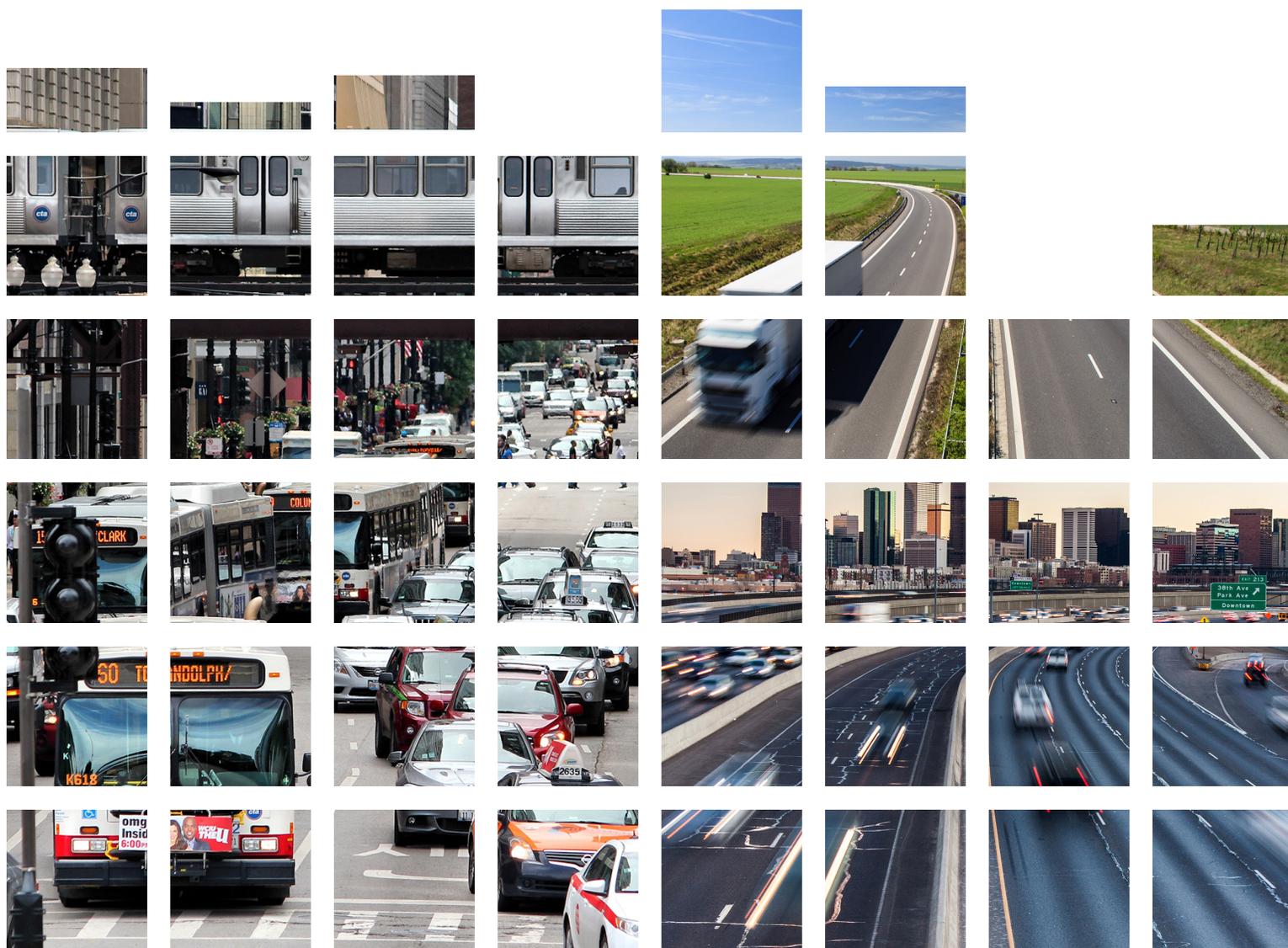# A Performance-Based Approach to
Addressing Greenhouse Gas Emissions through Transportation Planning

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Technical Report Documentation Page

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7. Authors Michael Grant (ICF), Sarah Siwek (Sarah J. Siwek & Associates), Laurence O'Rourke (ICF), Eliot Rose (ICF), Jenny O'Connell (ICF)		**8. Performing Organization Report No.**	
9. Performing Organization Name and Address ICF International, Inc. 9300 Lee Highway Fairfax, VA 22031 Sarah J. Siwek & Associates 4519 Admiralty Way, Suite #140 Marina Del Ray, CA 90292		**10. Work Unit No. (TRAIS)**	
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16. Abstract This publication is a handbook designed to be a resource for State DOTs and MPOs engaged in performance-based planning and programming to integrate greenhouse gas performance measures into transportation decisionmaking. It discusses key approaches for integrating GHG emissions into a PBPP approach, considerations for selecting an appropriate GHG performance measure, and using GHG performance measures to support investment choices and to enhance decisionmaking.			
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Contents

Acronyms and Abbreviations

AASHTO – American Association of State Highway Transportation Officials

AB 32 – California Assembly Bill 32

AR5 – Fifth Assessment Report

ARC – Atlanta Regional Commission

Caltrans – California Department of Transportation

CARB/ARB – California Air Resources Board

CH_4 – Methane

CO_2 – Carbon Dioxide

CO_2e – Carbon Dioxide Equivalent

DOT – Department of Transportation

DRCOG – Denver Regional Council of Governments

DVRPC – Delaware Valley Regional Planning Commission

EERPAT – Energy and Emissions Reduction Policy Analysis Tool

EMFAC – California's Emissions Factors Model

EPA – Environmental Protection Agency

GBNRTC – Greater Buffalo Niagara Regional Transportation Commission

GHG – Greenhouse Gas

GTC – Genesee Transportation Council

GWP – Global Warming Potential

HFCs – Hydrofluorocarbons

HPMS – Highway Performance Monitoring System

IPCC – Intergovernmental Panel on Climate Change

LCDC – Land Conservation Development Commission

LRTP – Long Range Transportation Plan

MAP -21 – Moving Ahead for Progress in the 21st Century

MassDOT – Massachusetts Department of Transportation

MDE – Maryland Department of Environment

MOVES – Motor Vehicle Emission Simulator Model

MPO – Metropolitan Planning Organization

MTC – Metropolitan Transportation Commission

N_2O – Nitrous Oxide

NAAQS – National Ambient Air Quality Standards

NCTCOG – North Central Texas Council of Governments

NJTPA – North Jersey Transportation Planning Authority

NYSDOT – New York State Department of Transportation

PBPP – Performance-based Planning and Programming

PSRC – Puget Sound Regional Council

RTAC – Regional Targets Advisory Committee

SACOG – Sacramento Area Council of Governments

SB 375 – California Senate Bill 375

SCS – Sustainable Communities Strategy

SHSP – Strategic Highway Safety Plan

SIT – State Inventory Tool

STIP – Statewide Transportation Improvement Program

TDM – Transportation Demand Management

TIP – Transportation Improvement Program

TPB – Transportation Planning Board

TRB – Transportation Research Board

VMT – Vehicle Miles Traveled

Forward

Why reduce greenhouse gas emissions?

Climate models predict that the global climate will shift in a number of ways over the next century in response to continued emissions of greenhouse gases (GHGs). According to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), global mean surface temperature is likely to rise by 2.0°F to 8.6°F (1.1°C to 4.8°C) by 2100, based on different scenarios in which human-produced GHGs are either constrained by mid-century or continue to rise. As the ocean warms and the melting of glaciers and ice sheets accelerates, we are likely to see global average sea levels higher by 12 to 32 inches.[1] Rainfall patterns are likely to change, with some parts of the world becoming wetter and experiencing more intense and frequent extreme precipitation events, and other parts becoming hotter and drier. The frequency and duration of heat waves is also very likely to increase. Climate changes are already clearly observable over the last century based on direct measurements and remote sensing from satellites, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. During the 20th century, GHG concentrations in the atmosphere have increased, the oceans have warmed, global sea levels have risen about 7 to 8 inches, and global average temperatures have increased by about 1.4°F. The IPCC has concluded that "[w]arming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia."[2]

Most climate scientists now agree that increases in global concentrations of GHGs, largely attributable to humans, are the predominant cause of climate change.[3] Human activities, such as driving cars, producing and consuming energy, and clearing forests, are significant contributors to GHG emissions, which are emitted into the atmosphere at a faster rate than they are absorbed back into the earth's land and water masses. The principal source of GHG emissions from human activities is the combustion of fossil based fuels, including oil, coal, and natural gas.

Climate change may have potentially catastrophic effects on both the natural and human environments as it disrupts ecosystems and threatens buildings, infrastructure, and human health. Expected shifts in

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[1] IPCC, Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Quin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Climate effects are described for scenarios RCP4.5, RCP 6.0, and RCP 8.5

[2] Ibid.

[3] IPCC, Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Also, supported by the IPCC Fifth Assessment Report.

climate may reduce crop yields, increase the risk of invasive species, exacerbate drought conditions, and threaten endangered species.[4]

The built environment is also at risk. Human settlements in coastal and low-lying areas are particularly vulnerable to changes in sea level and to storm and precipitation events. These areas will almost certainly be at higher risk from flooding as the climate changes. Transportation infrastructure in particular will be threatened by shifts in the global climate. Changes in temperatures, precipitation, and water levels threaten to strain asphalt roadways, railroads, airports, and shipping lanes beyond the design conditions they were built to withstand.

According to the IPCC, limiting climate change will require substantial and sustained reductions of GHG emissions. Global GHG emissions must be reduced to 50 to 85 percent below year 2000 levels by 2050 to limit warming to 2.0°C to 2.4°C (3.6°F to 4.3°F).[5] Limiting global warming to approximately 2.0° C is often considered a level that will minimize many of the worst effects of climate change. An increasing number of nongovernmental organizations and U.S. States are now calling for this scale of reduction in emissions. A short term target was identified by President Obama in 2009 when he made a pledge to reduce U.S. GHG emissions by roughly 17 percent below 2005 levels by 2020 if all major economies agreed to limit their emissions as well. This target was reaffirmed in the President's Climate Action Plan in 2013.[6]

What greenhouse gases are produced by transportation?

GHGs are heat trapping gases that are released into the atmosphere from a number of sources. The four main gases that comprise transportation GHGs are carbon dioxide (CO_2), various hydrofluorocarbons (HFCs), nitrous oxide (N_2O), and methane (CH_4).

