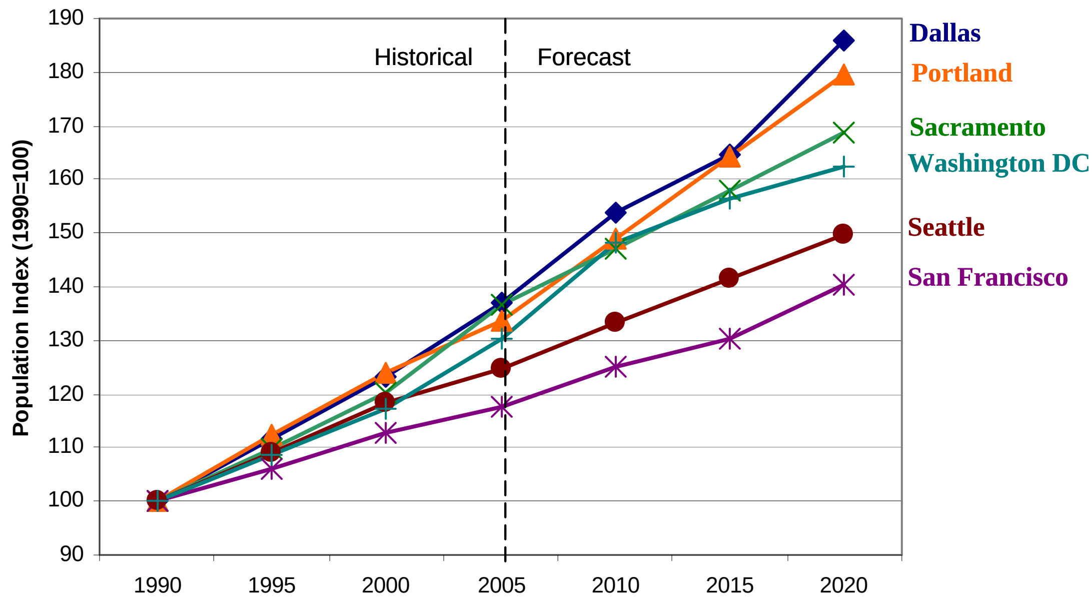
Exhibit 4-5: State Heavy Duty VMT, 1990-2020



Source: Historical VMT from Highway Statistics. Forecast VMT from state climate action plans.

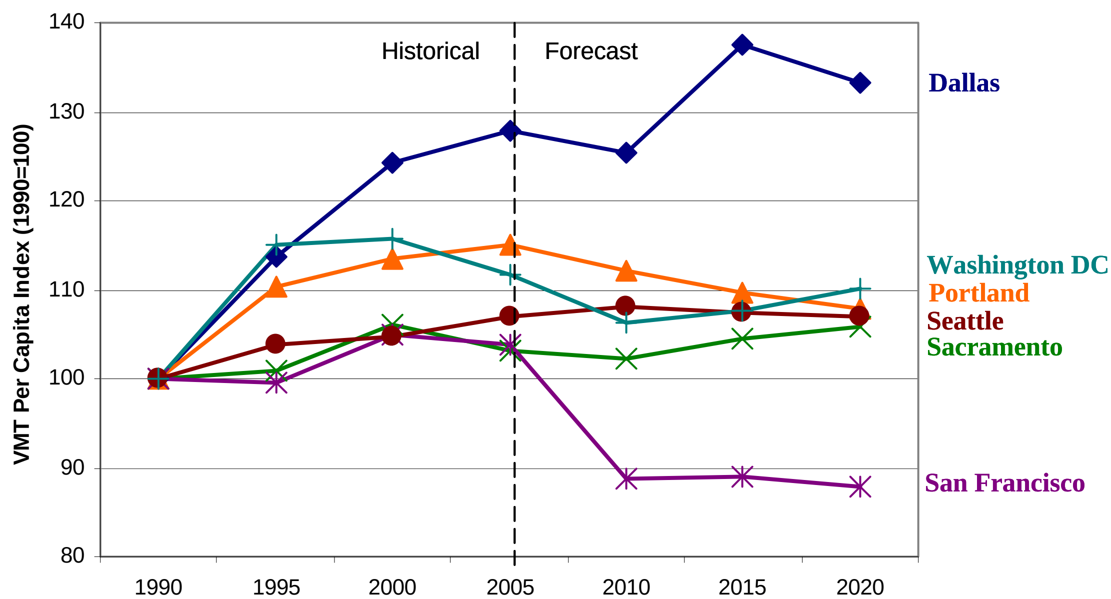
Exhibits 4-6 and 4-7 show historical (1990-2005) and forecast (2005-2020) trends in population and travel patterns within the sample MPOs. Forecast figures are shown beyond the dashed line. From 1990-2005, population grew fastest in the areas of Dallas and Sacramento. From 2005-2020, population growth is expected to be highest in Dallas (Exhibit 4-6). Average travel per resident grew fastest in Dallas between 1990-2005, but increased in all other areas as well. From 2005-2020, some MPOs are planning to see falling VMT per capita, including Portland and San Francisco (Exhibit 4-7). These expectations reflect planned investments and strategies in those areas' regional transportation plans.

Exhibit 4-6: MPO Population Growth, 1990-2020



Source: Historical data and forecasts provided by MPOs.

Exhibit 4-7: MPO VMT per capita, 1990-2020



Source: Historical figures based on data from MPOs and Highway Statistics. Forecasts provided by MPOs.

4.2 Reduction in GHGs from Base Year

In this scenario, each state and MPO has a target to reduce its on-road GHG emissions to 20 percent below its 1990 GHG emissions by 2020. As can be seen in Exhibits 4-8 and 4-9, this target implies very different levels of GHG reductions for the sample states and MPOs. Arizona, the state that has seen the most rapid population growth and is expected to continue to see high population growth, would need to reduce the greatest share of emissions under this target—more than half of its projected on-road emissions in 2020. Even with improvements in vehicle fuel economy, Arizona's expected increase in population implies that CO_2 emissions will be about double their 1990 level by 2020. In order to reduce GHGs to 20 percent below 1990 levels, on-road GHGs per capita would need to drop by half. In contrast, Vermont, the state that has seen the slowest population growth, would have a smaller share of emissions to reduce —about one third of projected 2020 emissions.

Likewise among MPOs, Dallas, which has experienced the most rapid population growth and VMT growth per capita, would have to reduce the greatest share of emissions – over half of its total projected on-road emissions in 2020. San Francisco, where population growth has been slowest and VMT per capita has not grown rapidly (and is projected to decline with implementation of its plan), would have to reduce the smallest share of emissions in 2020.

Exhibit 4-8: State-level Total Emissions Target—
Reduce Total On-Road CO_2 Emissions 20% Below 1990 Levels by 2020

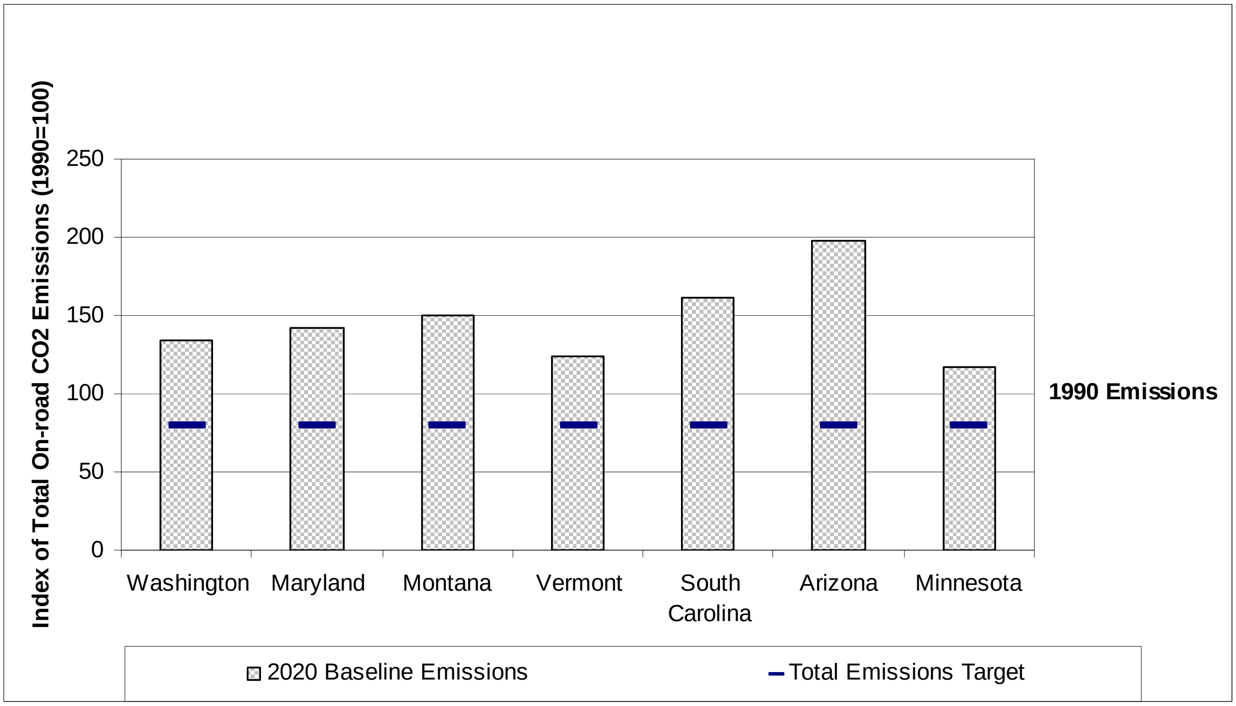
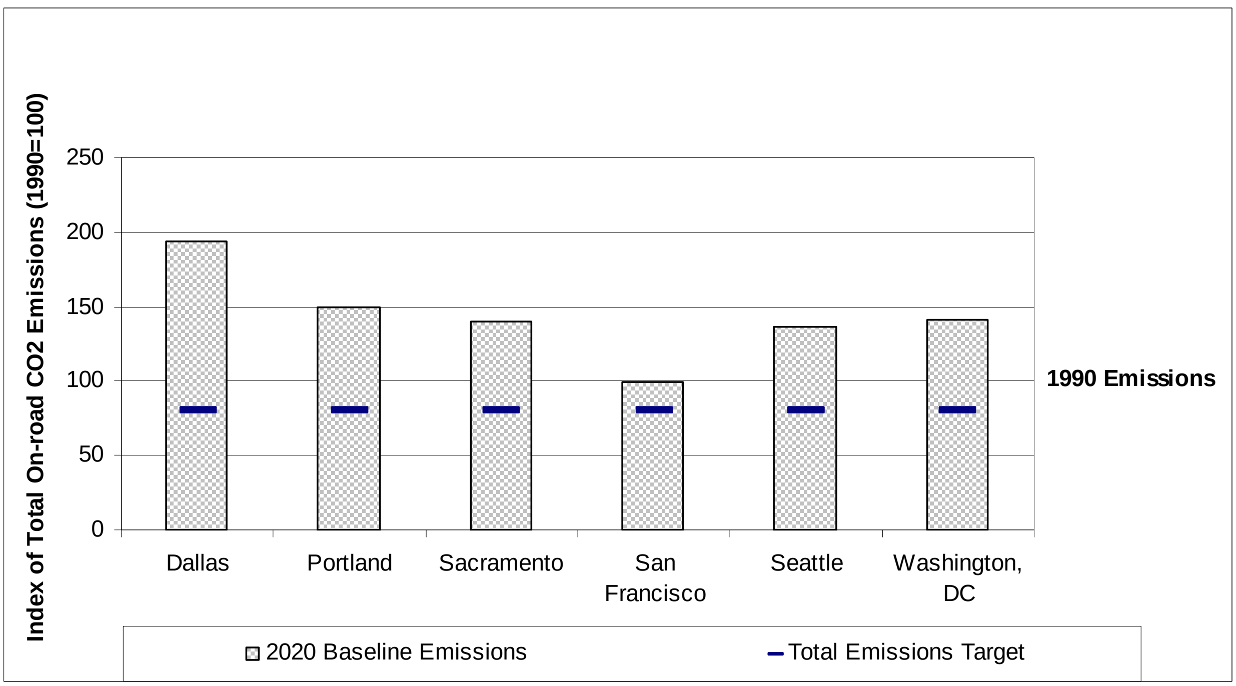


Exhibit 4-9: MPO-level Total Emissions Target—
Reduce Total On-Road CO_2 Emissions 20% Below 1990 Levels by 2020



4.3 Reduction in GHGs per capita from Base Year

In order to address the impacts of population growth, the concept of per capita targets is a reasonable alternative, and could be represented as on-road GHGs per capita (or VMT per capita). Per capita targets emphasize changes in the average on-road emissions (or amount of travel) per resident. Under this type of target, areas with high population growth would be allowed to see an increase in total GHG emissions, but states and MPOs with low population growth might have to reduce total GHG emissions back to 1990 levels or below.

Nationally, in order to achieve the same GHG levels as a target of 20 percent below 1990 levels by 2020, on-road transportation GHG emissions per capita would need to be reduced by significantly more than 20 percent, given that the U.S. population is expected to grow.