CO_2, CH_4, and N_2O are all emitted via the combustion of fuels, while HFCs are the result of leaks and end-of-life disposal from air conditioners used to cool people and/or freight. Carbon dioxide makes up the vast majority of transportation GHGs

Transportation Greenhouse Gases

CO2 96%

HFCs 3%

CH4 0.1%

N2O 1%

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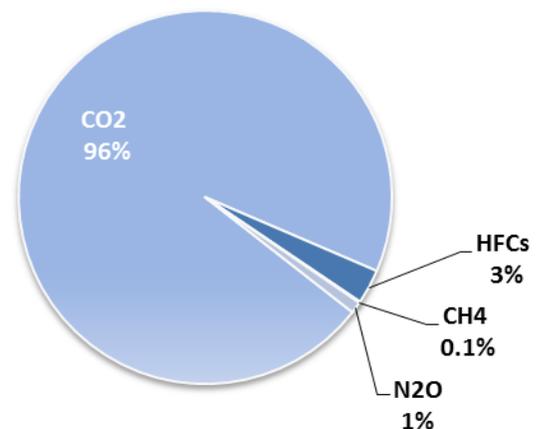
[4] U.S. EPA. 2013. Climate Change Impacts and Adapting to Climate Change. http://www.epa.gov/climatechange/impacts-adaptation/.

[5] IPCC, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[6] The President's Climate Action Plan. June 2013. http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

in the United States, at about 96 percent, weighted by 100-year global warming potential (GWP). CO_2 is released into the atmosphere through burning fuels such as gasoline and diesel. HFCs are the second most important GHG from transportation comprising approximately three percent of GHGs measured in CO2 equivalent (CO_2E). N_2O comprises about one percent of GHGs and CH_4 about a 0.1 percent.[7]

How do transportation agencies reduce emissions?

The transportation sector directly accounts for roughly 28 percent of total GHG emissions in the U.S. It is also a significant source of indirect emissions through the extraction and refining of fuel, the manufacture of vehicles, and the maintenance of supporting infrastructure. In 2011, over 83 percent of direct transportation emissions came from on-road vehicles. Passenger cars and light-duty trucks (which include pick-up trucks and minivans) together make up the largest share of transportation GHG emissions at 61 percent (passenger cars

Transportation GHG Emissions by Source

Light-Duty Trucks, 18%

Medium- and Heavy- Duty Trucks, 22%

Aircraft, 8%

Ships and Boats, 3%

Rail, 3%

Other, 4%

Passenger Cars, 43%

at 43 percent and light-duty trucks at 18 percent). Medium and heavy-duty trucks, which are largely used in freight movement, made up 22 percent of transportation GHG emissions.[8] Consequently, reducing transportation GHG emissions significantly will require reductions in emissions from on-road vehicles.

Most analyses have shown that a suite of strategies is necessary to make significant reductions in GHG emissions from transportation sources. It is important that States and MPOs identify the key drivers of GHG emissions in their areas and then analyze potential GHG reduction strategies to assess potential effectiveness in their specific State or regional circumstances.

Transportation GHG reductions can be achieved by implementing strategies in five broad categories:

- Vehicle efficiency,
- Low-carbon fuels,
- Reductions in Vehicle Miles Traveled (VMT),
- Vehicle/systems operations, and
- Construction/maintenance and agency operations.

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[7] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, 2013.

[8] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, 2013.

Vehicle and fuel standards are regulated at the national level, but States also play a role. For instance, State DOTs and MPOs can influence State policies and take other actions such as education, supporting low-carbon fuel planning scenarios, and reducing fuel use by public fleets. Agencies can also support truck stop electrification, and related strategies to reduce vehicle fuel use and promote use of alternative fuels.

State Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) can contribute to reductions in motor vehicle emissions through transportation system investments, such as multi-modal transportation options that reduce dependence on vehicle travel, and operational strategies and targeted capacity improvements to reduce recurring and non-recurring congestion. State and local governments can also implement a range of strategies, including those related to land use planning, incentives to purchase more energy efficient vehicles, or other pricing mechanisms. Moreover, agencies can reduce construction/maintenance-related emissions through policies and contracting requirements that include improving equipment fuel economy, using alternative equipment technologies and fuels, and using recycled and alternative materials, among others.

The purpose of this handbook is to assist transportation agencies in their efforts to reduce GHG emissions by integrating GHG emissions into a performance-based planning and programming process.

1. Introduction

Background

The Nation's surface transportation system requires significant investment, yet most transportation agencies are operating with increasingly constrained financial resources. Within this environment, State Departments of Transportation (DOTs), metropolitan planning organizations (MPOs), transit providers, and other transportation agencies have increasingly been applying performance-based approaches to support investment decisionmaking and to prioritize investments. Performance-based planning and programming (PBPP) is the application of performance management principles to the investment decisionmaking process, using data and tools to make investment decisions based on their ability to lead to improved system performance outcomes.

Because a performance-based decisionmaking approach is focused on ensuring that transportation investment decisions are made based on their ability to address transportation system and societal goals, PBPP is a cost effective way to make decisions in an environment of limited financial resources. A performance-based approach to investment decisions improves resource allocation since information about past and expected future system performance is used to inform the selection of strategies, projects, and programs. Enabled by improvements in data collection and analysis techniques, transportation agencies can utilize information on anticipated investment impacts to develop priorities for funding. The result is increased transparency by providing clearer documentation about the reasoning for specific transportation spending choices and the impacts of transportation investments. Such transparency can yield increased public understanding, trust, and involvement.

As the prevalence of performance-based planning and programming grows, many States and regions across the country have also been recognizing the important role that transportation plays in climate change, and have begun to consider and/or implement strategies to reduce greenhouse gas (GHG) emissions. As of 2013, 32 States have developed Climate Change Action Plans, which identify policy recommendations to reduce GHGs.[9]

States and regions also have begun to integrate GHG emissions considerations in transportation planning decisions. Some State departments of transportation (DOTs), including Maryland and Vermont, have developed climate action plans focused on transportation emissions reductions. Under California's Senate Bill 375 (SB 375), the Sustainable Communities and Climate Protection Act of 2008, every MPO in the State is required to develop a sustainable communities strategy (SCS) that details its approach for meeting a regional GHG emission reduction target set by the State's Air Resources Board (CARB). As a result of the differing analytical capabilities of different agencies, California's MPOs have taken various

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[9] U.S. Environmental Protection Agency, State and Local Climate and Energy Program, Climate Climate Action Plan web page, http://www.epa.gov/statelocalclimate/state/state-examples/action-plans.html, accessed July 10, 2013.

analytical approaches to modeling transportation-related GHG emissions. New York State Department of Transportation has developed guidance for each of the MPOs in the State to analyze GHG emissions as part of the development of their long range transportation plans (LRTPs) and Transportation Improvement Programs (TIPs). MPOs have also begun to develop goals related to climate change and sustainability to help guide their plan development, and a number of MPOs have developed forecasts of transportation GHG emissions and analyses of potential GHG reduction strategies.[10]

Moving Ahead for Progress in the 21st Century (MAP-21), signed into law in 2012, places increased emphasis on performance management within the Federal-aid highway program. The MAP-21 establishes a set of national goals, including environmental sustainability.[11] States and MPOs must provide for the establishment and use of a performance-based approach to transportation decisionmaking to support the national goals.[12]

Handbook Purpose

This handbook is intended to serve as a resource for State DOTs and MPOs interested in addressing GHG emissions through performance-based planning and programming (PBPP). It describes considerations for selecting relevant GHG performance measures, techniques for evaluating performance, and approaches for using performance information to support investment choices and enhance decision-making.

This document builds on a wealth of related resources addressing PBPP, as well as resources focused on integrating GHG emissions considerations and related analysis in decisionmaking. (See Section 9 for references to many useful supporting documents.)

Handbook Organization

This Handbook is organized in the following sections, designed to answer key questions that transportation planners and other stakeholders may have about addressing GHG emissions within a PBPP approach:

- Section 2:   What is Performance-based Planning and Programming?
- Section 3:   Key Considerations for Addressing GHGs in a Performance-based Approach
- Section 4:   Establishing Goals and Objectives
- Section 5:   Selecting Greenhouse Gas Performance Measures
- Section 6:   Analyzing Trends and Setting Targets

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[10] For instance, the Atlanta Regional Commission (ARC), Atlanta's MPO, performed a forecast of regional GHG emissions through the year 2030 under several policy and land use scenarios (Atlanta Regional Commission's PLAN 2040 and associated documents. Available at: http://www.atlantaregional.com/plan2040/documents--tools).

[11] 23 U.S.C. 150(b).

[12] 23 U.S.C. 134(h)(2) and 135(d)(2).

- Section 7:   Identifying Strategies, Analyzing Alternatives, and Developing Investment Priorities
- Section 8:   Monitoring, Evaluating, and Reporting on Performance
- Section 9:   Relevant Resources

2. What is Performance-based Planning and Programming?

The emphasis on performance measurement and accountability is increasing not only in the transportation sector, but across all levels of government. In transportation, Performance-based Planning and Programming (PBPP) refers to the application of performance management principles within agencies' planning and programming processes to achieve desired performance goals and outcomes for the multimodal transportation system.[13] Linking planning and programming within a performance-based approach supports the selection, funding, and implementation of programs and projects to achieve desired outcomes. The figure below shows basic elements of a performance-based planning and programming process. It is important to note that the process is iterative, as investment decisionmaking is a continuous and cyclical process in which information from implemented projects helps to inform new cycles of investment decisions.

Performance-Based Planning and Programming
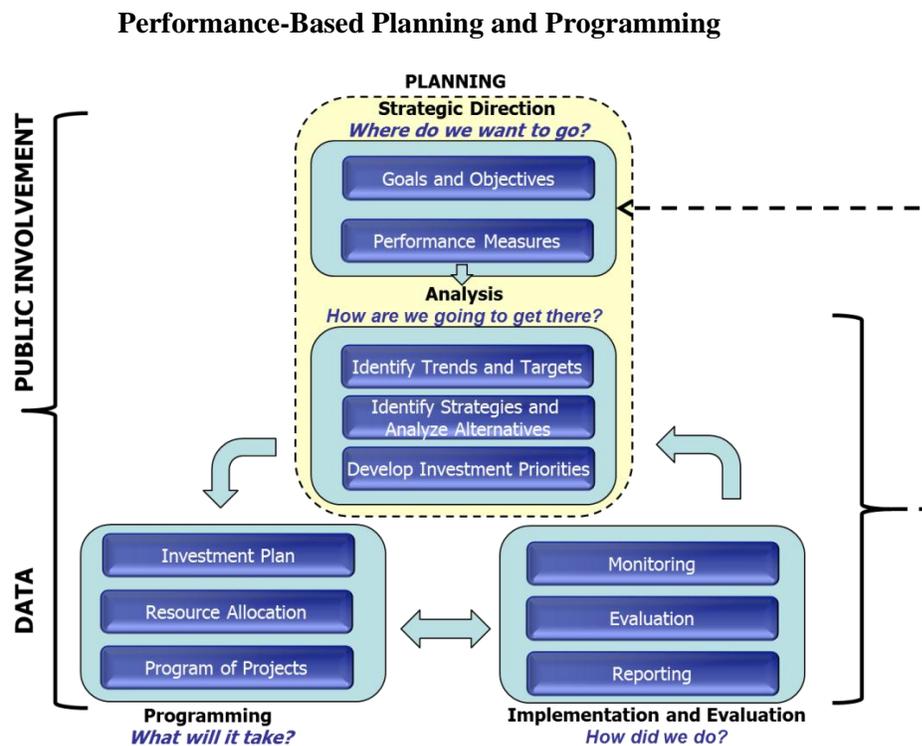
Source: Performance-Based Planning and Programming Guidebook (FHWA, 2013)

PBPP starts with *strategic direction* (answering the question, "what do we want to achieve?"), and includes the development of goals and objectives, and associated performance measures. Performance measures play a critical role both in 1) informing investment decisions by serving as a basis for

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[13] Performance management is the practice of setting goals and objectives; it is an on-going process of selecting measures, setting targets, and using measures in decisionmaking to achieve desired performance outcomes; and reporting results. See http://www.fhwa.dot.gov/tpm/about/tpm.cfm for more information.

comparing alternative investment strategies and policies and 2) tracking progress over time toward intended outcomes.