Exhibits 4-10 and 4-11 show the impact of per capita targets on the sample states and MPOs. The 20 percent reduction in per capita CO_2 emissions still allows for some growth in overall emissions, due to increases in population. Under this target, Arizona's required reduction is among the smallest. Arizona has seen only modest increases in average driving per resident. South Carolina and Montana, where VMT per capita has grown the most and is projected to continue to grow, would need to reduce the greatest shares of emissions.

Among MPOs, Dallas would need to reduce the greatest share of emissions compared to its baseline figures because average driving per resident has increased most rapidly in that MPO. San Francisco, which plans to reduce VMT per capita with its most recent Regional Transportation Plan, would be able to achieve the target as long as the plan was successful in achieving the projected reductions in VMT per capita, along with expected improvements in vehicle fuel economy.

Exhibit 4-10: State-level Per Capita Emissions Target—
Reduce On-Road Per Capita CO_2 Emissions 20% Below 1990 Levels by 2020

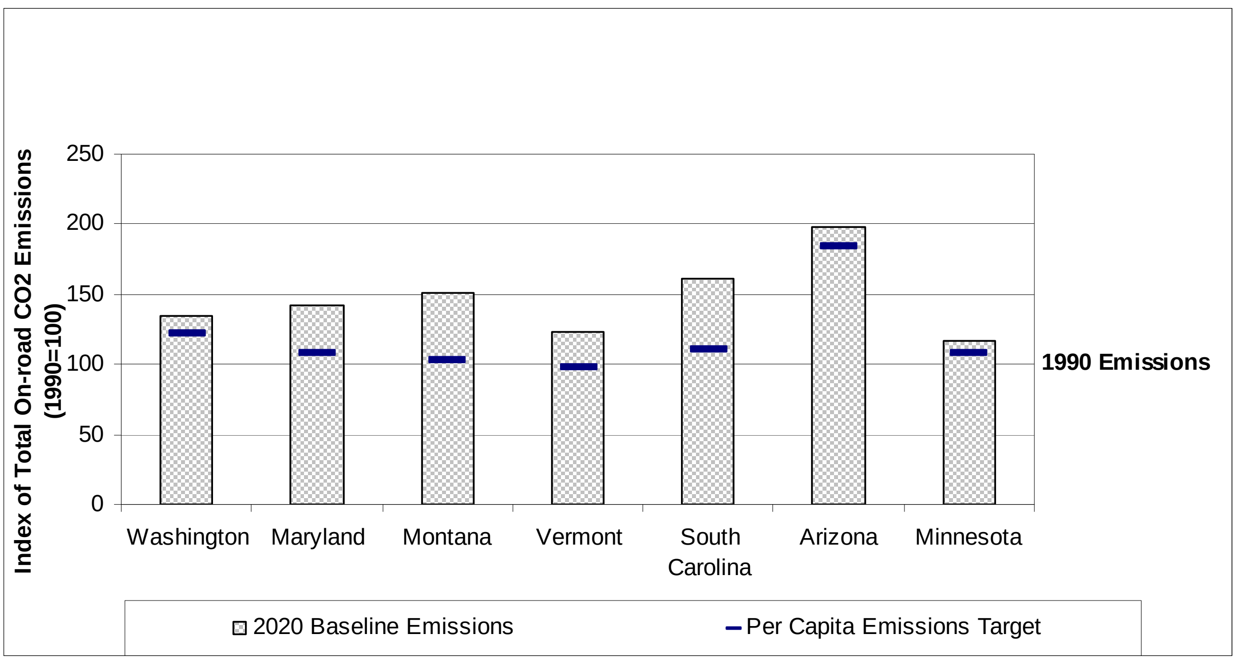
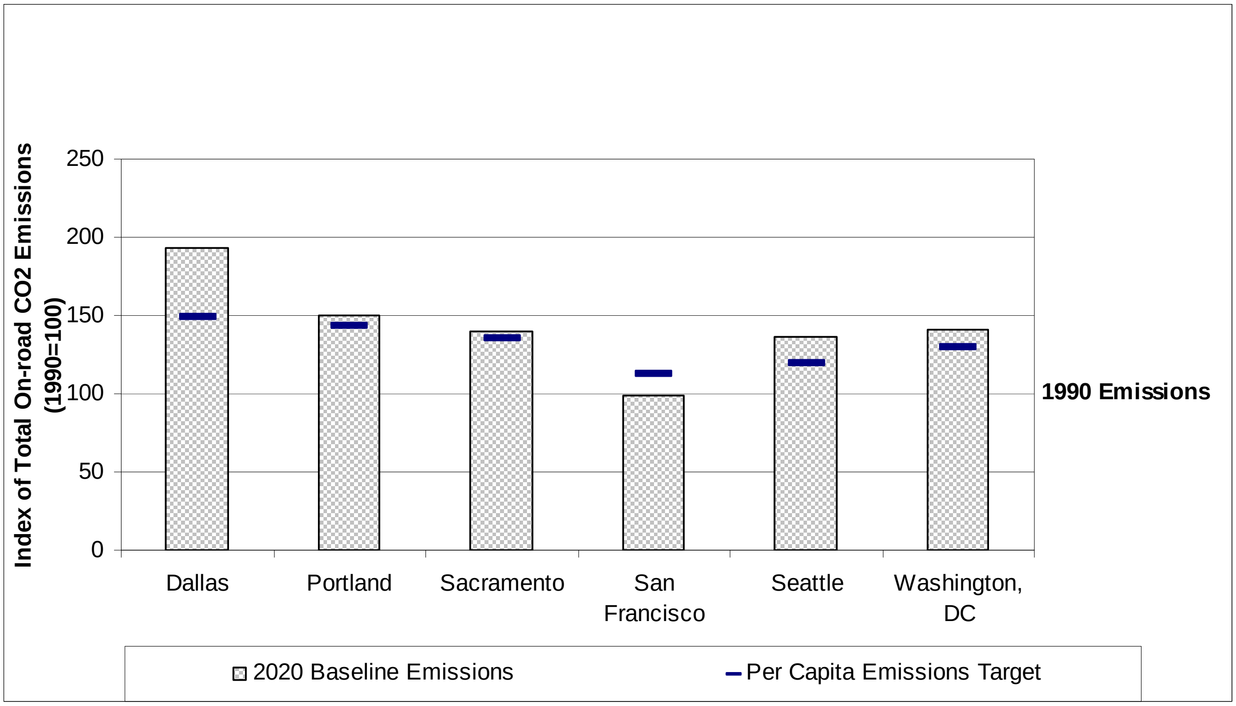


**Exhibit 4-11: MPO-level Per Capita Emissions Target—
Reduce On-Road Per Capita CO_2 Emissions 20% Below 1990 Levels by 2020**



4.4 Reduction in Relation to Projected Emissions

In the previous scenarios, targets were set in relation to a level of emissions (or per capita emissions) from a past year (i.e., 1990). Instead, targets could be developed in relation to future emissions under a business as usual (BAU) scenario in which no special actions are being taken to reduce GHG emissions. This BAU scenario could account for federal policies, such as CAFE standards that are expected to increase the fuel efficiency of vehicles.

In Exhibits 4-10 and 4-11 above, those states and regions that have kept average driving per resident lowest would need to reduce the smallest shares of emissions. States and regions that have seen greater increases in per capita VMT would have to reduce per capita emissions more. In contrast, targets based on a future forecast emissions level require all states and regions to reduce projected emissions by the same proportions of their projection. Since baseline on-road emissions are expected to be higher in 2020 than in 1990, in this case, we assume a 30 percent reduction target in comparison to BAU emissions. Exhibits 4-12 and 4-13 show the impact of CO_2 reduction targets based on forecast emissions on the sample states and MPOs. Relative to the 2020 forecast, each state and MPO must reduce emissions by 30 percent.

States and regions that have kept emissions relatively low since 1990 would not see this translate into a more modest reduction target. States and regions that already plan to reduce average driving per resident would not receive credit for such actions unless the forecasts used to set targets exclude those actions. For example, the forecast used for the San Francisco region included the impacts of the most recent Regional Transportation Plan. In Exhibit 4-13, San Francisco would be required to reduce emissions an additional 30 percent beyond the reductions already provided for in the RTP if this were considered the baseline.

**Exhibit 4-12: State-level Target Based on Forecast Emissions—
Reduce CO_2 Emissions 30% Below Business As Usual Levels by 2020**

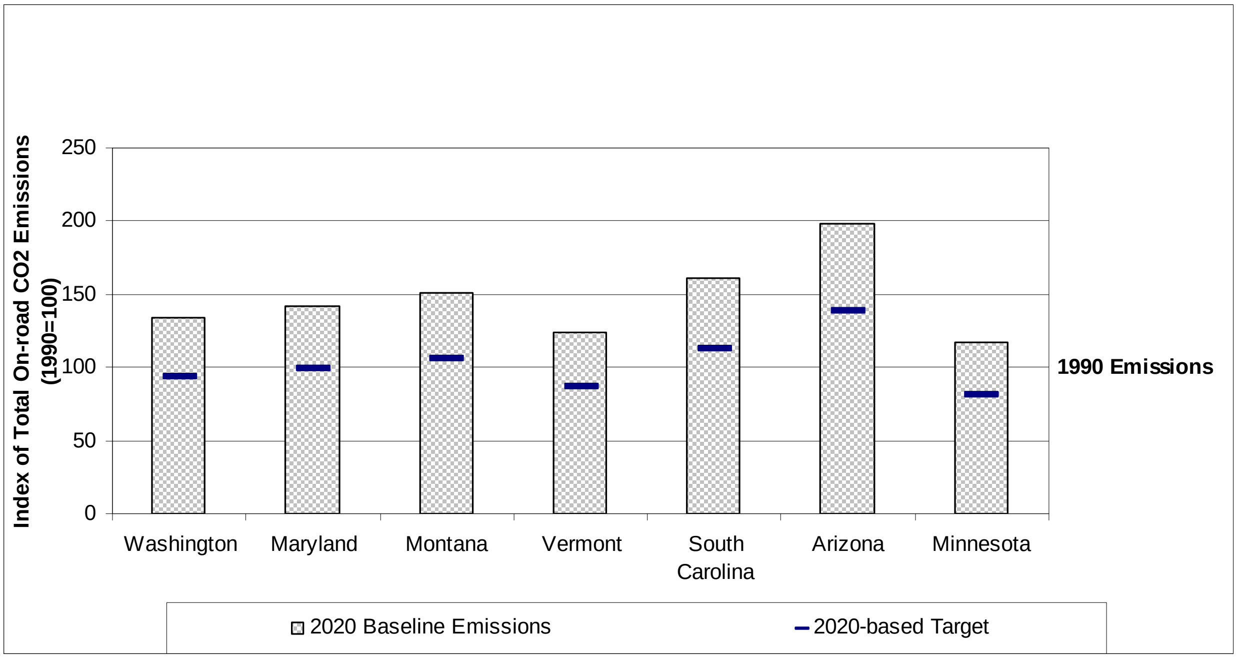
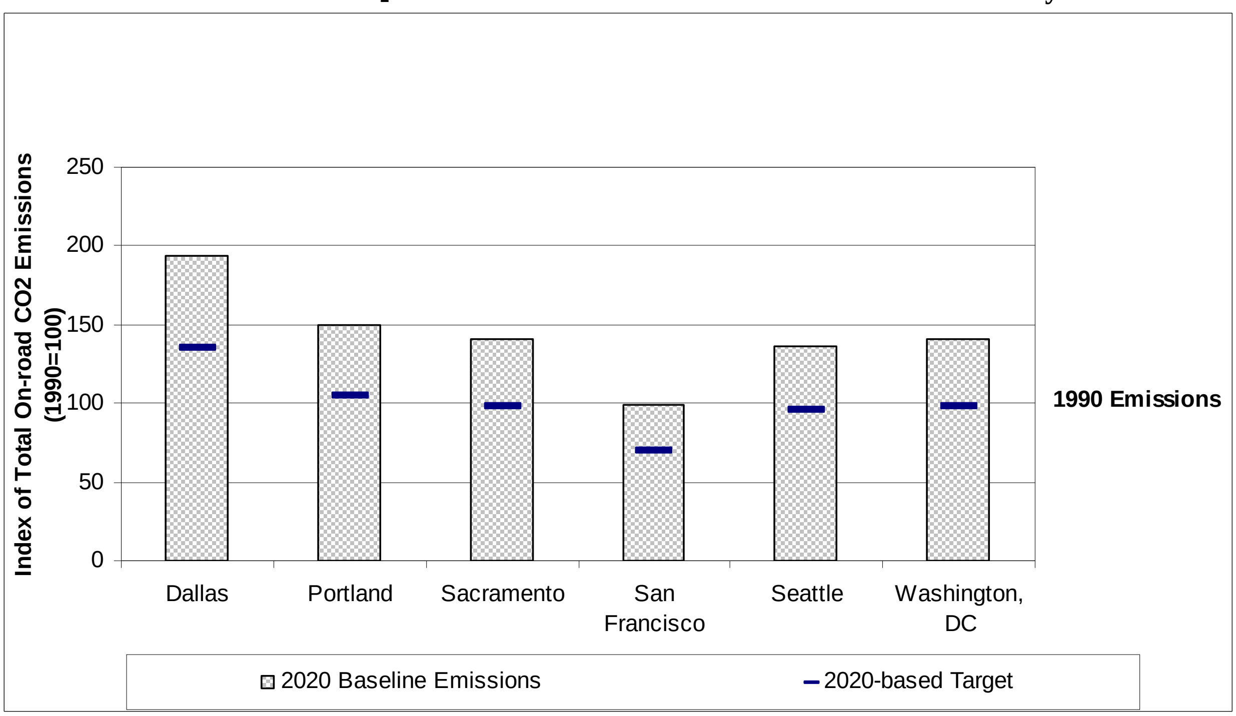