Planning analysis ("How are we going to get there?") relies upon data and analysis tools, along with public involvement and policy considerations, to develop investment priorities. Agencies identify trends, and directional outcomes or targets (specific levels of performance desired to be achieved within a certain timeframe) for each measure to provide a basis for comparing alternative sets of strategies. Scenario analysis may be used to compare alternative packages of strategies, to consider alternative funding levels, or to explore what level of funding would be required to achieve a certain level of performance. The result is a set of investment priorities that can be identified in the Long Range Transportation Plan (LRTP) and associated planning documents.

Programming ("What will it take?") involves the selection of specific investments to include in an agency capital plan and/or in a metropolitan or statewide Transportation Improvement Program (TIP or STIP) to support attainment of intended trends or targets. An agency may develop a mid-range (e.g., 10 year) investment plan, and develop project prioritization or selection criteria to select a program of projects.

Implementation and evaluation ("How did we do?") includes monitoring system performance (gathering information on actual conditions), evaluation (conducting analysis to understand to the effectiveness of implemented strategies), and reporting (communicating information about system performance and the effectiveness of plans and programs).

PBPP involves a range of activities and products undertaken by a transportation agency, working together with other agencies, stakeholders, and the public, as part of a 3C (continuing, cooperative, and comprehensive) process. These activities include development of LRTPs, TIPs, and STIPs; other Federally-required plans and processes (such as Strategic Highway Safety Plans, Congestion Management Processes, and Asset Management Plans); and other efforts such as corridor, investment, or modal plans that support investment decisionmaking.

FHWA, the American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Research Board (TRB) have developed a number of resources on performance-based planning and programming in recent years, including Guidebooks, White Papers, and Findings from Peer Exchanges and other research activities. Many of these can be found at: http://www.fhwa.dot.gov/planning/performance_based_planning/resources/.

While there is a significant amount of information available to practitioners on performance-based planning and programming in general, little has been written to help transportation agencies consider GHG reduction as part of this process. This guidebook can help to meet the needs of communities and practitioners interested in addressing GHGs through transportation planning. Within this approach, transportation agencies will typically take the following steps, discussed through sections of this document:

- Identify how GHGs relate to key goals and objectives (Section 4).
- Identify and select a GHG performance measure or measures (Section 5) – This is a key issue, since the selection of a performance measure(s) will form a foundation for understanding baseline conditions and anticipated trends, establishing targets, analyzing alternative investment strategies, and ultimately for providing information that supports planning and project selection decisions.
- Analyze trends and set targets (Section 6) – Conduct planning analysis, including development of a baseline inventory and forecast of GHG emissions, and identify desired outcomes for GHG levels to be achieved.
- Analyze alternative investment and policy strategies, and make decisions about investment priorities that are incorporated into the LRTP. Develop an investment plan and program of projects for inclusion in the TIP or STIP, using GHG reduction as one factor in helping to prioritize projects for selection (Section 7).
- Monitor, evaluate, and report on progress toward achieving desired outcomes (Section 8).

Integrating GHGs into PBPP does not mean that all projects will reduce GHG emissions, or that the selected set of investments and policies will be the alternative that minimizes GHG emissions. It should, however, provide an informed basis for investment decisionmaking to support environmental sustainability and allow a more rigorous consideration of both tradeoffs and co-benefits of GHG emissions reduction in relation to other goals.

3. Key Considerations for Addressing GHGs in a Performance-based Approach

Key Attributes of GHG Emissions

Climate change is an issue of growing concern, and methods to assess and address the issue are evolving rapidly. Many States and MPOs have set aggressive GHG reduction targets and transportation agencies have a role to play in meeting this challenge. Increased interest from policy makers and planners at all levels of government demonstrates that there is growing awareness of the challenges of climate change. This section discusses four key attributes of GHG emissions that should be considered by agencies as they seek to address this issue in transportation planning and programming.

GHG Emissions are Global, Not Local

The severity of climate change is determined by the total concentration of GHG emissions in the earth's atmosphere. Though scientists have broadly projected the level of global change that we can expect to see with different levels of emissions, it is less certain how this change will affect different areas of the globe. Moreover, the impacts experienced locally will not necessarily be in proportion with the amount of emissions that a city, metro area, or State produces. This means that the scope of emissions (in terms of the geographic area where emissions are generated, the source of the emissions) is a key concern to address when selecting GHG performance measures. It also means that GHG reduction efforts are often driven by the aim of increasing the collective impact of overlapping efforts at the local, State, national levels to reduce global emissions.

GHG Emissions are Cumulative

Unlike criteria pollutants, which stay in the atmosphere for a relatively limited time, many GHG emissions remain in the atmosphere for decades and even centuries. Even if human-produced GHG emissions were to dramatically decline, some climate change would occur over the coming years due to the increased concentration of emissions that is already in the atmosphere. This means that transportation agencies' efforts to address GHG emissions often take place in the context of larger-scale and longer-term efforts to address climate change. It also means that the time horizon of a transportation plan will have a substantial effect on how different GHG reduction strategies perform under different measures. As we discuss below, transportation planning decisions typically have a much greater effect on GHG emissions over the long term than over the short term. Though the cumulative impact of emissions can be challenging to analyze and address in the context of performance measurement, it is important to consider when thinking about actions to achieve emissions reductions. It should be noted that while it is critical for agencies to plan for GHG reductions on a long time-scale, this should occur in conjunction with efforts to meet short term reduction targets as well which can

make a down payment on GHG reductions. This can make the larger long term reductions required more manageable. Smaller reductions that are taken early will have cumulative impacts over time.

Exogenous Factors Significantly Impact Transportation-related GHG Emissions

In developing GHG reduction targets and in tracking progress, it is important to recognize the important role of exogenous factors – those not under the direct control of State and local agencies – including Federal policies in affecting transportation GHG emissions. Some key factors that affect GHG emissions include:

- *Population and economic growth* – Population and economic growth are key drivers of GHG emissions from on-road sources, and depending upon the performance measures used, their effects may outweigh those of transportation investments and policies. For instance, short-run economic conditions, such as a recession, may reduce commuting activity, and therefore drive down GHG emissions.
- *Fuel prices* – Fuel prices are largely driven by global market forces. They are highly variable in the short-term and highly uncertain in the long-term; yet they have important implications for GHG emissions. Low fuel prices may tend to encourage increased driving and use of less fuel efficient vehicles, and therefore increased GHG emissions, while high fuel prices may encourage the opposite.
- *Clean vehicle and fuels policies and technologies* – Vehicle technology improvements, driven by increasingly stringent motor vehicle emissions standards, have been the dominant source of reductions in vehicle emissions since the 1970s. Moving forward, Federal fuel economy standards will have a large effect on GHG emissions, as will market factors that affect the cost and availability of more efficient vehicles. In comparison with these policies and factors, States and regions generally have limited ability to require or incentivize consumers to use more efficient vehicles. It should be noted that California is different than other States in the legal authority it has to regulate vehicle technology and air emissions. To the extent that California adopts more stringent rules for vehicle technologies, other States may follow its lead by adopting its standards.

Consequently, while transportation investments and strategies play an important role in addressing GHG emissions, other factors may have a larger absolute impact on emissions, particularly in the short-term. For example, in California, the Air Resources Board estimates that regional transportation and land use policies to meet GHG reduction targets will be responsible for about one-sixth of the GHG reductions associated with standards for light-duty vehicle efficiency and low carbon fuels through 2020.[14] However, the Board also emphasizes that transportation and land use planning will play a more central

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[14] California Air Resources Board, Greenhouse Gas Reductions from Ongoing, Adopted and Foreseeable Scoping Plan Measures, Available at: http://www.arb.ca.gov/cc/inventory/data/tables/reductions_from_scoping_plan_measures_2010-10-28.pdf.

role in reducing GHG emissions between 2020 and 2050 due to the long-term benefits of these strategies.[15] A study by the National Research Council on the effects of compact development also noted that the benefits of compact development increase over time, illustrating on the one hand the longevity of the built environment and, on the other, the cumulative effect of land use changes.[16,]

Many other transportation outcomes that are commonly measured in plans and programming documents are affected by exogenous factors. For instance, safety (traffic fatalities and injuries) is affected not only by roadway design and operations, but also by driver behavior and vehicle technologies. Similarly, traffic congestion is affected not only by investments in the transportation system but also by land use, fuel prices, and economic activities.

As with these examples, a transportation agency may focus on GHG emissions as a key performance measure in its planning and programming -- even emissions that are beyond its direct control – because GHG emissions are directly related to an outcome with significant impacts on society, climate change. Moreover, the transportation planning process offers a forum to bring together the public, key partners, and stakeholders in developing coordinated solutions.

GHG Emissions are Not Directly Measured

Another challenge associated with using GHG emissions as a performance measure is that GHG emissions cannot be monitored in a literal sense, the way it is possible to monitor some other outcomes such as the number of fatal crashes or metrics related to pavement and bridge conditions. GHG emissions have to be modeled or calculated using emissions factors. This approach is not unique to GHGs, since estimation and modeling are typically conducted for some metrics, such as traffic congestion measures (e.g., hours of delay experience by travelers) and measures of accessibility to transit (e.g., share of households within ¼ mile of transit). However, it is important to recognize that the available tools and assumptions that transportation agencies make when estimating GHG emissions have important implications for the results.