**Exhibit 4-13: MPO-level Target Based on Forecast Emissions—
Reduce On-Road CO_2 Emissions 30% Below Business As Usual Forecast by 2020**



4.5 Reduction in VMT

VMT targets are a possible proxy for CO_2 targets, since reducing VMT in a given state or region reduces on-road CO_2 emissions nearly proportionally. But VMT targets do not account for the full range of variables that affect on-road CO_2 emissions, which also include:

- Light-duty and heavy-duty vehicle efficiency
- Carbon content of fuels
- Mix of light-duty and heavy-duty traffic

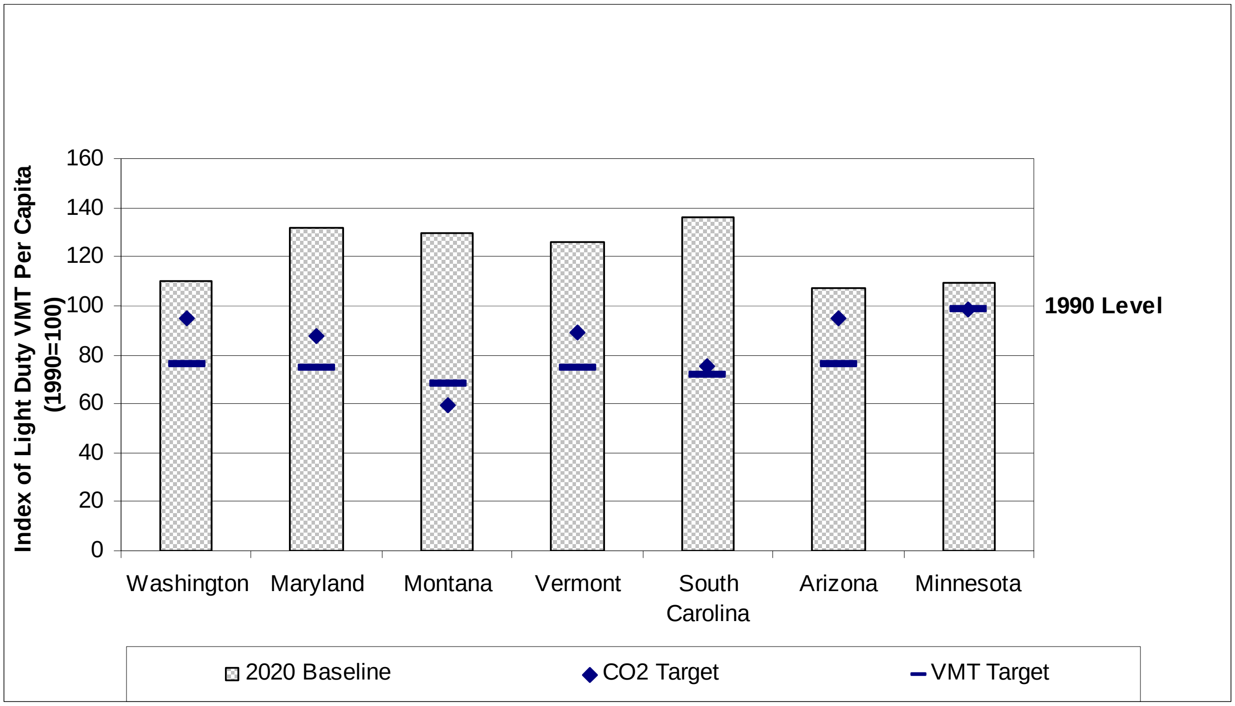
Average vehicle efficiency and the carbon content of fuels vary relatively little from state to state and region to region. Vehicle efficiency responds chiefly to federal regulations and national trends in vehicle markets, although EPA's recent granting of a waiver to California will allow states to influence vehicle efficiency within their borders. Some states are also beginning to regulate the carbon content of fuels. For example, California's Low Carbon Fuel Standard aims to reduce the GHG emissions of light-duty vehicle fuels by 10 percent per unit of energy by 2020. If some states and regions are able to improve the fuel economy of vehicles and reduce the carbon content of fuels more than others, a CO_2 target would not require those areas to reduce as much VMT as other areas to achieve the same level of CO_2 reduction.

The mix of light-duty and heavy-duty traffic on roadways also affects CO_2 emissions. Heavy-duty vehicles emit around 3 to 4 times as much CO_2 per VMT as light-duty vehicles. But states and MPOs may have more viable strategies to reduce light-duty travel (mostly passenger travel) than heavy-duty travel (mostly freight travel). A CO_2 target based on historical emissions would place more pressure on areas that have seen rapid growth in heavy-duty traffic. In order for an area to keep on-road emissions stable, it must reduce 3 to 4 light-duty VMT for every additional mile traveled by a heavy-duty vehicle.

Exhibit 4-14 shows the requirement that comparable per capita VMT and CO_2 reduction targets would place on states to reduce light-duty travel, if they do not reduce any heavy-duty VMT. Under the VMT target, states that have seen the most rapid growth in VMT per capita, including South Carolina and Montana, must reduce average travel per resident the most. These states must reduce around twice the share of VMT per capita as Arizona, where VMT per capita has grown most slowly.

The CO_2 target also requires the greatest reductions in Montana and South Carolina; but because of increasing shares of heavy-duty traffic in these states, they must reduce around five times as much VMT per capita as Arizona. The shares of heavy duty traffic in Montana and South Carolina are expected to increase by 4 percent and 3 percent respectively from 1990-2020, while the share in Arizona is expected to remain flat.

Exhibit 4-14: VMT Target vs. CO_2 Target (Assuming No Reduction in Heavy Duty VMT)—Reduce VMT or CO_2 Emissions 20% Below 1990 Levels by 2020



5. Analysis Tools and Techniques to Support Implementation of Policy Mechanisms

In order for transportation agencies to comply with policy mechanisms such GHG or VMT budgets or performance standards, they may need analytical methods that are not widely used today. In some cases, the tools and techniques necessary to implement new GHG policy mechanisms are available and sufficient; in other cases they are not. This section reviews these tools and techniques and discusses their limitations and capabilities.

Policy mechanism implementation could require two types of analysis that are closely related but distinct.

1) First, a DOT or MPO would need analysis to determine if it meets a target. This would require quantifying VMT or GHGs for the current year and potentially for multiple future years, based on how the target is set. The ability to do this accurately, in the face of changing policies, technologies, and transportation systems, varies widely.
2) Second, a DOT or MPO will need tools and techniques to determine the effects of GHG reduction strategies. In many cases, these tools and techniques will be the same as used by the DOT or MPO to determine if it meets a target in the first place. In other cases, additional tools and techniques will be needed to analyze strategies.

This section focuses on three basic analysis functions:

- Measuring and estimating VMT
- Forecasting VMT
- Estimating and forecasting GHGs

For each of these functions, we first describe the analytical options and then discuss their capabilities and limitations. For the purpose of this section, we use the term VMT or GHG “estimate” to refer to a current year (or recent historic year) calculation of VMT or GHGs. A VMT or GHG “forecast” is a calculation for a future year. In addition to these three analysis functions, Section 5.5 reviews the non-model tools and techniques for analyzing GHG reduction strategies.

Key findings from this section are as follows.

1. **The tools and techniques for implementing a state-level target are more limited than for an MPO-level target.** Most states do not have tools to produce accurate strategy-sensitive forecasts of statewide VMT. Except for a handful of small states that function essentially like MPOs and a few others that have invested in complex statewide forecasting models, state DOTs use relatively simplistic VMT forecasting methods for the purpose of fuel tax projections. Fuel-based state GHG inventories in many state climate action plans are available but differ from MPO estimates and do not provide information to select strategies.

   For many larger states, creation of a new network-based travel demand model to forecast VMT would not be feasible. Instead, econometric models can be used to forecast statewide VMT, as is done in California and several other states. But approaches that do not involve travel modeling do not lend themselves to analysis of many types of transportation GHG reduction strategies.

2. **MPOs are generally better positioned than DOTs to implement a VMT or GHG target.** Most use a travel demand model for long range planning analyses, and some have applied regional models to analyze emission reduction strategies or comply with air quality conformity regulations. Many

MPOs also have experience with emissions modeling through the conformity process. But there is a wide variation in technical capabilities among MPOs, often related to the size and resources of the agency. Many small MPOs do not maintain travel demand models, and a few have no VMT forecasting capabilities at all.

3. **Current travel demand models are not suitable to analyze many types of demand management strategies that can reduce VMT and GHGs.** This is in part because zone-based models are simply not sensitive to fine-grained changes in land use, bicycle/pedestrian systems, and transit service. Several off-model tools and techniques can be used to analyze these types of strategies, but they are inherently limited in their predictive ability because they rely on generalized relationships (i.e., they are not customized for a specific region). Traffic simulation models are being developed but their current use is limited.

4. **Current travel demand models and emissions models are not suitable to analyze most types of operations strategies**. These strategies are often of greatest interest to DOTs because they can be directly controlled by DOTs and often can be implemented relatively quickly. Analysis of operations strategies typically must be done using sketch planning tools or traffic simulation models. Even if the transportation impacts of operations strategies can be accurately predicted, previous transportation and emissions models have not been suitable for analyzing strategies that affect congestion and traffic flow. Traffic simulation models and EPA's new MOVES2010 model help to remedy this shortcoming.

5. **Freight transportation is not as well represented in MPO travel models as passenger transportation.** While most MPOs include truck forecasts in their models, relatively few independently model truck travel. Moreover, the traffic counts used to calibrate travel demand models may not accurately reflect truck volumes. Most MPOs do not estimate travel or emissions from rail, marine, or other non-road freight transportation. The tools and techniques for analyzing freight strategies are limited.

5.1 Measuring and Estimating VMT

A policy mechanism that involves a per capita VMT target would require DOTs or MPOs to develop accurate estimates of current VMT within their boundaries. VMT estimates are also essential inputs to a GHG inventory, and thus are necessary for implementation of a GHG target.

Description of Options

Data used for estimating VMT is typically based on traffic counts collected by states and localities. FHWA requires that states report annual statewide VMT by 12 functional roadway classes and 4 vehicle types through the Highway Performance and Monitoring System (HPMS). A number of different procedures are used to collect this data. All states rely on samples of traffic counts on state, county, and city roadways to estimate the current VMT on state highways in the HPMS database. Continuous traffic counters can collect data year-round at fixed locations. States also employ portable traffic counters to conduct counts for shorter times on a larger sample of roadway segments. Statistical methods that account for seasonal and weekday variations in traffic are then employed to expand these counts into annual estimates of traffic volumes on all segments of the road system. Volumes are multiplied by the length of the roadway segment and summed to get total annual VMT. Data on traffic counts collected by the states are used by the federal government. Two separate but related federal traffic data programs are the HPMS and the Traffic Volume Trends (TVT) program.

- HPMS provides limited data for the entire universe of public roads and more detailed information for a sample of these segments. The sample data can be expanded to represent the universe of public roads. The sample data includes information on the physical characteristics, condition, performance, use, and operations on sampled roads, including estimates of average annual daily traffic (AADT) on each segment. The database contains information on peak and off-peak volumes. In addition, VMT can be calculated for truck and other vehicles separately. Due to lag times in collecting and processing the data, published HPMS VMT estimates are often two years old.

- The TVT program is intended to track travel activity by month and report results quickly. TVT estimates of travel activity (including annual month-on-month data) lag current conditions by only two or three months. TVT is based on continuous traffic counts that are voluntarily reported by the states, using information collected from approximately 4,000 continuous traffic counters. Data for missing functional classes and states are imputed based on available functional classes, surrounding state data, or national estimates.

Other traffic counts

There are other sources of traffic count data besides the information collected by state DOTs to satisfy federal requirements. Many local governments perform traffic counts as part of their planning and congestion management processes. Regional traffic management centers may maintain archived real-time traffic data, although this data is available only for select roadways, usually the most heavily traveled. Because of the lack of standardization in these traffic counts (conducted for a variety of purposes by multiple state, regional, and municipal agencies), they are generally not a reliable source of VMT estimates.