Fuel consumption can serve as a proxy for tailpipe GHG emissions, since fuel sales are tracked at the State level, and CO_2 is emitted in direct proportion to fuel consumption, with differences in emissions rates based on different types of fuel (e.g., motor gasoline, diesel, compressed natural gas). In fact, State-level on-road GHG emissions have often been calculated based on fuel sales in multi-sector GHG

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[15] California Air Resources Board, Climate Change Proposed Scoping Plan, Appendix C: Sector Overviews and Emission Reduction Strategies, page C-80, available at: http://www.arb.ca.gov/cc/scopingplan/document/appendix1.pdf

[16] National Research Council, *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy use, and CO$_2$ Emissions*. Washington, D.C.: Transportation Research Board Special Report 298, 2009. Available at http://cta.ornl.gov/cta/Publications/Reports/Reducing_GHG_from_transportation%5b1%5d.pdf. This study estimated CO$_2$ reductions of 1.3 to 11.0 percent compared to a baseline in 2050 due to more compact development. The broad range is based on different assumptions associated with the share of new and replacement development that is compact and the reductions in VMT in compact development areas.

inventories, since emissions of carbon dioxide (CO_2), the primary GHG, are directly related to fuel consumption, and because fuel sales data are typically readily available. However, fuel sales may not correspond exactly with travel within a particular State, especially in instances where drivers commonly travel between States (e.g., New York, New Jersey, Connecticut). These boundary issues are particularly important when examining emissions in smaller geographies, such as metropolitan areas.[17] In addition, non-road use of motor fuels means that there may be some discrepancies between fuel sold and fuel used by motor vehicles. In these cases, GHG emissions can be calculated by collecting data on vehicle miles traveled (VMT) and operating conditions and then using an emissions model, such as EPA's Motor Vehicle Emission Simulator Model (MOVES) – or California's Emissions Factors (EMFAC) model – to estimate emissions.

As a result, transportation agencies' GHG analysis will likely be shaped by the tools and data that are available, the extent to which these tools and data capture different strategies that agencies may undertake to reduce emissions, and the need for consistency with the analytical methods used in evaluating GHG emissions under overlapping climate policies. Some States and MPOs have invested in creating new tools or enhancing models to expand the analytical capabilities available to analyze policies. For instance, Oregon DOT developed the GreenSTEP model to analyze a broad range of GHG reduction strategies that could not be addressed in traditional travel models.

Policy Implications

The four factors described above demonstrate that there is no single measure that "best" addresses GHG emissions within a PBPP approach, nor is there a single correct way to calculate a given measure. Instead, several different factors can collectively shape transportation agencies' choices regarding GHG performance measures and how GHG emissions are integrated into decisionmaking, including:

- The GHG reduction strategies that are under consideration by transportation agencies;
- The geography and travel characteristics of the area under consideration (e.g., city, metropolitan area, or State);
- Consistency with other local, State, and national climate policies;
- The extent to which agencies collaborate with stakeholders to identify additional opportunities to reduce GHG emissions;
- The effect of Federal policies and other exogenous factors on GHG emissions;
- The time horizon of the planning process; and
- Available tools and data.

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[17] Road based VMT in small geography analyses can also have inherent errors if the GHG is related to the population or economy (per capita and per GDP metrics) and there are significant volumes of external trips or pass through traffic.

It is important that transportation agencies understand how these factors affect their options when selecting a GHG performance measure(s), and understand the limitations associated with various approaches. In the following sections of this guidebook, we describe different choices that transportation agencies face when selecting GHG performance measures, as well as how the factors listed above can shape agencies' options.

4. Establishing Goals and Objectives

Developing goals and objectives is a fundamental part of any successful planning effort, and this is especially true for performance-based planning and programming. Goals and objectives provide strategic direction for investment and policy decisions, and consequently play a critical role in guiding the selection of performance measures and investment priorities. Regional, State, and national goals associated with sustainability, climate change, and related community outcomes can be a primary motivation for including GHGs within a performance-based approach to transportation planning and programming. For a more detailed discussion of establishing goals and objectives in a performance-based planning and programming process, see the FHWA/FTA *Performance Based Planning and Programming Guidebook*.[18]

State and Regional Climate Change Mitigation Goals and Policies

Scientific evidence makes clear that the buildup of greenhouse gases in the atmosphere is causing the Earth's climate to change in ways that affect our weather, oceans, snow, ice, and ecosystems. Human activities contribute to climate change through the release of heat-trapping GHGs. Climate change has substantial impacts on our transportation systems and on society as a whole. For example, warmer temperatures increase the frequency, intensity, and duration of heat waves, which can pose health risks, particularly for young children and the elderly. Rising sea levels threaten coastal communities and ecosystems. An increase in the frequency and intensity of extreme weather events, such as heat waves, droughts, and floods, can harm transportation systems and cause costly

> **California's Sustainable Communities and Climate Protection Act of 2008**
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> In 2006, California's legislature passed, and the Governor signed, The Global Warming Solutions Act, Assembly Bill 32 ("AB 32"), which called on the State's Air Resources Board (ARB or CARB) to prepare and approve a plan for achieving ambitious and cost-effective GHG emissions reductions, establish an emission limit for 2020, adopt a regulation requiring the mandatory reporting of GHG emissions, identify "early action" measures that could be taken to reduce emissions, and establish a cap-and-trade program.
>
> In 2008, the Legislature passed, and the Governor signed, the Sustainable Communities and Climate Protection Act, more commonly known as "SB 375," which called on the ARB to develop emission reduction targets for cars and light trucks. The law also requires California's MPOs to prepare Sustainable Communities Strategies (SCSs) that demonstrate how each region will meet these emission reduction targets. SCS's are land use and transportation plans that are expected to address regional housing needs as well as more traditional GHG reduction approaches. The SCSs under SB 375 must also meet all the Federal requirements for a long range transportation plan. The SCS components were added to existing Federal and State requirements. The bill aims to foster the implementation of "bottom-up" solutions for addressing GHG emissions.

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[18] While the terms goals and objectives are often used interchangeably, the PBPP guidebook defines a goal as a broad statement that described a desired end state, and an objective as a specific, measurable statement that supports achievement of a goal. An objective may address a focus area under a broad goal (e.g., an objective could address GHG reduction under a broad goal of sustainability), with the specific measure defined outside of the objective statement, or the objective could be defined specifically to include a measure and target (discussed further in the next two sections). See http://www.fhwa.dot.gov/planning/performance_based_planning/pbpp_guidebook/index.cfm.

disruptions to society.[19] According to the IPCC, global GHG emissions must be reduced to 50 to 85 percent below year 2000 levels by 2050 to limit these adverse effects of global warming.[20]

As noted earlier, thirty-two States and many regions have already developed climate action plans, and through those have identified transportation-related GHG emissions reduction as a desired outcome. Moreover, several States have passed laws or have had Executive Orders that call for GHG reduction. Although climate change action plans typically have not been integrated with transportation plans and programs, State and regional goals for GHG reduction may lead to a transportation planning goal or objective that addresses climate change. While in some cases State laws may influence the adoption and implementation of GHG goals and objectives, input from the community may also provide grassroots support for their adoption. For instance, the Delaware Valley Regional Planning Commission (PA-NJ) has set a specific target for reducing greenhouse gas emissions by 50% by 2035.[21]

As an example within the transportation planning process, the Mid-America Regional Council, the MPO for the Kansas City metropolitan area, adopted its LRTP, called *Transportation Outlook 2040*, in June 2010. An extensive public outreach process was utilized in the development of a regional vision statement and nine goals to serve as a foundation for the plan's content, identification of performance measures, and project evaluation and prioritization. The selected goals include several that have been used in the past – system performance, system condition, safety and security, accessibility, and economic vitality – as well as new goal areas, including one focused on climate change/energy use. The selected climate change/energy use goal is to: "Decrease the use of fossil fuels through reduced travel demand, technology advancements and a transition to renewable energy sources."[22]

Supporting Related Community Outcomes

Protecting and enhancing the natural environment is an end in and of itself, but it can also be a means to achieving other broad goals such as supporting sustainable land use patterns, encouraging walking and biking, increasing household incomes by reducing energy costs, and boosting employment through the implementation of investments in energy efficiency. A number of MPOs discuss climate change as an issue in their long range transportation plans, addressing various reasons to care about climate change.[23] These include regional concerns about the consequences of climate change, such as increases in severe weather, sea level rise, air pollution, and public health impacts.

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[19] For more information, see: U.S. Environmental Protection Agency, "Climate Change Science" web page at: http://www.epa.gov/climatechange/science/.

[20] IPCC, 2007. Contribution of Working Groups I, I and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 5, Section 5.4. Available at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains5-4.html.

[21] Delaware Valley Regional Planning Commission, *Connections – The Regional Plan for a Sustainable Future. Public Comment Document*, 2009.

[22] Mid-America Regional Council, *Transportation Outlook 2040,* available at: http://www.marc.org/transportation/lrtp.htm.

[23] FHWA, "Climate Change – Model Language in Transportation Plans." Prepared by ICF International, 2010.

For instance, the Baltimore Metropolitan Council notes in its LRTP, called *Plan It 2035*, which was adopted in November 2011, that GHG emissions and climate change are an environmental concern for multiple reasons: "[I]ncreased runoff and rainfall events from climate change could affect the [Chesapeake] Bay through increased erosion and sediment loads. Higher peak stormwater flows also would mean greater amounts of nutrients transported downstream, degrading water quality. Additionally, climate change will likely cause a decline in biodiversity of plants and animals in the forests of Maryland. Increasing summer temperature will likely cause higher ozone levels and more frequent exceedances of the Federal ozone air quality standard. Sea level rise will also require costly mitigation measures to protect the region's transportation infrastructure from higher water and damage caused by storm surges."[24]

A number of State DOTs and MPOs also emphasize sustainability, and policies that support GHG reduction, such as managing travel demand, ensuring multimodal options, and optimizing system performance before adding new highway capacity. For instance, the Delaware LRTP, *Moving the First State Forward,* which was adopted in 2010, focuses on developing "smart transportation systems consistent with the State's smart growth strategies." These strategies seek to guide growth to areas that are most prepared to accept it in terms of infrastructure and thoughtful planning; preserve farmland and open space; promote infill and redevelopment; facilitate attractive, affordable housing; and protect quality of life while slowing sprawl. Consequently, the Plan includes goals related to economic vitality, safety, accessibility and mobility, multi-modal transportation, efficiency and effectiveness, and environmental stewardship, including integrated land use and transportation and "responsible energy consumption".[25]

The Grand Valley Metropolitan Council, MPO for the Grand Rapids, Michigan, metropolitan area, includes within its 2035 LRTP, adopted in March 2011, a vision to "Establish a sustainable multimodal transportation system for the mobility and accessibility of people, goods, and services; it will provide an integrated system that is safe, environmentally sound, socially equitable, economically viable, and developed through cooperation and collaboration." The Plan includes a goal to "Strengthen the link between transportation and land use policies to encourage people and businesses and to live and work in a manner that reduces dependence on single occupancy vehicles." Under its environmental goal, the plan includes an objective to "Prioritize transportation projects which reduce the frequency and length of trips, minimize the energy resources consumed for transportation, and promote a sustainable transportation system."[26]

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[24] Baltimore Metropolitan Council, *Plan It 2035,* Chapter 2, available at: http://www.baltometro.org/plans/final-plan-it-2035.

[25] Delaware Department of Transportation, *Moving the First State Forward: Delaware Long Range Transportation Plan*, 2010, available at: http://www.deldot.gov/information/pubs_forms/delrtp/delrtp_102510.pdf.

[26] Grand Valley Metropolitan Council, *2035 Long Range Transportation Plan,* Chapter 3, available at: http://www.gvmc.org/transportation/longrangeplan.shtml.

National Environmental Sustainability Goal

Sustainability goals at the national level have been driven by both legislative action and executive initiatives. President Obama has established a target to reduce total U.S. greenhouse gas emissions by about 17 percent below 2005 levels by 2020.[27]

The MAP-21 establishes seven national goal areas; one of these is "Environmental sustainability: To enhance the performance of the transportation system while protecting and enhancing the natural environment." [Section 1203, or 23 USC 150(b)]

Although State DOTs and MPOs are not required to use a consistent national environmental sustainability performance measure, they will be expected to use a performance-based approach to decisionmaking that supports the national goals. The MAP-21 requires that the metropolitan and statewide transportation planning process "shall provide for the establishment and use of a performance-based approach to transportation decisionmaking to support the national goals" [23 USC 134(h)(2)(A) and 23 USC 135(d)(2)(A)].

The environmental sustainability goal area could include many different focus areas or objectives, including minimizing water runoff from transportation facilities, increasing habitat restoration, encouraging the use of low-emission transportation options, such as walking, bicycling, taking public transit, or using low-emission vehicles. Given the potentially severe impacts associated with climate change, States and MPOs may choose to consider GHG emissions as a measure of environmental sustainability. GHG emissions have been identified by some States as a promising measure to track agency performance in the area of environmental stewardship.[28] It addresses a key component of sustainability – "meeting the needs of the present without compromising the ability of future generations to meet their own needs."[29]

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[27] The President's Climate Action Plan. June 2013.
http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

[28] See NCHRP 20-24(37), "Technical Guidance for Deploying National Level Performance Measurements." Prepared by Cambridge Systematics, 2011. See page 3-30.

[29] Common definition of sustainability, derived from the "Brundtland definition" in the World Commission on Environment and Development, *Our Common Future* (New York: Oxford University Press, 1987).

5. Selecting Greenhouse Gas Performance Measures

Transportation agencies face numerous options when selecting a GHG performance measure or measures. This section describes several of the choices that transportation agencies face when selecting a GHG performance measure(s) and discusses how local context, overlapping climate and sustainability policies, tools, modeling and data availability, and other factors can shape transportation agencies' choices. It then discusses the pros and cons of specific commonly-used GHG performance measures.

It is important to note that a GHG measure should be carefully chosen to support public policies for GHG mitigation. The selection of a measure is not merely a technical issue, but rather is closely related to the type of vision that a State or region has developed for transportation sustainability. Ultimately the performance measure selected should assist an agency or area in implementing its vision.

A number of States have policies in place that establish transportation-related GHG reduction targets, and in some cases, specify performance measures and methodologies. Though this report outlines general considerations, the consistency of the measure with State-level policies, initiatives and community priorities should be considered carefully by transportation agencies.

Key Issues in Defining a GHG Performance Measure

The options that transportation agencies face when selecting GHG performance measures can be summarized by three questions:

1. Which emissions should we measure?
2. How should we measure these emissions?
3. How should we express the results?

Answering each of these questions will require agencies to consider how the policies that they need to implement can be supported by these measures. Below we summarize the options that transportation agencies face within the categories represented by each of the above questions.

Which Emissions are Measured

The first step in selecting a GHG measure (and correspondingly conducting most GHG analyses) is to establish the scope of the analysis, including which types of GHG emissions will be measured, which sources will be covered, and whether to account for tailpipe or life-cycle emissions.

Which GHGs to Include

Carbon dioxide (CO_2) is the most prevalent GHG and accounts for roughly 95 percent of transportation GHGs based on global warming potential.[30] As such, the number of tons or pounds of CO_2 emitted is a reasonable stand-alone indicator of GHG emissions. However, transportation emits several other GHGs, such as methane (CH_4) and nitrous oxide (N_2O), so agencies can also measure **multiple GHGs**. Some gases have a stronger effect on climate change than others; the relative strength of a given GHG's effect on the climate is commonly referred to as its global warming potential (GWP). When measuring multiple GHGs, agencies typically state results in tons of carbon dioxide equivalent (tCO_2Eq. or tCO_2e), a unit that accounts for differences in GWP. This can be slightly more complex than just measuring CO_2 emissions, but many emissions models make it easy to measure multiple GHGs in tCO_2Eq.

The choice of which GHGs are included generally does not affect the responsiveness of a performance measure to different strategies to reduce transportation-sector GHG emissions, except in the context of choices between different advanced vehicle technologies that typically occur outside of the transportation planning and programming process. Consistency with other agencies' policies and accounting methods is typically the driving factor in determining which GHGs to include in a transportation analysis.

Which Transportation Sources are Included

Transportation agencies face several choices when determining which vehicles and sources should be included in an analysis of GHG emissions:

- **Light-duty vehicle GHG emissions** accounts largely for emissions from passenger vehicles, as opposed to commercial travel.
- **Total on-road GHG emissions** accounts for the emissions produced by both passenger and freight vehicles. This is a more comprehensive approach than the measure above, and will capture the benefits of strategies to improve the efficiency of freight movement. This measure is also consistent with the scope of analysis for conformity with air quality goals, and addresses heavy-duty trucks, which in particular are a significant contributor to on-road GHG emissions.
- **Total transportation GHG emissions** accounts for GHG emissions from all transportation sources, potentially including rail, transit, and ferries in addition to on-road vehicles. This is the most comprehensive approach, and will capture the benefits of some GHG reduction strategies that other measures will ignore, such as strategies to increase the efficiency of transit vehicles. However, it is also more complicated to calculate than the two measures described above, since this measure not only requires agencies to account for more diverse sources, but also potentially to develop emissions factors for transit vehicles such as railcars that are not covered by on-road mobile source emissions models.

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[30] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, 2013.

In addition to choosing between one of the three measures described above to describe GHG emissions related to usage of the transportation network, transportation agencies may choose to account for **construction and maintenance GHG emissions**. Though the amount of GHG emissions due to construction and maintenance of the transportation system is generally much smaller than the amount of emissions due to use of the system, transportation agencies have the potential to directly influence these emissions through procurement policies and contracting requirements. On-road emissions models do not typically account for construction and maintenance GHG emissions, but tools are available and are being developed to help agencies account for these emissions.

Greater Buffalo Niagara Regional Transportation Council (GBNRTC) Energy and GHG Analysis

Based on guidance from New York State DOT (NYSDOT), MPOs in New York State have been analyzing construction and maintenance related emissions associated with their LRTPs and TIPs. In 2007, GBNRTC completed an energy and GHG analysis of its 2030 Long Range Transportation Plan. In addition to estimating GHG emissions from vehicles, GBNRTC also estimated the "indirect" GHG emissions associated with construction of transportation infrastructure. GBNRTC's analysis included GHG emissions from construction equipment, transportation of materials, and production and extraction of materials. GBNRTC used procedures specified by NYSDOT to estimate the energy used by construction on a per lane-mile or per track-mile basis, and then converted this energy consumption to GHG emissions.

Source: Greater Buffalo Niagara Regional Transportation Council (GBNRTC), Energy and Greenhouse Gas Analysis For the Greater Buffalo Niagara Regional Transportation Council (GBNRTC) 2008-2012 TIP and 2030 Long Range Transportation Plan, July 2007, Available at: http://www.gbnrtc.org/index.php/resources/publications/reports/

Two key factors commonly play a role in transportation agencies' choice of which sources to include in GHG performance measures:

- **Agency interest in developing policies related to GHG emissions from different sources**. While including more sources is more comprehensive, it often requires more effort. Transportation agencies may choose to invest this effort only if it will offer additional insight on the relative effectiveness of different GHG reduction strategies; otherwise they typically use simpler measures in order to avoid analyzing emissions that are outside of their control. For example, passenger travel is more closely tied to regional or State transportation planning decisions (e.g., land use coordination, transit service, demand management, etc.) than freight travel, which often is primarily determined by broader economic factors and involves more interstate and interregional travel, so some transportation agencies choose to limit analysis to light-duty GHG emissions. However, if a transportation plan contains strategies to reduce freight emissions through corridor management or other measures, more comprehensive measures will be necessary to capture the resulting GHG reductions.
- **Consistency with regional emissions analysis.** Regional emissions analysis to meet Clean Air Act requirements in non-attainment and maintenance areas must consider both heavy- and light-duty vehicles. For areas that violate the National Ambient Air Quality Standards (NAAQS), this makes it easier for MPOs to account for GHG emissions from all on-road vehicles if they are analyzing GHG emissions alongside other criteria pollutants.

Addressing Life-Cycle Emissions

Transportation agencies typically focus on **tailpipe GHG emissions**, which are the emissions that are produced by vehicles as they combust fuel, because the analysis of tailpipe emissions is simpler to conduct and because it mirrors the approach that agencies typically use to assess criteria pollutant emissions. However, since GHGs are global pollutants that have the same impact on the climate regardless of where they come from, it can also be beneficial to estimate **life-cycle emissions**, which account for emissions associated with the production, transport, and disposal of transportation fuels, and potentially also emissions generated by vehicle production, maintenance and disposal. A life-cycle analysis will better account for strategies that involve shifting fuels, such as encouraging adoption of hybrid passenger vehicles or using biodiesel in transit vehicles. However, a comprehensive life-cycle analysis can also require much more effort and a greater number of assumptions on a transportation agency's part than a tailpipe analysis. An agency can pursue a mixed approach, using tailpipe GHG emissions as a primary performance measure and estimating life-cycle GHG reduction factors for strategies or projects that primarily impact life-cycle emissions. For instance, Oregon and California have quantified the impact of implementing a low carbon fuel standard. Since this approach does not result in an "apples-to-apples" comparison, it merits extra caution when interpreting results. Nevertheless, it can be helpful to understand the full life-cycle emissions impacts of investments.