Travel demand models

Travel demand models can be used to estimate current-year VMT at a regional (or county) scale. Many MPOs estimate baseline or other past years in the conformity process, to either meet baseline year conformity tests or validate models. In some states, a statewide travel model can be used to estimate VMT at the state level. These models (discussed in the following section) are created for the purpose of forecasting VMT. The models are calibrated to match current-year volumes on selected roadways and screenlines. The models produce estimates of traffic volumes on every link represented in the model network – typically collector and higher functional classes. Local roadways are not included in these models, so local roadway VMT is typically estimated as a fixed fraction of total VMT.

Capabilities and Limitations

HPMS is designed to produce VMT estimates at the state level. In addition, special sampling is conducted in HPMS to allow accurate estimation of VMT in air quality nonattainment areas and selected other regions. HPMS sample sizes are typically not large enough to allow accurate estimation of VMT at the county level or smaller geographic areas, although some states collect sufficient sample data to allow county-level estimates with sufficient accuracy.

The HPMS sample segment data includes peak and average daily volume fractions for single unit trucks and combination trucks, so VMT for these vehicle types can be estimated at the state level. However, the vehicle classification counts used to estimate truck fractions are not updated every year, so this data may be less reliable than total vehicle counts.

HPMS is available free from FHWA, and summary statistics are reported in *Highway Statistics*. Since it is a large database, there are costs associated with manipulating and analyzing the raw data. A limitation of HPMS is that there are relatively few samples available for urban arterials, resulting in more variability over time in these estimates and greater uncertainties in the estimates. HPMS does not include traffic volumes on local roads, so although state-level estimates for local road VMT are available in *Highway Statistics*, the quality of these estimates is considered low. States use a variety of methods to estimate VMT for local roadways. Using HPMS data to track urban-area VMT over time can sometimes be problematic when roadways are reclassified from rural to urban categories.

Like HPMS, TVT data is available free from FHWA. An important limitation of TVT is that it does not provide data below the state level. Since TVT is based on using trends in continuous traffic count data to grow HPMS VMT estimates, the TVT estimates are subject to the same uncertainties associated with HPMS. In addition, TVT data is subject to additional uncertainties because missing data for functional classes and even whole states are imputed. TVT estimates at the state level are typically within five percent of HPMS data, but VMT estimates for particular functional classes can vary by 25 percent or more.[33]

The capabilities and limitations of travel demand models are discussed in the following section.

5.2 Forecasting VMT

VMT is the key variable in estimating and forecasting GHG emissions from on-road transportation. CO_2 emissions are a function of VMT, vehicle efficiency, and carbon content of fuels; but the latter two are relatively constant and predictable. The ability to accurately forecast VMT is therefore essential for MPOs or DOTs to implement a policy mechanism like a VMT or GHG target. Transportation agencies would need VMT forecasts in order to demonstrate compliance of their long range plans with a target and to evaluate the effects of many GHG reduction strategies. Approaches to forecasting VMT can be distinguished in two ways: MPO-level vs. state-level, and approaches using network-based travel models vs. non-travel model (or “off-model”) approaches. Network-based travel models include not only traditional four step models, but newer “activity-based” travel models using network simulation (discussed below).

MPO Travel Models

MPOs are required by federal law to develop transportation plans and programs for their regions. To develop these plans, most MPOs rely on travel demand forecasting models to estimate future vehicle travel patterns and to analyze the impacts of alternative transportation investment scenarios. In regions required to conduct air quality conformity analysis under the Clean Air Act, the MPO travel demand model typically provides the inputs used to estimate emissions using emissions models.[34]

Nearly all MPO travel modeling involves a sequential four-step approach. The basic four-step model (1) estimates the number of daily trips generated by analysis zone, (2) distributes trips from origin zones to destination zones, (3) divides the trips according to mode of travel, and (4) assigns the trips to the roadway (and sometimes transit) network. The trip assignment step produces an estimate of volumes on each roadway link in the network; link volume multiplied by link length give link VMT, which can then aggregated to develop regional VMT estimates. This basic structure has been used since the 1950s. MPO

[33] ICF Consulting, “Estimation of Monthly State Level Highway Travel: Final Report,” Prepared for the Federal Highway Administration, November 2005.
[34] 40 CFR 93.122(b).

travel models can be more complex or simpler, depending on the resources and needs of the region. For example, some larger MPOs have models that include separate components for forecasting truck travel or automobile ownership, or models designed to be responsive to changes in the pedestrian environment. Conversely, a region without transit or with limited transit may eliminate the mode choice step. A small number of MPOs are replacing their existing models with advanced tour- or activity-based models.

Other Regional-Level VMT Forecasting Methods

Many small urban and rural areas are not covered by a travel demand forecasting model. Some of these areas may be in nonattainment for federal air quality standards, and therefore require VMT forecasts in order to demonstrate transportation conformity.[35] Areas without travel demand forecasting models generally rely on calculations that involve spreadsheets to forecast future VMT. The methodologies range from very simple linear trend lines to more complex non-linear regression analyses.[36]

State Travel Models

Statewide travel models have been developed and are operational in about half the states. Statewide models are used for different purposes, and they range widely in their form and capabilities. In small states (such as Rhode Island, Massachusetts, New Hampshire, and Delaware), the statewide travel model is often an extended MPO travel model, with the same use and capabilities. Other states have models that use a coarse zone system for modeling travel in inter-regional corridors or for modeling freight movement. A handful of mid-size states have created statewide travel models with extensive networks and relatively fine-grained zonal systems. These models are capable of estimating VMT for the purpose of demonstrating transportation conformity in areas not covered by an MPO model, and likely produce relatively accurate statewide VMT forecasts. Florida's Statewide Urban Transportation Modeling System (FSUTMS) joins together MPO models with county models for non-MPO areas to provide coverage for the entire state.[37] The following states appear to have comprehensive statewide travel models that could produce accurate VMT forecasts.

- District of Columbia (MPO model)
- Florida
- Indiana
- Kentucky
- Massachusetts
- Michigan
- New Hampshire
- Oregon
- Rhode Island (MPO model)
- Wisconsin
- Vermont
- Delaware

Aside from these examples, most states do not maintain travel models capable of forecasting statewide VMT.[38]

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[35] 40 CFR 93.122(d).
[36] ICF International, *Sample Methodologies for Regional Emissions Analysis in Small Urban and Rural Areas: Final Report*, Prepared for the Federal Highway Administration, October 18, 2004.
[37] Robert McCullough. "Evolution of Statewide Modeling in Florida." Florida Department of Transportation. September 1999.
[38] NCHRP Synthesis 358, *Statewide Travel Forecasting Models*, TRB, 2006.

Other State-Level VMT Forecasting Methods

Many states develop VMT forecasts without the use of network-based travel demand models. These forecasts are often done for the purpose of estimating future fuel tax revenues. For example, historical trends in traffic volumes can be used to project statewide VMT by functional class and vehicle type. Colorado, for example, develops traffic volume and VMT projections using 20-year growth factors based on a statistical analysis of trends. The trend method is sufficiently accurate for projecting federal-aid funding for a state, but is of little value in exploring the effects of policy options or infrastructure improvements on VMT.

Other states have more sophisticated tools for forecasting VMT without travel modeling. California's Motor Vehicle Stock, Travel and Fuel Forecast (MVSTAFF) model uses a macroeconomic approach to forecast statewide vehicle mix, VMT, and total fuel consumption. VMT forecasts are based on variables of population, income, vehicle ownership and fuel cost per mile.

Capabilities and Limitations

MPO Level

Regional travel demand models maintained by MPOs are designed to forecast traffic on the entire roadway network, and most are capable of producing regional VMT forecasts with acceptable levels of accuracy. However, some smaller MPOs maintain models that forecast peak-period travel only. These models are not intended to estimate daily or annual VMT as would be needed for GHG estimation; factoring of peak-period volumes to estimate AADT can potentially introduce significant levels of error.

Because the model networks do not include most local roads, VMT on these facilities must be estimated outside the model framework. Local roadway VMT typically ranges from 5 to 20 percent of total metropolitan VMT.[39]

Nearly all large and mid-size MPOs (those with population greater than 200,000) use a travel model; some smaller MPOs (those with population less than 200,000) may not. In a 2004 survey, 15 percent of small MPOs reported no modeling capabilities at all.[40] According to a recent GAO survey, about half of the MPOs do their own travel modeling, while the rest rely on consultants or their state DOT.[41] In general, larger MPOs are more likely to develop and operate models in-house, and smaller MPOs, if they use a model, are more likely to require outside technical assistance.

If MPO travel models are to be used to demonstrate compliance with a regional VMT or GHG target, a critical question is to what extent can they capture the impacts of strategies that transportation agencies might use to reduce VMT and GHG emissions. There is extensive literature on the capabilities and shortcomings of four-step travel demand models. As noted in a recent TRB report: "The demands on forecasting models have grown significantly in recent years as a result of new policy concerns. Existing

[39] Based on Federal Highway Administration, *Highway Statistics*, Table HM-71.
[40] Transportation Research Board, "TRB Special Report 288: Metropolitan Travel Forecasting – Current Practice and Future Direction." October 2007.
[41] U.S. Government Accountability Office, "Metropolitan Planning Organizations: Options Exist to Enhance Transportation Planning Capacity and Federal Oversight," Report GAO-09-868, September 2009.

models are inadequate to address many of these new concerns."[42] Below are some key points on this subject.

- **Sensitivity to Land Use Changes**. All travel demand models rely on socioeconomic data (population, households, employment) as an input at the zone level, and therefore the models are sensitive to land use changes that shift population or employment among zones. However, because they operate at the zonal level, most models are not sensitive to small-scale land use changes, such as mixing of residential and commercial uses, that occur within zones.
- **Sensitivity to Transit Improvements**. Models that include a mode choice element will be able to capture at least some of the mode shift effects of strategies that make transit use more attractive. However, many small and mid-size MPOs do not incorporate mode choice in their models, or do so in ways that do not sensitive to transit improvements.
- **Sensitivity to Pedestrian and Bicycle Improvements**. Some MPOs include bicycling and walking modes within their mode choice models, and some even assign these trips to a non-motorized facility network. However, most MPO models do not account for these trips. Even models that do include bicycling and walking modes will have difficulty capturing changes to the bicycle and pedestrian network, since these changes typically occur within zones.
- **Sensitivity to Road Pricing**. Most travel models can simulate the effects of static road pricing by changing the composite travel cost associated with a roadway link. However, the static nature of the traffic assignment process in a four-step model does not allow analysis of variable pricing.
- **Sensitivity to Operations Strategies**. Four-step travel demand models do not account for non-recurrent (incident) delay. Therefore, without post processing, they are not capable of capturing the effects of operational improvements designed to address non-recurrent congestion, including many ITS strategies.
- **Sensitivity to Time-of-Day Shifts**. Travel models vary greatly in the time periods they cover. Small MPOs may only model peak periods. Large MPOs typically model the AM peak, mid-day, PM peak, and evening time periods separately; the sum of these provides total daily volumes. Because they model fixed time periods, the models may not accurately capture effects of strategies that shift travel times, such as peak-period pricing or changes in freight delivery times.
- **Sensitivity to Fuel Prices**. Models are typically not sensitive to changes in fuel

Model Improvements for SB 375

California has identified model improvements necessary for MPOs to accurately quantify and meet the GHG emission reduction targets under SB 375. The state is awarding $12 million in voter-approved bond funds to MPOs to accelerate and implement improved modeling capabilities. The priorities for model improvement are:

1. A 4-step model with post-processing capabilities to include density, diversity, design, destinations, etc. This minimum level of modeling is considered critical to effectively evaluate all strategies relating to SB 375.
2. A tour/activity-based model with post-processing capability. These models illustrate that trips made by a household are not independent of each other but are often connected or chained together for efficiency or convenience.
3. An inter-regional/regional integrated tour/activity-based transportation model with land use and economic modeling components that support a healthy quality of life.

[42] Transportation Research Board. "TRB Special Report 288: Metropolitan Travel Forecasting – Current Practice and Future Direction." October, 2007.

prices, with the exception that models containing mode choice components would see a shift in some trips from automobile modes to other modes as the relative cost of driving increases.

- **Sensitivity to Freight Strategies**. A majority of MPOs include truck forecasts in their models, but many estimate truck trips simply as a fraction of passenger vehicle trips. Relatively few MPO models independently model truck travel. Thus, most MPO models cannot accurately forecast the effects of investments or policies directed at the freight sector.

For MPOs that do not use a travel model to forecast VMT, their ability to capture the effects of VMT or GHG reduction strategies rests entirely on off-model techniques, some of which are discussed in Section 5.5.

It is worth noting that a small number of MPOs are using or developing more advanced "activity-based" travel models in order to address some of these shortcomings (see Exhibit 5-1). While the traditional four-step model estimates an aggregate number of trips from each zone, activity-based models estimate the travel patterns of individual household members, using the specific socioeconomic details of the household along with time of day constraints, accessibility indicators, available modes of travel, and other factors. And rather than modeling discrete trips between a single origin and destination, activity-based models analyze travel in "tours" that can have multiple stops. The activity-based modeling framework is therefore better suited to understanding the impacts of transportation programs and policies on underlying traveler behavior, which determines travel patterns in a region.[43] Exhibit 5-1 lists agencies currently known to be using or developing activity-based travel models.