How Emissions are Measured

One of the key challenges of selecting GHG performance measures is selecting measures that reflect the impact of transportation agency investments. In particular, it can be challenging to attribute global emissions to a particular State or region, or to attribute cumulative emissions that remain in the atmosphere for decades or more to a plan with a limited time horizon.[31] As a result, it is important for agencies to consider how emissions are measured at the outset when selecting GHG performance measures in order to ensure that GHG analysis is responsive to agency goals. This section broadly outlines key methodological considerations; Section 6 discusses GHG analysis methods further.

Geographic Scope of Analysis

The fact that GHG emissions are global, not local, pollutants means that transportation agencies should consider the source of emissions when analyzing GHG performance measures. A **geographic analysis** accounts for GHG emissions due to all vehicle travel that takes place within the boundaries of a region or State. This includes internal trips that begin and end within these boundaries, interregional or interstate trips, and trips that pass through the region or State. This approach is consistent with the approach used in transportation conformity for criteria pollutants. However, a geographic analysis may undercount GHG emissions due to trips that may be influenced by a region's policies or investments (i.e., interregional or interstate trips that begin or end at a point near the edges of the region or State)

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[31] Different GHGs can remain in the atmosphere for different amounts of time, ranging from a few years to over a thousand years.

or count emissions from trips that are largely beyond an agency's influence (i.e., pass-through trips). Alternately, a **trip-end analysis** accounts for GHG emissions due to vehicle trips that begin or end within the boundaries of a region or State. Typically, a trip-end approach counts all GHG emissions from internal trips and half of the emissions from interregional or interstate trips, while ignoring pass-through trips. As a result, it ties the emissions most directly to their sources.

Four factors often play a role in transportation agencies' choice between a geographic and trip-end approach to analyzing GHG emissions:

- **Consistency with regional emissions analysis requirements**: Analysis of criteria air pollutants takes a geographic approach to analyzing emissions (e.g. nonattainment or maintenance area boundaries), which reflects the fact that criteria pollutants are local, not global. This can make it easier for MPOs to use geographic analysis of GHG emissions if they are analyzing GHG emissions alongside other criteria pollutants.
- **Role of inter-regional or interstate travel.** States and regions that experience a large proportion of interregional or interstate and pass-through travel may find that a trip-end analysis focuses more on the GHG emissions over which they have the most control, while areas where most travel is internal may be better suited to a geographic analysis. The amount of non-internal travel typically depends upon a State or region's size, location, and economic activity relative to nearby population centers. A geographic analysis is typically well-suited to regions or States that cover a travelshed, a large geographic area, or do not border on other population centers. This includes many western States and regions located within sparsely-populated States. On the other hand, small States and regions that are adjacent to other metropolitan areas, such as States and regions in the densely-populated northeastern U.S., will likely find that their neighbors contribute to travel within their boundaries, and that a trip-end analysis may be more responsive to certain types of transportation policies and strategies, such as those focused on VMT reduction (e.g., land use changes).
- **Strategies being considered.** If a plan contains significant elements that affect interregional or interstate travel, such as new transit connections to adjacent regions or States or major land use changes that will attract travelers from nearby population centers, a trip-end analysis may better capture the resulting GHG emissions, particularly if the focus is on passenger travel. However, if a region or State is considering or implementing strategies that include traffic operations improvements, reductions of freight bottlenecks, and other strategies that affect inter-regional and interstate traffic, a geographic analysis may be better to capture GHG emissions impacts.
- **Consistency with neighboring jurisdictions**. A trip-based analysis may leave some GHG emissions unaccounted for; particularly GHG emissions from pass-through trips. Transportation agencies will minimize the risks of leaving emissions uncounted if they coordinate with neighboring or overlapping jurisdictions to align approaches to analyzing GHG emissions. For example, under California's SB 375, MPOs use a trip-end approach to calculating emissions, and

the State DOT will conduct an aggregate analysis of all regional plans to account for emissions from pass-through trips and other interregional travel.

Accounting for Changes in Vehicle Technology

Improvements in vehicle technology have the potential to reduce transportation-sector GHG emissions significantly. At the same time, transportation agencies' control over vehicle technology is typically limited to funding research, offering incentives to consumers to purchase more efficient vehicles, and purchasing alternative vehicles and fuels for fleets. These actions often have a marginal effect on GHG emissions compared to Federal fuel efficiency standards and market factors. The way in which transportation agencies account for technology changes will affect the extent to which performance measures are responsive to GHG reduction strategies.

Measuring total GHG emissions, including emissions from technological changes, is typically the simplest approach, and may better align with State targets that specify an absolute emissions reduction goal. However, this approach will account for GHG reductions due to fuel efficiency standards and other factors that are typically beyond transportation agencies' control. Alternately, transportation agencies can **control for the effect of changes in technology on GHG emissions**, which can help to focus planning efforts on GHG reductions that are most directly under agencies' control. This approach is more complex, and the level of effort involved in controlling for technological changes depends heavily on the extent to which Federal and State policies offer a basis for controlling for GHG emissions due to exogenous factors.

How Emissions are Expressed

In addition to determining the scope of GHG emissions that will be considered in an analysis and how these emissions will be measured, transportation agencies can also choose to express emissions in ways that control for growth or are easier to communicate.

Total or Normalized Emissions

Total GHG emissions offer an indicator of the overall impact of the transportation system, and are more closely aligned with the many State-level policies that establish GHG reduction goals in terms of overall emissions. However, transportation agencies may choose to normalize GHG emissions in order to account for the effect of population and economic growth on emissions. Two common normalized GHG performance measures are:

- **Per capita GHG emissions**: This measure accounts for the effect of population growth on GHG emissions, but it does not directly address the overall environmental impact. A decrease in per capita emissions would indicate that the average resident of a region or State is reducing his or her transportation-related GHG footprint, but total emissions will still increase if population growth outpaces the decline in per capita emissions. Per capita GHG emissions can be easier to communicate and interpret than total GHG emissions because residents are more likely to be

accustomed to seeing per capita or household-level GHG emissions figures from carbon footprint calculators and other resources.

- **GHG emissions per unit of economic output**: This measure controls for the effect of economic shifts on GHG emissions, such as declines in commute-related GHG emissions due to increased unemployment. However, as with per capita emissions, this measure does not always align with overall emissions, and poses added challenges to communicating results because definitions of economic output differ among planning agencies.

Since the transportation planning process typically includes population projections, and sometimes uses performance measures that assess economic growth or other trends, normalizing emissions often does not involve significant additional effort. Therefore, it may be feasible for transportation agencies to use total and normalized GHG performance measures side by side; for example a total measure to track overall progress toward sustainability goals and a per capita measure to control for population growth and facilitate communication.

Examples of GHG Emissions Metrics

The various combinations of options for each aspect discussed above yield a large variety of potential GHG emissions metrics. However, in practice, the metrics used by transportation agencies to date typically vary in terms of three key characteristics:

- The type of vehicles that they account for,
- Whether they normalize for population growth, and
- How they account for technology-related reductions in GHG emissions

Table 1 below summarizes examples of GHG emissions metrics drawn from existing practice, as well as the strength and limitations of each example. This is not an exhaustive discussion of the metrics available or the strengths and limitations of each, but provides illustrative examples for some key metrics.

Table 1: Strengths and Limitations of Example GHG Emissions Metrics

Metric	Agencies that Use the Metric	Strengths	Limitations
Total on-road related CO_2 emissions (light duty + freight)	National Capital Region Transportation Planning Board at the Metropolitan Washington Council of Governments [32] Puget Sound Regional Council[33]	Accounts for the vast majority of GHG emissions Easy to assess progress toward national or State goals	Emissions from freight sources may be difficult for transportation agencies to address Outcomes may be affected by population growth
Light-duty vehicle CO_2 emissions per capita	Portland Metro[34]	Focuses on light-duty emissions, which are most responsive to transportation policies and strategies	Does not account for benefits of freight-related improvements
Light-duty CO_2 emissions per capita (removing effect of reductions from State fuel and vehicle policies)	All California MPOs[35]	Focuses on light-duty emissions, which are most responsive to transportation policies and strategies. Controls for improvements due to fuel efficiency that are outside of agencies' control	Does not account for benefits of freight-related improvements Requires additional analysis of technology-related reductions
Total on-road and off-road related greenhouse gas (GHG) emissions	Massachusetts DOT[36] Maryland DOT[37]	Accounts for all major sources of GHG emissions Easy to assess progress toward national or State goals	Emissions from freight and non-road sources may be difficult for transportation agencies to address. Outcomes may be affected by population growth and other exogenous factors.

Note: These examples only include combustion emissions. The strengths and limitations would be different if life- cycle emissions, alternative fuels, electrification, freight, or clean construction and maintenance practices were included.

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[32] Metropolitan Washington Council of Governments, Long Range Transportation Plan, Air Quality, Available at: http://www.mwcog.org/clrp/performance/air_quality.asp.

[33] Puget Sound Regional Council, Transportation 2040, available at: http://www.psrc.org/assets/4847/T2040FinalPlan.pdf.

[34] State established a target for a 20 percent reduction in per capita light-duty CO_2 by 2035. See: http://www.oregon.gov/LCD/CLIMATECHANGE/pages/metropolitan_greenhouse_gas_reduction_targets.aspx. Prior to establishment of this target, the Metro 2035 Regional Transportation Plan also included an aspirational target for total CO_2 emissions from on-road sources. See: http://library.oregonmetro.gov/files//2035_rtp_final_document_as_submitted_and_approved_by_dlcd_usdot_web.pdf.

[35] California Air Resources Board, Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies (SCS) Pursuant to SB 375, available at: http://www.arb.ca.gov/cc/sb375/scs_review_methodology.pdf.

[36] Massachusetts Department of Transportation (MassDOT), GreenDOT Implementation Plan, available at: http://www.massdot.state.ma.us/Portals/0/docs/GreenDOT/finalImplementation/FinalGreenDOTImplementationPlan12.12.12.pdf.

[37] Maryland Climate Action Plan: Maryland Department of Transportation Draft 2012 Implementation Plan, available at: http://www.mdot.maryland.gov/Office_of_Planning_and_Capital_Programming/Plans_Programs_Reports/Documents/Climate_Change_2011.pdf.

As Table 1 illustrates, each metric has its respective strengths and limitations. An area may also consider using a combination of total on-road (or transportation-related) GHG emissions and light-duty GHG emissions per capita. These measures complement each other well. A light-duty GHG emissions per capita measure can be easier for the general public to interpret and focuses attention on policies such as coordinated land use and transportation planning and multimodal travel options that may be State or regional policy priorities. A total transportation-sector GHG emissions measure allows the public and decision makers to see how transportation agency efforts fit into larger-scale GHG emissions trends and multi-sector climate change planning efforts. If a total transportation-sector measure or on-road emissions measure is selected, the emissions figures may be broken into components, such as emissions from freight and passenger travel, or from heavy-duty trucks, buses, and light-duty vehicles, to provide a more detailed understanding of emissions sources.