Exhibit 5-1: Agencies Currently Using or Developing Activity-Based Travel Models

Currently using advanced activity-based travel models	Current developing advanced activity-based travel models
Mid-Ohio Regional Planning Commission (Columbus)	Atlanta Regional Commission
New York Metropolitan Transportation Council (New York City)	Denver Regional Council of Governments
San Francisco County Transportation Authority	Metropolitan Transportation Commission (San Francisco Bay Area)
Sacramento Area Council of Governments	North Central Texas Council of Governments (Dallas–Fort Worth)
Tahoe Regional Planning Agency (Lake Tahoe, CA and NV)	Portland Metro (Oregon)
Puget Sound Regional Council (Seattle)	St. Louis East-West Gateway Council of Governments
	San Diego Association of Governments
	Southern California Association of Governments

Sources: TRB Special Report 288, Metropolitan Travel Forecasting: Current Practice and Future Direction, Transportation Research Board, 2007; Cambridge Systematics, A Snapshot of Travel Modeling Activities, Prepared for the Federal Highway Administration, August 8, 2008; Bowman, John, "How is an Activity-Based Model Set Developed?", Presentation at 12th TRB Conference on Transportation Planning Applications, May 17-21, 2009.

To be fully responsive to policy questions, activity-based models need to use network simulation or "dynamic traffic assignment," rather than the traditional static network assignment process. Dynamic traffic assignment intends to account for congestion effects that evolve over time by using a much more detailed representation of network characteristics, including turn lane capacities, intersection controls, and

[43] Cambridge Systematics, A Snapshot of Travel Modeling Activities, Prepared for the Federal Highway Administration, August 8, 2008.

time-dependent demand.[44] However, use of dynamic traffic assignment for a full region is not yet a feasible option for MPOs because of the required computational time and resources.[45]

State Level

Most DOTs produce statewide VMT forecasts, but few do so using travel models or other methods that are sensitive to policies and strategies that affect VMT. For the limited number of states that have statewide travel models with detailed road network representation, the capabilities and limitations of the models are similar to those described above for MPOs. In these states, statewide VMT forecasts can be developed with acceptable levels of accuracy, and the forecasts will be sensitive to some of the strategies that influence travel demand. Many other types of GHG reduction strategies of interest to transportation agencies will not be captured in these statewide models.

In the remainder of states, statewide VMT forecasts are generally not developed for planning purposes. Many of these states forecast VMT for fuel tax estimating only, using statewide variables such as population and economic forecasts. The VMT forecasts in these states would often not be suitable for determining compliance with a statewide VMT or GHG target.

A related shortcoming with statewide VMT forecasts is their inconsistency with MPO forecasts. While a few states (such as Florida) have statewide modeling systems that are built off MPO models, most do not make use of MPO models. Thus, a state VMT forecast from a DOT is likely to be inconsistent with the forecasts from the MPOs in that state.

5.3 Estimating and Forecasting GHG Emissions

The estimation and forecasting of GHG emissions is a new exercise for many transportation agencies. A majority of states have developed an inventory and forecast of GHG emissions, often as part of a state climate change planning process led by the state environmental agency. DOTs usually participate in these exercises, but do not lead the GHG forecasting. A small number of MPOs have estimated GHGs resulting from transportation plans, and many more are now in the process of doing so.[46]

Vehicle emissions for a state or region are not “measured;” rather, emissions must be modeled using related parameters. Conceptually, there are two approaches to estimate on-road transportation GHG emissions – a fuel-based top-down approach and VMT-based bottom-up approach. The top-down approach, used in national and state GHG inventories, relies on fuel consumption by fuel type to determine emissions. The bottom-up approach, typically applied at the regional or municipal level, relies on estimates of VMT data and fleet fuel efficiency or emission factors to calculate GHG emissions.[47]

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[44] Virginia DOT, Implementing Activity-Based Models in Virginia, VTM Research Paper 09-01, July 2009.
[45] Transportation Research Board. “TRB Special Report 288: Metropolitan Travel Forecasting – Current Practice and Future Direction.” October, 2007.
[46] ICF International, Integrating Climate Change into the Transportation Planning Process, Prepared for FHWA, July 2008. Available at: http://www.fhwa.dot.gov/hep/climatechange/index.htm.
[47] Gallivan, Frank, Michael Grant, and John Davies, “Improving the Transportation Component of State Greenhouse Gas Inventories.” Paper presented at the 17th Annual International Emission Inventory Conference, Portland, Oregon, June 2008.

MPO Level

Regional-level transportation GHG estimates and forecasts can start with VMT by vehicle and fuel type. Current and future year VMT is estimated using the techniques described in Section 5.3 – typically a four-step travel demand model. CO_2 emissions can be calculated using per-mile emissions factors, or combined with fleet fuel efficiency information to estimate fuel use, which in turn can be used to estimate CO_2 emissions based on the carbon content of the fuel. Emissions of the other two significant transportation GHGs, CH_4 and N_2O, are calculated using per-mile emission factors.

GHG emission factors typically come from EPA's emission factor models – MOBILE6 or the next generation model, MOVES2010, which was released in December 2009, and provides improved estimates. Agencies in California use the Air Resources Board's EMFAC model.

Vehicle fuel efficiency, and hence CO_2 emission rates, vary with vehicle speed and operating conditions (i.e., congestion levels). These effects may or may not be reflected in a regional-level GHG estimate. More simplistic estimates ignore speed and congestion effects. VMT across all roadway types is simply summed by vehicle type, and translated into emissions using fleet-average fuel efficiency data or emission factors. Use of the MOBILE6 model necessitates this approach, because CO_2 emission factors in MOBILE6 do not vary with speed.

More sophisticated regional GHG estimates attempt to capture speed and congestion effects. California's EMFAC model provides CO_2 emission factors that vary with speed. Using travel demand model output, each roadway link is assigned an average speed, and VMT is then grouped into speed "bins," to be multiplied by the appropriate CO_2 emission factor for that speed.

The MOVES2010 model allows for much more sophisticated and complex analysis of GHGs that attempts to capture effects of both speed and vehicle operating conditions (acceleration patterns). MOVES2010 defines vehicle types on the basis of HPMS vehicle classifications (as opposed to EPA's weight-based emission classifications used in MOBILE6) to avoid the need for transportation practitioners to map their HPMS data to EPA categories.[48]

State Level

Approximately 35 states have developed statewide GHG inventories, which report emissions by source category for a recent year. Most states follow a process developed by EPA called the State Inventory Tool (SIT) to develop these estimates. The key input variable is the amount of each fuel consumed in the state by fuel type. Fuel consumption data comes from fuel tax records, state energy estimates, or U.S.

Scenario Planning

A number of MPOs are using scenario planning to evaluate the impacts of alternative regional growth scenarios. MPOs began developing and comparing regional growth scenarios in the 1990s, often as part of the long-range planning process, in part to minimize congestion and air quality impacts. More recently, scenario planning has been used to evaluate the effects of transportation investments and land development patterns in GHG emissions.

A variety of software tools are available to assist with scenario planning, such as: INDEX, CorPlan, UPlan, Places, CommunityViz, MetroQuest, PlanMaster, and WhatIf? These tools can be used to facilitate a process in which stakeholders (the general public, business leaders, and elected officials) strive to agree on a preferred scenario. This scenario becomes the long-term policy framework for the community's evolution, is used to guide decision making, and can be embodied in the long-range transportation plan.

[48] For more information on MOVES, see: U.S. Environmental Protection Agency, MOVES (Motor Vehicle Emission Simulator) web site at: http://www.epa.gov/otaq/models/moves/index.htm.

Energy Information Administration data. The inventory process typically splits fuel use into modal categories for reporting purposes (e.g., automobile vs. aviation gasoline, marine vs. railroad diesel). CO_2 emissions are calculated based on the carbon content of the fuel; CH4 and N2O emissions are calculated by applying emission factors to VMT (for on-road vehicles) or as a fraction of CO_2 emissions (for non-road sources).

Most of these states have also developed GHG forecasts, typically to 2020 or 2025. GHG forecasts are calculated by multiplying base year emissions by growth factors for each mode. For on-road vehicles, the growth factors usually come from state DOT forecasts for light- and heavy-duty VMT. For non-road sources, growth factors are typically based on past trends.

5.4 Agency Forecasting Capabilities and Limitations

The tools and techniques for creating regional-level GHG estimates and forecasts are relatively new and not fully developed. In general, because regional-level forecasts are based on travel demand model output, they are far more sensitive to transportation policy and investment changes than top-down, fuel-based approaches. For example, regional-level GHG forecasts would capture the effects of shifts in regional land use patterns or increases in transit use, but only to the extent the region's travel model captures the VMT effects of these changes.

MPO Level

Regional-level GHG estimates reflect the emissions that occur within the political boundaries as defined by the MPO modeling area. In this way, the emissions estimate matches well with the portion of the roadway system under the jurisdiction of the MPO. This contrasts with a fuel-based approach, which can suffer from "leakage" – vehicles purchasing more or less fuel in a geographic area than is consumed in that area.

Regional-level GHG estimates contain a fine level of detail that is useful for analyzing many local and regional GHG reduction strategies. Because they are built from VMT and other local data (e.g., local fleets) for every roadway link, GHG emissions can be accurately estimated for individual roadway types (e.g., freeways), or for individual cities or counties in the region. And many regional GHG estimates contain more detailed information on vehicle types than fuel-based inventories, which can be useful for analyzing some GHG reduction strategies.

Region-level GHG forecasts suffer from the same limitations as regional-level VMT forecasts. They do not directly model emissions on local roads, since these facilities are typically not included in travel model networks. Most importantly, they cannot fully capture the effects of some types of strategies due to the modeling limitations outlined in Section 5.3. For example, in the absence of post-processing or other off-model techniques, region-level GHG forecasts will not be able to capture the effects of many fine-grained land use and urban design changes, bicycle and pedestrian improvements, or operational strategies.

Another potential shortcoming of a regional VMT-based emissions estimate is the treatment of emissions caused by alternative fuels. For example, a proper regional transportation GHG estimate should include the electricity generation emissions attributable to electric rail or trolley bus service. Activity data for these sources might need to be calculated outside of the travel demand model. Similarly, off-model adjustments may be necessary to properly capture emissions from buses running on natural gas or other alternative fuels. If battery electric or plug-in hybrid electric vehicles establish significant market share, their electricity generation emissions will also need to be included.

A critical issue for transportation agencies is the extent to which regional-level GHG forecasts can capture the effects of system efficiency improvements that seek to improve traffic flow. As noted above, the use of vehicle fuel consumption rates or emission factors that do not vary with speed (e.g., those from MOBILE6) prevents almost any analysis of system efficiency improvements. The use of average link speeds and emission factors that vary with average speed (e.g., those from EMFAC, or similar to the way MOBILE6 criteria pollutant emission factors are applied) will capture some system efficiency impacts. However, this approach also has limitations, in that it will not reflect differences in operating conditions and congestion levels. For example, emissions would look identical for a roadway segment with traffic moving at a steady-state 30 mph as compared to a congested segment on which speed averages 30 mph. (The latter would have higher emissions in reality, because of the acceleration effects.) EPA's MOVES model is intended to better capture the congestion effects on emissions, provided it can be paired with detailed traffic flow data.

The average vehicle speed by roadway link is available from metropolitan travel demand models, but with several caveats. The main caveat is that these models do not simulate traffic in order to determine specific delays caused by intersections, bottlenecks, signal timing, lane configurations, or other detailed factors that influence travel speed. Instead, the models typically use a lookup table based on certain basic roadway features, such as the number of lanes and the functional classification of the roadway, to determine a default "free flow" speed for each road in the model, which is then factored using a formula to reflect the "congested" travel speed accounting for traffic. The default speeds and formula factors are typically adjusted to aid in model calibration such that they may not accurately represent ground conditions. Some MPOs use post-processing tools to adjust the speeds taken from the model output for use in air quality conformity analyses.[49] These issues can also be addressed by using speed outputs from traffic microsimulation models such as SimTraffic, Paramics, or VISSIM. Microsimulation models typically reflect on-the-ground conditions much better than standard travel demand models, but they are typically not available at a regional scale.[50]

State Level

The top-down fuel-based approach to estimating transportation emissions has the advantage of its basis on a relatively accurate metric that captures all activity – fuel sales. Unlike VMT estimates, which must be modeled based on data samples, fuel sales reflect the activity of all vehicles on all roadways. At a large geographic scale with minimal cross-border leakage, this likely makes a fuel-based GHG estimate more accurate than a VMT-based estimate. A fuel-based approach also has the advantage of being simple to calculate.

The state-level GHG forecast is subject to the same limitations as state-level VMT forecasts described in Section 5.3. In most states, the state-level GHG forecast is simply the product of the base year emissions estimate and a growth rate for that fuel type. The growth rate for on-road gasoline is usually based on the state's automobile VMT projection, which may not be reflective of adopted transportation policies and investments. In many cases, the state's VMT growth forecast has no relationship to the VMT forecasts in the state's metropolitan areas.

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[49] Gong H, Chen M, Mayes J, and Bostrom R. "Speed Estimation for Air Quality Analysis." Journal of Transportation and Statistics, Vol. 9, No. 1, 2006.
[50] Federal Highway Administration. "Traffic Analysis Toolbox, Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools." July, 2004.

For transportation agencies, the main limitation of the fuel-based approach is the lack of sufficient detail to assess emission reduction strategies. State-level transportation emissions are typically reported only by the following categories:

- On-road Gasoline
- On-road Diesel
- Aviation Gasoline
- Jet Fuel
- Rail
- Boats and Ships
- Other

In order to analyze most emission reduction strategies, these totals need to be disaggregated. For example, to analyze strategies affecting automobiles, on-road gasoline emissions must be split into light-duty vehicles and heavy-duty trucks (some of which burn gasoline). Analysis of statewide land use strategies may require splitting vehicle emissions into urban and rural components. This type of disaggregation can be done using state or national VMT factors, but reduces the accuracy of the estimates, particularly in forecast years.

Most GHG reduction strategies for transportation would be applied in the state's urban areas. The analysis of these strategies using the statewide GHG forecast is challenging because the emissions are not reported by urban area. Moreover, as noted above, the statewide GHG forecast may bear no relationship to the GHG forecasts for the metropolitan areas in the state, since they are developed independently using fundamentally different approaches.

Both State and MPO Level

Several analytical limitations apply to both state and MPO level approaches to GHG estimation and forecasting. One relates to the accuracy of fleet fuel efficiency data, a key component in performing GHG analysis without emissions models. Fuel efficiency is reliable on a national level, but less so at the state and MPO levels. The vehicle fleet mix varies from state to state based on factors such as the physical environment and personal vehicle preferences. Fuel efficiency varies based on the type of vehicles in the fleet, the age of vehicles, and driving conditions. For example, urban areas are likely to have more small vehicles; rural areas may have more large utilitarian vehicles. The fleet mix and fuel efficiency of vehicles in any given state may vary significantly from national averages. However, few states and regions (with the notable exception of California) have data on the fuel efficiency of their fleets. EPA's MOVES2010 model accounts for fleet efficiency information to calculate GHG emissions factors, based on inputs of state or local vehicle registration information. These inputs are similar to what is used for criteria pollutant analysis in conformity, but states and MPOs that have not already conducted emissions analyses will need to collect appropriate vehicle registration data.

5.5 Off-Model Tools and Techniques for GHG Reduction Strategy Analysis

Some types of GHG reduction strategies cannot be analyzed using conventional travel demand models and the GHG forecasting methods described in Section 4.4. For example, a number of transportation demand management (TDM) strategies are not easily incorporated into MPO travel demand forecasting models.[51] Similarly, the travel impacts of many operations strategies cannot be analyzed using current travel forecasting tools. A variety of other tools and techniques are available for these analyses. Some techniques simply involve spreadsheet calculations that rely on the effectiveness of a strategy as reported in the literature. Other strategies are best analyzed using software tools designed to estimate the travel and

[51] Regional Targets Advisory Committee (California). "MPO Self-Assessment of Current Modeling Capacity and Data Collection Programs." May 5, 2009.

emissions impacts of specific types of transportation strategies. Most of the analytical strength of these tools is in the estimation of travel impacts; the user does not need to calculate a change in VMT or speeds, since the model performs that analysis.

TDM Strategies

TDM strategies include a wide variety of measures to reduce VMT, including transit improvements, ridesharing programs, and bicycle and pedestrian improvements. In general, if a TDM strategy affects transportation between zones throughout a region, a travel demand model is the best approach to analyze strategy VMT impacts. Some tools are designed to process trip tables that are the output of regional travel models – allowing for region-wide analysis without the need to re-run the full travel model. If a strategy affects only regional sub-areas or affects transportation within a zone (such as employer-based strategies, parking, and bicycle/pedestrian transportation), then an off model tool such as sketch planning or spreadsheet analysis is the best approach.

Some examples of tools to analyze TDM strategies are summarized below.

- The **COMMUTER** model, developed by the U.S. EPA, is designed to analyze the impacts of transportation control measures such as transit employer-based transportation demand management programs and transit improvements, on VMT, criteria pollutant emissions, and CO_2. By default, the COMMUTER model uses national average MOBILE6 emission factors for criteria pollutants and CO_2, but the user has the option of importing locally specific MOBILE6 emission factors for more locally accurate emissions estimates.
- **TRIMMS** (Trip Reduction Impacts for Mobility Management Strategies) has recently been developed by the University of South Florida. It is conceptually similar to the COMMUTER model, but tends to report lower VMT reductions than the COMMUTER model.
- **TCM Analyst** is a spreadsheet based tool developed by the Texas Transportation Institute in 1994-95. It is now considered somewhat dated.
- The **Transportation Emissions Guidebook** was created by the Center for Clean Air Policy; it allows for relatively simplistic analysis of a large number of emission reduction strategies.
- **STEAM** (Surface Transportation Efficiency Analysis Model) is essentially a benefit-cost analysis tool that can also be used to analyze travel activity and emissions changes. STEAM requires extensive inputs from regional agencies in the form of baseline and improvement case trip tables for each type of strategy.

Operations Strategies

Operations strategies include measures such as traffic surveillance, work zone management, electronic toll collection, traffic incident management, road weather management, emergency management, and traveler information services. These strategies reduce vehicle delays associated with incidents and other non-recurring events; they typically reduce emissions by reducing idling and delay, and allowing for smoother traffic flow.

Most travel demand models do not capture non-recurrent delay. In addition, most regional travel models are not capable of simulating traffic flows to account for factors such as intersections, bottlenecks, signal timing, lane configurations, etc. For these reasons, a regional travel model cannot, by itself, be used to analyze most operations strategies.

The tools and techniques for analyzing operations strategies is an area of on-going research, led in part by FHWA.[52] Some of the most common current methods for analyzing operations strategies are outlined below.[53]

- **Sketch planning tools** produce general order-of-magnitude estimates of travel demand and traffic operations in response to transportation improvements. These approaches are typically the simplest and least costly of the traffic analysis techniques, but are usually limited in scope, analytical robustness, and presentation capabilities. Three examples are: the ITS Deployment Analysis System (IDAS), Screening for ITS (SCRITS), and STEAM.
- **Deterministic tools** typically implement the procedures of the Highway Capacity Manual (HCM) to quickly predict capacity, density, speed, delay, and queuing on a variety of roadway types. They are good for analyzing the performance of isolated or small-scale transportation facilities, but limited in their ability to analyze network or system effects. Two examples of deterministic models are Traffix and Highway Capacity Software (HCS).
- **Traffic simulation tools** perform detailed representations of traffic flow in real-world locations. These tools require a large amount of detailed input data, including detailed roadway geometric, signal timing, and trip generation/distribution data, and extensive validation and quality control. Because of their data and computer processing requirements, simulation tools are generally not appropriate for use at a regional scale.[54] Simulation tools can be combined with travel demand models to examine freeway performance in individual corridors. Simulation tools include macroscopic simulation models such as FREQ, PASSER, and TRANSYT-7F, mesoscopic simulation models such as SYNASMART-P and TRANSIMS, and microscopic simulation models such as CORSIM/TSIS, Paramics, and VISSIM.

Freight and Non-Road Strategies

The options for analyzing freight and non-road transportation emission reduction strategies are generally less developed than the tools and techniques for automobile-focused strategies. These strategies can include:

- Strategies to reduce idling/berthing emissions by trucks, locomotives, or ships
- Strategies to reduce truck travel to/from a port or rail intermodal facility
- Strategies to shift freight to more fuel efficient modes
- Strategies to enable smoother, more fuel efficient movement of trains or ships
- Strategies to reduce emission from transportation refrigeration units (i.e., refrigerated trailers and shipping containers)

The US EPA SmartWay Transport Partnership offers information to analyze the benefits of these types of strategies. For example, the SmartWay web site (www.epa.gov/smartway) includes several calculators and models that provide fuel consumption rates of idling trucks and of idle reduction solutions; guidance for states that want to incorporate idle reduction projects in their air quality plans; current and prior idle reduction projects funded by SmartWay and others, and the environmental and related benefits of these projects; and other key tools and information on the effectiveness and benefits of reducing idling from

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[52] See http://ops.fhwa.dot.gov/travel/plan2op.htm
[53] FHWA, *Applying Analysis Tools in Planning for Operations*, (unpublished).
[54] Federal Highway Administration. "Traffic Analysis Toolbox, Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools." July, 2004.

trucks and locomotives. EPA also has created the SmartWay Transport Partnership FLEET Performance model, which can also be found on EPA's website.

5.6 Summary of Findings on Analysis Tools and Techniques

As this section illustrates, new policy mechanisms for integrating GHGs into transportation planning would place analytical demands on DOT or MPOs that these agencies are not necessarily prepared to meet. The exhibit below summarizes the main capabilities and limitations for each of the three basic MPO and DOT functions reviewed in this section.

Exhibit 5-2: Summary of Findings on Analysis Tools and Techniques

Function	Level	Capabilities	Limitations
Measuring and Estimating VMT	MPO level	▪ Many MPOs used travel models to estimate VMT ▪ Some MPOs estimate VMT based on counts rather than model ▪ A few smaller MPOs lack capability to estimate VMT	▪ No local roads in models ▪ Truck fraction may not be reliable
	State level	▪ HPMS (and TVT) programs provide current statewide VMT by major vehicle and facility type	▪ No speed information ▪ Truck fraction may not be reliable ▪ HPMS data has 2-3 year time lag
Forecasting VMT	MPO level	▪ Most MPOs have models that forecast VMT ▪ Some smaller MPOs don't use travel models for VMT forecasts ▪ A few smaller MPOs do not have VMT forecasting capability	▪ MPO models not sensitive to some TDM strategies (bike/ped, transit/land use changes, etc.) ▪ Most MPO models not sensitive to operations strategies
	State level	▪ A few states have travel models that can forecast statewide VMT ▪ Most states use spreadsheet analysis for VMT projections	▪ Most states: VMT forecasts not sensitive to VMT reduction strategies ▪ Most states: VMT forecasts not sensitive to changes in fuel prices, fleet fuel efficiency
Estimating and Forecasting GHGs	MPO level	▪ GHG inventory reflects emissions within MPO boundaries ▪ MPOs doing conformity have experience that could be used in GHG emissions modeling ▪ VMT-based GHG forecast more useful for strategy analysis than fuel-based forecast	▪ MPO models not sensitive to some TDM strategies and operation strategies ▪ Fleet fuel efficiency data is limited (but emissions models help address this limitation)
	State level	▪ Fuel-based GHG inventory is highly accurate (if minimal cross-border travel) ▪ Easy to account for statewide technology and fuels changes	▪ If cross-border travel is extensive, GHG inventory may not reflect emissions within state boundary ▪ Forecast of statewide GHGs are based on statewide VMT forecasts, which may not be accurate ▪ Not sufficiently disaggregated for analysis of many strategies ▪ Fleet fuel efficiency data is limited (but emissions models help address this limitation)

APPENDIX A: LIST OF WORKSHOP PARTICIPANTS

Two workshops were held in order to gain feedback on the final report. A panel comprised of 16 members oversaw the report's development. Both workshops were held over the course of a day and a half in Washington, D.C. The first workshop took place on April 2-3, 2009 and the second workshop took place on August 25-26, 2009. Two webinars, one focused on policy considerations and one focused on technical aspects, were held on April 14 and 15, 2009. Attendants for both workshops and the webinars are listed below. Not all participants attended both workshops.

Workshops 1 and 2—Participants

Name	Organization
Mike Brady	*California Department of Transportation (Caltrans)*
Cora Cook	*Georgia DOT*
Eddie Dancausse	*Federal Highway Administration, NC Division Office*
Rich Denbow*	*Association of Metropolitan Planning Organizations*
Kim Ellis	*Metro (Portland, OR)*
Damon Fordham*	*American Association of State Highway and Transportation Officials*
Mark Glaze	*Delaware DOT*
Larry Greene	*Sacramento Metropolitan Air Quality Management District*
Don Halligan	*Maryland DOT*
DeLania Hardy*	*Association of Metropolitan Planning Organizations*
Jane Hayse	*Atlanta Regional Commission*
Cecilia Ho*	*Federal Highway Administration*
Charlie Howard	*Puget Sound Regional Council*
Brian Hug	*Maryland Department of Environment*
Ronald Kirby*	*Metropolitan Washington Council of Governments*
Chris Klaus*	*North Central Texas Council of Governments*
Don Kopec	*Chicago Metropolitan Agency for Planning*
Andrew Lemer	*Transportation Research Board*
Jesse Mayes	*Kentucky Transportation Cabinet*
Therese McMillan*	*Metropolitan Transportation Commission*
Val Menotti	*San Francisco Bay Area Rapid Transit*
Jonathan Nadler	*Southern California Association of Governments*
Kathleen Neill	*Florida DOT*
Janet Oakley*	*American Association of State Highway and Transportation Officials*
Rob Padgette*	*American Public Transportation Association*
Meg Patulski*	*U.S. Environmental Protection Agency*
Phil Peevy	*Georgia DOT*
Rich Perrin	*Genesee Transportation Council*
Kyle Schneweis	*Kansas DOT*
Brian Smith*	*Washington State DOT*
John Thomas*	*U.S. Environmental Protection Agency*
John Thomas	*Utah DOT*
Joan Weidner	*Southeast Michigan Council of Governments*

NOTE: Panel members denoted with *.