The metrics in Table 1 illustrate different approaches to address the relationship between GHG emissions metrics and the reduction strategies that are available to different transportation agencies. For instance, California MPOs use a light-duty per capita metric that controls for advances in alternative vehicles and fuels because existing State policies include light-duty fuel-efficiency standards, a low-carbon fuels standard, and measures to increase the efficiency of heavy-duty vehicles. The metric that MPOs use controls for the effect of these policies and focuses on GHG emissions that are most responsive to regional transportation and land use planning, and the metric is designed to encourage sustainable planning practices (e.g., efforts to support land use policies and transportation investments that reduce vehicle travel). On the other hand, Massachusetts DOT's GHG reduction target uses a metric account for a much broader scope of emissions, and MassDOT is considering GHG reduction strategies that address alternative fuels and light- and heavy-duty vehicle efficiency. In both cases, the agencies' GHG emissions metric reflects the scope of the emissions that they intend to address with their reduction strategies.

Establishing GHG performance metrics under California's Senate Bill 375

Under California's SB 375, every MPO in the State is required to develop a sustainable communities strategy (SCS), which is an integrated land use and transportation strategy that details its approach for meeting a regional GHG emission reduction target set by the State's Air Resources Board (ARB). The GHG reduction metric chosen by ARB is per capita greenhouse gas emissions from passenger vehicles and light-duty trucks. ARB's choice of metric illustrates how the policy goals of SB 375, interaction with state-level GHG reduction strategies, and other factors influenced its choices with respect to the key considerations discussed in this chapter.

- **Which sources are included**: In addition to reducing GHG emissions, SB 375 aims to better integrate regional transportation and land use planning. Since passenger vehicles and light-duty trucks are more likely to respond to changes in land use than heavy-duty vehicles, the GHG metric used by ARB focuses on emissions from these vehicles.
- **Geographic scope**: The Regional Targets Advisory Committee (RTAC), which developed the recommended metric for ARB, suggested a trip-end approach to accounting for emissions, but allowed that ARB, in consultation with the State Department of Transportation, Caltrans, may determine the extent to which an MPO has extent over interregional trips.[1] This choice reflects SB 375's emphasis on land use and transportation strategies that are likely to affect both internal and interregional travel, the fact that many of California's MPOs share borders with one another, and Caltrans' active role in analyzing interregional travel.
- **Accounting for technology**: ARB specifies a baseline set of assumptions about GHG reductions due to implementation of the State's fuel efficiency standards for passenger vehicles and its low carbon fuel standard. When calculating regional GHG reductions, MPOs only count reductions that exceed these baseline reductions in order to avoid double-county.
- **Ease of communication**: According to the RTAC, a per capita metric "is preferred for its simplicity, since it is easily understood by the public."

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

Other Supporting Measures

In addition to using a GHG metric, States or regions could consider related measures to support GHG reduction goals. One measure that has sometimes been identified for consideration as a proxy for GHG emissions is VMT or VMT per capita. Although this measure is not responsive to a wide range of transportation strategies that reduce GHG emissions, including operational strategies to improve traffic flow and eco-driving techniques, incentives to use alternative fuels or low-or zero-emission vehicles, and vehicle idling reduction, some areas may be interested in considering these measures. In particular, VMT can be a useful measure of progress or success when States or MPOs make a policy decision to focus on transportation demand management and land use strategies as a priority. Many MPOs also forecast these measures as a matter of course in analyzing plan alternatives.

For instance, MARC, the MPO for the Kansas City metro area, chose two performance measures to support its goal related to climate change/energy use: VMT per capita and average number of vehicle occupants.[38] Washington State's House Bill 2815 established GHG emissions and VMT reduction goals and targets, including an 18 percent VMT per capita reduction below business–as-usual projections for 2020; 30 percent by 2035; and 50 percent by 2050.

The U.S. Environmental Protection Agency's (EPA) Guide to Sustainable Transportation Performance Measures also provides examples of a range of other metrics that might be considered.[39]

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[38] Mid-America Regional Council, *Transportation Outlook 2040,* available at: http://www.marc.org/transportation/lrtp.htm.
[39] This resource is available at: http://www.epa.gov/smartgrowth/pdf/Sustainable_Transpo_Performance.pdf.

6. Analyzing Trends and Setting Targets

While a performance measure itself provides a metric for evaluating outcomes, a PBPP approach requires a transportation agency to identify trends (directions for impacts) or targets (specific levels of performance desired to be achieved within a certain timeframe) for each performance measure to provide direction to strategy analysis and performance tracking. There are multiple ways in which targets can be set:

- Policy-based
- Consensus-based
- Analysis-based

Regardless of the approach, it is important to first understand baseline conditions. For GHG emissions, the baseline should provide information on the key sources of emissions and factors affecting emissions. Baseline conditions will include past trends and current performance levels. In addition, it is important to conduct analysis to understand expectations for future performance.

Developing a Baseline: Looking Back and Looking Ahead

A first step for agencies in developing a baseline is to develop an inventory of past and/or current GHG emissions (such as estimating an inventory of on-road CO_2 emissions in 2010) and a long-range forecast of CO_2 emissions (20, 25 or 30 years out), and then translating that inventory into the selected metric, if necessary. The long-range forecast period should ideally correspond with the end date of the long-range transportation plan, and could potentially include developing estimates of CO_2 emissions at a few mid-range points in time (for instance, in 10-year increments).

Many States have already developed GHG inventories, typically relying on fuel-based methodologies. A useful GHG inventory will provide information not only about total GHG emissions, but can provide information on the key sources of emissions (e.g., passenger cars, trucks) in order to inform policy and investment analysis. Just as detailed data on the sources and locations of crashes is helpful to develop effective countermeasures to improve safety, understanding the sources of GHG emissions is helpful in identifying potential strategies. Some more sophisticated inventory analyses also provide information on the locations of emissions (e.g., either by road link or assigning emissions to origins and destinations).

Depending on the organization's resources, modeling can be conducted to develop a baseline (or business as usual) forecast for the future. This forecast can be used as a basis for comparing emissions under alternative scenarios. This modeling can be relatively sophisticated. Having a business as usual scenario is important in understanding where emissions are expected to be headed and what level of reduction may be realistic to achieve. Given that PBPP is an iterative or cyclical process, performance that is monitored may become the new base line against which results from the next performance cycle are reported.

It is important to note that particularly at the State level, GHG inventories are often calculated based on fuel consumption data. As noted earlier, one limitation of a fuel-based inventory is the potential disconnect between the place of fuel sales and the location of the travel activity and/or generators of emissions. For instance, Maryland DOT has found that fuel sales do not provide as accurate a basis for estimating GHG emissions as VMT-based methods, given the amount of cross-border traffic, and has switched to developing inventories and forecasts based on VMT data and the MOVES model.[40] Another issue is that fuel-based inventories often do not connect well with future emissions forecasts, which are typically developed using VMT forecasts and emissions models. This has been noted as an issue by State DOTs, including the Vermont Agency of Transportation, which had a transportation GHG inventory developed based on fuel consumption data and was trying to reconcile it with its forecasts based on travel data.[41]

Considerations for Developing a Historic Baseline GHG Inventory

There are a number of key considerations for developing a historic inventory, which are discussed below.

- *Boundaries* – Define the geographic boundaries of analysis. Some MPOs may have modeling areas that are larger than the geographic boundary of the MPO. This may affect the ease with which existing data can be utilized. In some cases, agencies may wish to account for emissions that are generated by external trips beginning or ending outside of the region separately.
- *Scope* – Decide which emissions source categories (e.g., on-road sources only, or all transportation sources) and subcategories (e.g., light-duty vehicles, heavy-duty vehicles, buses) should be included, as well as which specific GHGs (CO_2 only, or also N_2O and CH_4).
- *Analysis method* – Depending on the data available and purpose of the inventory, choose a top-down (fuel-based), bottom-up (VMT-based), or hybrid approach. The geographic scope tends to influence the type of method that is selected for GHG analysis, based on data availability. At the State level, fuel-based methods are often used given the availability of State-level fuel consumption data, whereas at the MPO level, fuel sales data may not be available.
- *Baseline year* – Select a baseline year to provide a benchmark to compare progress going forward, considering whether data for that year are available, the chosen year is representative, and the baseline is coordinated with baseline years used in other inventories.[42] (Note: In some cases, legislation or executive direction will specify the baseline year.)

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[40] See Chapter 2, "2006 Baseline and 2020 BAU Forecast Greenhouse Gas Emissions Inventory Update," from Maryland DOT's *2011 Climate Action* Plan available at
http://www.mdot.maryland.gov/Office_of_Planning_and_Capital_Programming/Environmental_Planning.html.

[41] Potential Methods to Improve Vermont's Transportation Greenhouse Gas Inventory. Prepared by ICF International, August 30, 2010.

[42] For a more detailed discussion of how to select a baseline year, refer to the "Inventory Development" section of Chapter 2.3 in FHWA's *Handbook for Estimating Transportation Greenhouse Gases for Integration into the Planning Process*, available at:
http://www.fhwa.dot.gov/environment/climate_change/mitigation/resources_and_publications/ghg_handbook/index.cfm.

- *Data limitations* - If necessary data are incomplete or have limitations, as will often be the case, it is important that all involved are aware of the limitations and assumptions. Having complete documentation of methodologies used is important when comparing inventories or forecasts conducted in future years to the current estimate.

Potential types of emissions that could be 'counted' or assigned to a State or region

- Emissions associated with fuel sold within the boundaries. This is the approach commonly used within fuel-based inventories; however, it raises some questions about whether a State or region should be responsible for fuel that is sold in an area but is used outside of it. From a performance-based planning perspective, an agency may want to focus its inventory on those travel activities that they have the greatest level of influence over.
- Emissions from travel on the transportation system within the boundaries. This is the approach that is applied for transportation conformity purposes - emissions from all travel on the roadway network, whether due to local traffic or interstate through trips, are analyzed and reported.
- Emissions generated by households and/or businesses within the boundaries. A State DOT or MPO might instead be interested in focusing on GHG emissions due to the transportation activity of residents living or working within their jurisdictional boundaries (possibly including business and freight travel, as related to household goods consumption), taking out the effect of "through trips." This can be useful for areas that would like to allocate emissions to particular jurisdictions within their planning area (e.g., allocating transportation emissions to each county within a State). In this case, it is necessary to understand trip origins and destinations, and assign a portion of emissions to each, while removing the effect of trips that entirely pass through an area.