Virtual Sessions—Participants

Name	Organization
Mary Ameen	*North Jersey Transportation Planning Authority*
Niles Annelin	*Michigan DOT*
Beverly Chenausky	*Arizona DOT*
Mike Conger	*Knoxville Regional Transportation Planning Organization*
Gordon Garry	*Sacramento Council of Governments*
Steve Gayle	*Binghamton Metropolitan Planning Study*
Robert Graff	*Delaware Valley Regional Planning Commission*
Brian Gregor	*Oregon DOT*
Paul Hamilton	*Tri-County Regional Planning Commission (Peoria, IL)*
Tim Hill	*Ohio DOT*
Nathan Howard	*Maine DOT*
Doug Ito	*California Air Resources Board*
Jim McKenzie	*Metroplan (Orlando, FL)*
Val Menotti	*San Francisco Bay Area Rapid Transit*
Debbie Neimeier	*University of California at Davis*
Steve Rudy	*Denver Regional Council of Governments*
Mark Tibbetts	*Santa Fe MPO*
Dennis Wade	*California Air Resources Board*
John Zamurs	*New York State DOT*

APPENDIX B: INFORMATION ON MARKET-BASED MECHANISMS

Market-based approaches to GHG abatement work by creating economic incentives for transportation sources to reduce emissions. These approaches target producers and consumers of transportation services. Most market-based approaches do not have direct implications for the transportation decision making process, and so are not the focus of this study. They are included in this Appendix since any consideration of planning- and project-level approaches should be viewed with an understanding of the potential implications of market-based approaches on transportation planning and programming.

The two types of market-based approaches that are generally viewed as broadly suitable for controlling GHGs are emissions trading and carbon taxes. This section presents an overview of these policy instruments and a discussion of how each relates to transportation planning and programming processes.

B.1 GHG Emissions Trading

Momentum has been building in the United States for the use of a multi-sector emissions trading system as part of a comprehensive policy approach to controlling emissions of greenhouse gases. During the 110th Congress, ten bills containing emissions trading provisions were introduced. If passed, the implications for transportation planning and programming will depend largely on the form of the trading system and whether and how transportation sources are covered in the final legislation.

This section provides background on emissions trading including an introduction to the rationale for including trading systems in environmental policies as well as a brief overview of the different types of trading systems.

The Rationale for Emissions Trading

Emissions trading systems can be used with a regulatory policy to provide regulated parties, which could be firms, individuals, jurisdictions, or other entities, flexibility to choose the lowest-cost means of complying with an emissions reduction requirement. The rationale for incorporating emissions trading in an environmental policy relates to the savings a trading system can generate relative to a stand-alone policy that requires each regulated party to reduce emissions on its own. When regulated entities are allowed to buy and sell emission instruments, market forces create an incentive for those with relatively low-cost emission reduction options to reduce their emissions by more than needed to satisfy their regulatory requirements. These entities are then able to sell surplus emission instruments to other regulated entities that are faced with relatively high-cost emission control options.

The opportunity to sell surplus emission instruments creates incentives for cost-effective compliance with environmental targets. Emissions trading can reduce the burden on those that would otherwise have to pay a relatively high cost to reduce emissions and provides an additional source of income for those with relatively low cost means of complying with an environmental regulation. Provided that the incremental costs of emissions control vary sufficiently across regulated entities, emissions trading can result in a more cost-effective overall level of control than would be the case under more traditional regulatory approaches. As a result, incorporating an emissions trading system into an environmental policy can mean that the same level of environmental protection can be achieved at a lower overall cost.

Emissions trading is potentially appealing within the context of efforts to control GHG emissions. The appeal of trading is due to the fact that, while the benefits of reducing GHG emissions are independent of the point of reductions,[55] the costs of reducing GHG emissions often vary widely across different firms, industries, and even countries. This strongly suggests that the cost-effectiveness of reducing GHG emissions could be significantly enhanced by allowing the various entities that will be obliged to reduce emissions to buy and sell GHG emission permits.

Basic Types of Trading Systems

Emissions trading systems take one of three basic forms: pure allowance systems, under which participating entities face an absolute limit on the mass of emissions they can collectively discharge; pure credit systems, under which participating entities are subject to an emissions target; and hybrid systems that combine elements of both pure allowance systems and pure credit systems. Each of these three forms is described in more detail below.

- *Pure Allowance Systems.* Under this type of trading system, the regulated group of entities is assigned an absolute emissions ceiling specified as a given amount of the pollutant that can be released within a compliance period. The regulatory authority creates and distributes or auctions allowances in an amount that is equal to the group of entities' emissions ceiling. Each allowance gives the owner the "right" to emit one unit (e.g., one ton) of the pollutant. The entities are free to buy or sell allowances but, at the end of the compliance period, each participant is required to surrender to the regulatory body enough allowances to cover all of its *actual* emissions during the compliance period. The EPA's Acid Rain allowance trading program is the best known example of a pure allowance system.
- *Pure Credit Systems.* Regulated entities that are covered by a pure credit system are given emission targets. Participating entities that can demonstrate that they have reduced their emissions by more that the required amount are eligible to sell emission reduction credits equaling the difference between their target level of emissions and their actual emissions. Entities that are unable to reduce their emissions in a more cost-effective manner can then purchase credits and use them to comply with their regulatory requirements. EPA's Lead Credit Trading program is an example of a pure credit system.
- *Hybrid Trading Systems.* Elements of pure allowance systems and pure credit systems are often combined, creating hybrid systems. Under a hybrid system, some regulated entities, typically those with the highest emission levels, are assigned an absolute emissions target and allocated an equivalent number of emission allowances. In addition, these entities are allowed to purchase emission reduction credits generated by entities that are not subject to an emission cap. There are several ways that such credits might be generated. For example, non-regulated entities could reduce emissions (relative to a baseline) and then sell credits, covered entities could obtain credits by investing in off-site emission abatement or sequestration projects, or a third party (such as a carbon fund or NGO) could invest in emission reduction or sequestration projects and sell credits to regulated entities. International emissions trading under the terms of the Kyoto Protocol include elements of both an allowances system (based on national emission caps) and credit systems (based on emission reductions achieved in developing countries as part of the Clean Development Mechanism).

Each type of system has advantages and disadvantages. Since the emission reduction options under pure allowance systems are limited to those emission reduction technologies and/or practices applicable to the set of entities that are directly covered by the trading system, these regimes tend to offer the least amount of flexibility of the three basic forms. On the other hand, by placing an absolute limit on the total mass of

[55] CO_2 and other GHG emissions have implications at the global as opposed to local level. Thus, they do not create local "hot spots" that would necessitate a link between emission point and mitigation efforts.

pollutants that regulated entities can emit during a specified compliance period, pure allowance systems tend to be more effective in assuring that the desired environmental results are realized.

Because they typically allow for more widespread participation, the pure credit system and the hybrid trading system tend to increase flexibility, and likely reduce compliance costs, relative to a pure allowance system. However, neither of these systems is assured of producing the targeted level of overall emission reductions that is being sought by the regulatory authority. By allowing regulated entities to use credits for compliance purposes, the hybrid system effectively releases the system wide cap and thus introduces the potential for total emissions to exceed the environmental target. Whether or not the cap is actually exceeded depends on how effective regulators are at determining whether emission reduction credits are based on real reductions that are additional to any that might have been achieved in absence of the opportunity to earn credits. In addition, because of the need to verify and certify that emission reductions have taken place, the administrative and transactions costs associated with either a pure credit or hybrid system tend to be significantly higher than they are under a pure allowance regime.

As applied to transportation sources, emission trading systems are typically discussed in terms of whether they are upstream, downstream, or mid-stream, depending on the point of regulation—i.e., where the obligation to hold permits is imposed. The following sections provide definitions and a discussion of the implications of each of these options for including emissions from the transportation sector under an emissions trading system.

Upstream Trading System

An upstream trading system covering transportation sources would place the cap on emissions at the level of the transportation fuel producer—i.e., oil refineries and fuel importers. This type of trading regime caps "potential" emissions based on the carbon content of transportation fuels. As fuel producers and importers adjust to the cap, fuel prices will tend to rise, creating an incentive for fuel consumers to reduce consumption of the higher cost fuels.

Coverage of Transportation Emission Sources

An upstream system would provide complete coverage of transportation sources of carbon emissions. That is, it would apply to on-road as well as off-road sources that use fossil fuels. An important factor contributing to the appeal of an upstream approach is that it can provide significant coverage while only involving a relatively small number of regulated entities. Thus, it would tend to be relatively easy to administer and enforce.

Implementation and Enforcement

The two leading pieces of legislation to control GHGs that are currently before Congress both include provisions for an upstream trading system to cover transportation sources.[56] The cap on transportation sources would be set by legislation and the U.S. EPA would be in charge of implementation and enforcement.

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[56] At the federal level, there are now legislative efforts underway in Congress and new initiatives being taken by the Obama Administration to tackle global climate change. The House of Representatives has passed legislation (Waxman-Markey HR-2454 *American Energy and Security Act of 2009 (ACES)*) that would establish an absolute cap on emissions and an upstream compliance mandate on petroleum and the majority of fluorinated gas producers and importers, and legislation was recently introduced in the Senate (Boxer-Kerry *Clean Energy Jobs & American Power Act*), which includes an upstream cap on emissions for natural gas liquid-, petroleum-, and coal-based liquid fuel producers and importers.

Likelihood of Implementation

It appears highly likely that an upstream trading system would be included in a federal government program on GHGs.

Issues of Potential Interest to Transportation Planning and Programming

Although state DOTs and MPOs will not be obliged to implement or enforce an upstream trading system, such a regime could have implications for transportation planning organizations.[57] First, fuel prices can be expected to rise as producers and importers adjust prices to reflect the cost of the allowances they will be required to hold. Depending on the elasticity of demand, the outcome of higher gasoline prices will be a reduction in fuel consumption brought about in the short run primarily by a reduction in VMT and over the longer term by changes in both VMT and improved fuel efficiency of vehicles. Analysis by U.S. EPA of the cap-and-trade program in the Waxman-Markey bill suggests that the increase in gasoline prices that result from the carbon price ($0.19 per gallon in 2015, $0.33 in 2030), however, is not sufficient to substantially change consumer behavior in regards to VMT or vehicle purchases.[58]

Another consideration is that transportation projects—e.g., public transit systems, transportation demand management programs, etc.—might become eligible for some portion of the revenues obtained from auctioning of emission allowances. It is not clear how much of the revenues might be distributed to different sectors, however, both the Waxman-Markey HR-2454 *American Energy and Security Act of 2009 (ACES)* and the Boxer-Kerry *Clean Energy Jobs & American Power Act* contain provisions for the flow of funds to key sectors of the economy to support research and development as well as discrete emission reduction projects. Both bills also contain provisions for helping consumers adjust to the new restrictions. It is important to note that the Obama Administration's 2010 budget provides for virtually all of the revenues from allowances auctioning to go to the federal government, with a small percentage to be used for federal deficit reduction.

Because the cap in an upstream system applies at the national level, the emission reduction benefits of transportation projects will tend not to have a net effect on the overall level of emissions—i.e., for that set of entities that are covered by the emissions cap, the absolute level of emissions will be the same whether a given transportation source reduces emissions or not. Consequently, with a multi-sector system that covers transportation emissions upstream, there might be less support for transportation GHG reduction projects. Specifically, if there are no net climate change benefits, it might be more difficult to build the necessary political support needed to secure funding for transportation emissions reduction projects. On the other hand, if transportation sources do not reduce emissions, the cost of allowances will increase significantly over time as the cap becomes more stringent and it becomes more difficult for other sectors to reduce emissions in place of the transport sector. As fuel prices increase, this might encourage more public demands for investments that provide alternatives to driving. Given the time it takes to plan and construct new transportation infrastructure (e.g., transit rail lines), transportation agencies may want to anticipate increases in fuel prices when determining investment priorities in their long range plans.

Finally, if an upstream system is implemented, opportunities for earning revenues through the sale of emission reduction credits—i.e., offsets—would be eliminated because the sector's emissions would

[57] The implications discussed are drawn from: Adam Millard-Ball, 2009. "Cap-and-Trade: Five Implications for Transportation Planners." Presentation at the 2009 Annual Meeting of the Transportation Research Board, Washington, DC.
[58] U.S. Environmental Protection Agency, "Analysis of the Waxman-Markey Discussion Draft – Appendix," p. 50. Available at: http://www.epa.gov/climatechange/economics/economicanalyses.html#wax

already be covered by the trading system and thus, transportation sector projects would not result in any additional reduction in emissions.

Downstream Trading System

In the context of transportation sources, a downstream trading system is one in which the cap on emissions is set at the actual point of emission—i.e., the regulation applies to the individual owner/operator of an emitting vehicle. Under this type of system, each vehicle owner/operator would be required to hold allowances equivalent to their total mass of emissions during a compliance period.[59] Because of the enormous number of potential entities that would be covered, downstream systems for transportation sources are widely viewed as impractical.

Coverage of Transportation Emissions Sources

Like an upstream system, a downstream emissions trading system could be designed to provide comprehensive coverage of transportation emission sources. While it might be technologically feasible to allocate allowances to all vehicle owners and operators (they could be issued something similar to a credit card that could be debited each time they purchase fuel), the aggregate transactions costs incurred by millions of individuals that would have to manage their "carbon accounts" could easily exceed the benefits from such a trading system.

A lower cost alternative to comprehensive coverage of all transportation sources might include only owners of fleets of vehicles. The total number of entities covered by this type of trading system would be considerably smaller and perhaps more manageable from an administrative perspective. However, since it would not provide coverage of the majority of sources, it would lack the environmental effectiveness of either an upstream or comprehensive downstream system.

Implementation and Enforcement

In addition to high transactions cost, enforcement and other aspects related to implementation and administration of a comprehensive downstream trading system could be extremely difficult and thus costly. Each vehicle owner or operator would have to be identified and given an allocation of permits. They would also have to receive some form of instruction on how to use the system. In addition, even if a system similar to a credit card account were to be created, every fueling station or other source of transportation fuel would need to be equipped with the technology to read and register changes in individual accounts. All of these aspects suggest that such a system would be very expensive to put into place.

Likelihood of Implementation

It appears highly unlikely that a downstream trading system covering transportation sources, whether comprehensive or not, would be implemented in the foreseeable future.

Issues of Potential Interest to Transportation Planning and Programming

If a downstream trading system is created for transportation sources, it is much more likely that allowances would be allocated to individuals free of charge than that allowances would be auctioned. This would mean that revenues from auctioning allowances would probably not be available for distribution to

[59] At the end of the compliance period, regulated entities need to surrender, or turn over, to the regulated authority allowances that equal the mass of their actual emissions during the year.

planning agencies. Thus, a source of funding for GHG planning and transportation projects that reduce emissions might be available under an upstream system is unlikely to exist if a downstream system were implemented.

Because vehicle owners and operators might be more aware of the carbon emission implications of their decisions regarding vehicle types and VMT under a downstream system, there might be more support for transportation projects that would help them reduce their emissions. For example, voters might be more supportive of funding transit system projects if they view these as providing transport options that help them avoid having to purchase additional carbon allowances and/or allowing them to sell some portion of their allotment of emission permits.

Mid-stream Trading System

Midstream systems impose the regulatory requirement at some point between the upstream fuel producers/importers and the downstream emitters. Because of the wide array of entities that can influence decisions in the transportation sector, there are numerous ways that midstream systems could be designed. For example, a system that places a carbon cap on vehicle manufacturers would be one example of a mid-stream system. Under a manufacturer based system, each vehicle manufacturer or importer might be required to hold emission allowances equaling the estimated lifetime emissions of the vehicles it sells. Alternatively, a system could be created that requires vehicle insurers to hold allowances based on emissions of all of the vehicles it provides insurance coverage for. Insurers would have an incentive to increase premiums on high emitting vehicles and thus this type of system would tend to encourage buyers to purchase lower emitting vehicles.

Another possibility is for a trading system to be created that places a state-level cap on emissions from light-duty vehicles, with states required to hold permits for all emissions from vehicles registered in the state. Under this type of system, MPOs and state DOTs could have a key role to play in developing transportation systems that discourage vehicle emissions by providing more public transit options, investments to reduce traffic delays, or any number of other programs that could have an impact on emissions from vehicles registered in their states or jurisdictions. Although the same sorts of activities might be desirable under other types of trading systems, if states or jurisdictions are the capped entities, there is likely to be a more urgent role for transportation planning to aid in the attainment of emission targets.

Coverage of Transportation Emission Sources

Emissions coverage under a mid-stream trading regime depends on which entities are targeted for control. A system that sets caps on manufacturers, for example, would capture emissions only from newly produced and purchased vehicles. As a result, a manufacturer based mid-stream system would provide comprehensive coverage only once all older vehicles are retired from the fleet. A system that caps insurers would not be comprehensive unless all vehicle owners are required to carry insurance. Without such a requirement there would be an incentive for owners to fraudulently register their vehicles in states that do not require vehicle owners to carry insurance, such as New Hampshire, Virginia, Wisconsin, and Tennessee. By contrast, a mid-stream system that targets states as the entities subject to emission controls could provide comprehensive coverage of transportation sources.

Implementation and Enforcement

Implementation and enforcement of a mid-stream system would also be a function of the point of regulation. A manufacturer/importer based system would likely have to be implemented and enforced at the national level. However, other types of systems could be created that would place some portion of the burden on individual states or jurisdictions. For example, a system based on capping emissions at the state level would require national level enforcement but states would need to undertake actions to reduce emissions and thus implementation would fall largely on the states. States might also be required to assist with implementation of a federal system that places the point of regulation on vehicle insurers, since states tend to have regulatory bodies in place to deal with insurers.

Alternatively, if no federal regulation is enacted, individual states or jurisdictions could establish mid-stream systems that target for example vehicle fleets such as those owned by rental car or freight companies that operate in their states. If one or more of these types of systems is created at the state level then implementation and enforcement would fall entirely on the state or states imposing the regulation.

Likelihood of Implementation

In part because of the difficulty in establishing comprehensive coverage, it appears highly unlikely that a mid-stream trading system would be established in the United States.

Issues of Interest to Transportation Planning and Programming

Midstream systems might provide more opportunities for transportation planning authorities to participate in emissions trading and/or other emission reduction activities. Most types of midstream systems would target only a sub-set of transportation emission sources. Thus, they will tend to present opportunities for transportation agencies to undertake discrete projects that could produce emission offsets (i.e., emission reduction credits) that could be sold to entities covered by a midstream system. For example, if insurers are required to hold permits for all light-duty vehicles they provide coverage for, then emission reductions achieved in other sub-sectors, such as at airports or ports, might be eligible to earn emission reduction credits that could be sold to insurers for use in satisfying their emission targets. Under a program that allocates emissions permits to vehicle manufacturers, transportation agencies might be able to get credit for programs that reduce VMT.

Transportation Offsets

To the extent that some or all transportation sources are not covered by caps under an emissions trading system, they might be made eligible to provide offsets or emission reduction credits based on projects that decrease emissions. Under a national cap-and-trade system that does not include transportation sources of GHG emissions, a mobile source emission reduction credit (ERC) option—or offset system—might be created to allow covered entities in other sectors to augment their allocation of allowances with emission reduction credits generated in the transportation sector. In this case transportation offsets could provide increased flexibility for covered sources in meeting their emission reduction goals and could enhance the overall cost-effectiveness of the trading system. In addition, if there are political, social, and/or economic barriers inhibiting the design of a program specifically for the transportation sector, an offset feature can be a means to provide at least partial coverage of the mobile sector.

There are two important limitations to relying on offsets to help reduce GHG emissions. First, given the magnitude of transport related GHG emissions it seems almost certain that the sector’s emissions need to decline significantly to avoid placing an excessive burden on other sectors. However, an offset feature added on to a stationary source trading program is unlikely to result in a substantial reduction in emissions for the transportation sector. Moreover, because offsets effectively raise the emissions cap for covered sources, they can make it more difficult to achieve target levels of reductions particularly if measurement issues result in less certain estimates of mobile source emission reductions than reductions from covered sources.

A variety of types of projects might be eligible for ERCs under an offset system. For example, employers might be eligible to earn ERCs if they can demonstrate that they have implemented programs that reduce emissions from employee commutes, states might be eligible if they can demonstrate that they have implemented transportation demand management programs that have decreased emissions, or cities might be able to earn ERCs if they have implemented programs that can be shown to have reduced emissions. One challenge to implementing an offset system, however, is to avoid double-counting of emissions reductions credits. For example, employers and transit agencies cannot both claim credit for reducing emissions by shifting commute trips from single occupancy vehicles (SOVs) to transit. The use of transportation projects for offsets also assumes that there is a professionally acceptable method to assess project-level emissions and reductions are permanent.

B.2 Carbon Taxes

A second type of market-based instrument mechanism places a tax on emissions. Here, government sets a price per unit of a pollutant, such as $30/ton of CO_2e, and emitters decide the extent to which they pay the tax and/or reduce emissions. A carbon tax can be implemented by taxing the burning of fossil fuels—coal, oil, and natural gas—in proportion to their carbon content. One advantage of the carbon tax is price certainty and that it is easily understood.

Coverage of Transportation Emission Sources

A national carbon tax could offer the same coverage as an upstream trading system. If imposed at the level of the fuel producer or importer, a carbon tax would have the same effect on fuel prices as an upstream trading system and thus would produce the same level of coverage.

Implementation and Enforcement

Carbon taxes can be difficult to set if they are being imposed to achieve a specific level of environmental protection. That is, if regulators are seeking to reduce emissions to a specific level, a carbon tax needs to be implemented that would generate the same incentives as a cap on emissions. However, while in theory carbon taxes can be set to achieve the exact same results as an emissions cap, in practice it is very difficult to determine what the tax rate needs to be.

In the event that a national carbon tax is used in the United States, imposing it at the level of the fuel producer or importer would facilitate collection of the tax revenues. An alternative to a nationwide carbon tax would be state level taxes that could be imposed on fuel providers located in each of the 50 states. In this case, each state would be free to decide on the appropriate level of the tax. However, it is unlikely that a state administered carbon tax system would be effective in achieving national GHG emission targets.

Likelihood of Implementation

Due to the strong resistance to higher taxes of any form in the United States, it appears unlikely that a carbon tax would be used to control emissions at the national level, even though its result should be essentially the same as an upstream emissions cap. British Columbia, Canada, is the first jurisdiction in North America to implement a carbon tax. The tax is set to increase gradually each year through 2012, with all of the revenues returned to consumers through a package of tax cuts and credits.

Issues of Potential Interest to Transportation Planning and Programming

A national level carbon tax could generate revenues that the federal government could pass on to states to help cover the cost of emission reducing transportation projects. It might be best if such funds come with certain conditions attached—e.g., the funds must be used for GHG planning and to fund transportation projects that reduce emissions and cannot be used to offset reductions in state fuel taxes.

Whether or not a national carbon tax is implemented, states might want to impose their own carbon tax to aid in funding GHG emission reduction projects. The United Kingdom is planning to continue imposing its Airline Passenger Duty, which was implemented to impose a cost of emissions on air travelers, even though the EU is planning to include aviation in it emissions trading scheme starting in 2011.

APPENDIX C: SUMMARY OF METHODOLOGY FOR ANALYSIS OF SAMPLE STATES AND MPOS

VMT data and forecasts for each area were compiled from several different sources. Data were available for various different years. Figures for intervening years were interpolated assuming constant rates of change. Key data sources and assumptions used are provided below.

State Data Sources

	Historical Years	**Forecast Years**
Population	U.S. Census Data	U.S. Census Forecasts
Total VMT (Urban and Rural)	FHWA Highway Statistics	VMT Forecasts from state climate action plans. Assumed proportions of urban and rural travel remain at 2007 levels.
LD/HD Split (Urban and Rural)	FHWA Highway Statistics Table PS-1: Percentage truck traffic used as a proxy for percentage HD. For 1990, percentages assumed to be the same as 1995.	Separate LD/HD forecasts from state climate action plans were used where available. Otherwise, assumed proportions of LD/HD traffic remain at 2007 levels.

MPO Data Sources

	Historical Years	**Forecast Years**
Population	Data provided by individual MPOs	Data provided by individual MPOs
Total VMT	Data from individual MPOs where available. Figures from missing years extrapolated using change in VMT per capita from Highway Statistics, Table HM-72.	Data provided by individual MPOs
LD/HD Split	Data from individual MPOs where available. Otherwise, assumed proportions are same as those for the entire state.	Data from individual MPOs where available. Otherwise, assumed proportions are same as those for the entire state.

Fuel consumption was calculated from VMT assuming that all light-duty vehicles burn gasoline and all heavy-duty vehicles burn diesel. Fuel economy figures were drawn from the sources below.

Fuel Economy Data Sources

	Historical Years	**Forecast Years**
Light-Duty Stock	EIA Annual Energy Review, 2008. Average of values for cars and light trucks.	EIA Annual Energy Outlook, 2009
Heavy-Duty Stock	EIA Annual Energy Review, 2008	EIA Annual Energy Outlook, 2009

CO_2 emissions were calculated using standard emission factors per gallon of gasoline and diesel fuel, as provided by EPA.[60] Combusting one gallon of gasoline emits 19.4 pounds of CO_2. Combusting one gallon of diesel emits 22.2 pounds of CO_2.

[60] U.S. EPA, Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel, February 2005. Available at: http://www.epa.gov/oms/climate/420f05001.pdf.