There are some advantages and challenges to each approach, so it will be important to agree upon what is the most desired way of counting emissions.

Considerations for Developing a Business-as-Usual GHG Forecast

Future emissions levels could differ from existing conditions for many reasons. It could be higher, for example, because VMT of the target population is rising. Or it could be lower because the vehicle fleet is becoming cleaner. While simple in concept, establishing an emissions baseline for the future, or "business-as-usual" forecast, can be challenging because it requires assumptions about travel behavior, vehicle technology and fuels, and other factors that affect emissions.

Some considerations for developing a baseline forecast are discussed below.

- *Forecast year(s)* – Forecasts may be developed for one or more milestone years in the future. The selection of milestone year(s) may be influenced by (a) legislative or executive branch GHG targets and laws and (b) synchronizing with planning timeframes of the State or area. Also, consider whether to analyze GHG on a cumulative basis, rather than for a specific forecast year, since climate change impacts are based on cumulative GHG, over decades.
- *Analysis method* – Depending on the data available and the purpose of the forecast, select a method that matches the appropriate level of detail and accuracy for the analysis purpose.

- *Additional strategy analyses* – Depending on the sophistication of the analysis method and existing modeling tools (e.g., the level of sophistication of the travel demand model), additional "off model" analyses may need to be conducted to adjust the forecast.
- *Results* – Clearly document the results, including assumptions and any limitations or caveats. Identify key areas of sensitivity affecting results

Key Tools and Methods to Consider

There are a variety of tools and approaches available to estimate baseline GHG emissions. These include both tools for estimating historic emissions as well as tools for forecasting baseline emissions into the future. More detail on all of these tools and methods is available from FHWA's *Handbook for Estimating Transportation GHGs for Integration into the Planning Process*, available at: http://www.fhwa.dot.gov/environment/climate_change/mitigation/resources_and_publications/ghg_handbook/index.cfm.

Fuel-based Methods – Fuel-based methods calculate GHG emissions based on fuel consumption data, such that emissions estimates are associated with the location of fuel sales. The most commonly used tool for developing a fuel-based inventory at the State level is EPA's State Inventory Tool (SIT). The SIT is a spreadsheet model that helps States to estimate their carbon dioxide (CO_2) emissions from all sectors (e.g., on-road gasoline, on-road diesel, aviation, rail, marine, and natural gas/other). It provides the option of using State-specific data or using default data that is generated by Federal agencies and some other sources. Based on its structure, the SIT approach is most appropriate for developing a transportation GHG inventory as part of a broader statewide inventory development process for all sectors, and for statewide analyses that do not require detailed breakdowns of transportation GHG emissions by transportation mode or by local jurisdiction. From a performance-based planning perspective, it is desirable to be able to disaggregate on-road vehicle emissions by vehicle class and geography (through trips, etc.). State agencies working with SIT have considered implementing approaches to disaggregate their on-road emissions further so they can be linked more closely with their existing transportation planning models and processes.

Fuel projections can be used to develop simple forecasts of CO_2 emissions, and EPA's State Inventory Project Tool is a useful tool for these calculations. However, it relies largely on projections of fuel consumption reported in the Energy Information Administration's *Annual Energy Outlook* by sector and region, and does not account for transportation investment strategies, or other characteristics, such as fleet composition changes.[43] Some States have developed vehicle fuel forecasting methods or tools, which can be used for GHG forecasts. Although State DOTs often estimate future fuel sales as part of their fuel tax revenue projections, in many cases, these methods are simplistic and do not account for many factors that influence GHG emissions.

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[43] "Annual Energy Outlook 2011 - Transportation," U.S. Energy Information Administration. http://www.eia.gov/forecasts/aeo/sector_transportation.cfm.

VMT-based Methods - VMT-based methods involve estimating vehicle travel (and its operating characteristics for more accuracy) and then applying emissions factors or an emissions model, such as EPA's MOVES Model, to calculate GHG emissions. States can develop VMT based GHG emissions inventories by using VMT estimates from the Highway Performance Monitoring System (HPMS) and applying emissions factors. HPMS forecasts of traffic can also be used to develop projections of VMT. Alternatively, States could extrapolate trends by functional class, using regression to correlate changes in the population to VMT, or other types of statistical analyses.

Most MPOs use network models for forecast VMT. Network models have the advantage of being able to capture changes related to population and employment growth as well as transportation network or system changes. Network models also allow for testing of both transportation demand and supply in an integrated model. Network models are commonly used by MPOs, their model framework is well understood, and the inputs they require are generally available. It is important to recognize, however, that many models are not sensitive to or sufficiently complex to address strategies that may be considered to reduce GHG emissions, including certain land use policies, demand management strategies, and operational strategies.

There are multiple approaches for converting VMT forecasts into emissions. Capturing changes in vehicle technology and improvements in the fuel economy of future vehicles is critical to creating an accurate forecast. Estimating how changes in vehicle speeds may affect emissions is also important for capturing how changes in traffic levels and infrastructure investment may affect future GHG emissions.

A more simplified approach is to use sketch planning methods to develop inventories and forecasts, such as building estimates of emissions using odometer, household travel survey or land use data. These VMT methods are generally intended for calculating household GHG emissions (not freight). They also are largely intended for developing inventories, although extrapolations of historical trends can be made to develop forecasts, recognizing a high degree of uncertainty in these results.

Delaware Valley Regional Planning Commission (DVRPC) GHG Inventory Analysis

One approach to developing a baseline GHG inventory using a transportation demand model can be seen in the inventory developed by DVRPC, the MPO for the Philadelphia metro area. DVRPC developed a regional GHG emissions inventory that relies on travel demand model output to allocate GHG emissions to different traffic analysis zones.

HPMS data was used to determine a VMT total. Through traffic was estimated based on the travel demand model trip table that shows trips with origins and destinations outside the region. VMT from through traffic was subtracted from total VMT to focus the analysis on travel within the region. VMT was then apportioned to municipalities based on trip origins, destinations and trip length. Emissions were mapped per acre, per population and per employee.
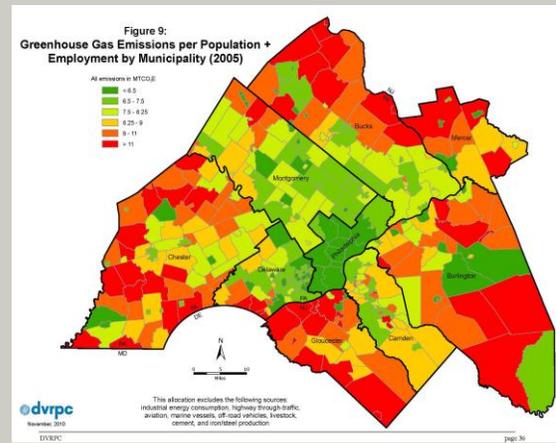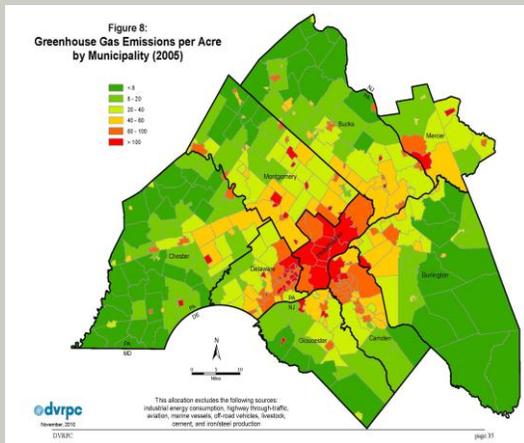
The map above to the left shows emissions per acre, and indicates that GHG emissions are higher in Philadelphia's urban core. If emissions for trips are allocated 50 percent to the trip origin and 50 percent to the trip destination, the map on the right shows that emissions are higher on a per population and per worker basis in the suburban and exurban areas around Philadelphia. The DVRPC inventory helps make the case for the role of denser land use development in reducing the GHG emissions intensity of development in the region. DVRPC's inventory is available at: http://www.dvrpc.org/EnergyClimate/inventory.htm

VMT based approaches use emission factors, generally expressed in terms of grams per mile, grams per hour, and grams per trip end. For a given pollutant, emission factors will vary according to the vehicle type (weight), engine technology, fuel type, vehicle model year, speed, and roadway type. Other factors affecting emissions rates include ambient temperature, inspection and maintenance programs, and vehicle deterioration.

EPA's MOVES model is the most robust tool available to produce estimates of on-road transportation GHG (and other) emissions. The model estimates energy consumption and emissions, including atmospheric CO_2, CH_4, N_2O, and CO_2e. MOVES can estimate emissions at the national, regional, or county, scales and for annual or shorter periods of time. The model itself requires many inputs, and

although defaults are available for most factors, defaults are generally poor substitutes for locally specific inputs. Inputs to MOVES include data on vehicle population, fuel type, and VMT. The model works by simulating actual vehicle drive cycles, including the effect of travel at different speeds and vehicle power loads. Sensitivity to vehicle operating conditions is important when examining transportation plans and policies, such as new highway capacity investments, congestion pricing, and other strategies that affect vehicle speeds and operating conditions.

Identifying Desired Levels of GHG Reduction

Desired outcomes and targets may be expressed in three primary ways:

- **Directional – Identifying a direction of impacts desired; in the case of GHG emissions, this would be a reduction in emissions.** Practitioners from State and regional transportation agencies may be hesitant to set specific targets for GHG emission reduction, just as they are often hesitant to set targets for other measures, given concerns about either setting targets too low as to seem unambitious or too high so that they are unattainable. Agencies also are often concerned about the potential ramifications – including public perception – of not meeting targets. Consequently, a simple step is to identify a desired direction to reduce GHG emissions. While setting only a direction for the desired impact does not provide specificity, it can serve as a basis for comparing alternative investment/policy scenarios. It is important to note that in areas with fast growing populations, reducing GHG emissions from on-road sources may be challenging. However, setting a desired direction sends a signal from higher levels of government that decision-makers are interested in committing to GHG reductions.

- **Aspirational – Setting targets based on policy priorities or to signal an issue's importance to the community,** often prior to conducting a detailed analysis to determine actual feasibility. Many of the States and regions that have already begun to set targets for GHG emissions reductions through climate action plans or related policies have set aspirational targets. The following States have established specific statewide GHG emissions targets: Arizona, California, Colorado, Connecticut, Florida, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, and Washington.[44] Although many of these aspirational targets address total GHG emissions from all sources (transportation and otherwise), setting an aspirational target can signal the importance of climate change to policy-makers at the State, regional, or local levels, as well as relevant interest and advocacy groups and the public, all of whom may later have some involvement in project and investment prioritization. Setting aspirational targets may also emphasize the importance of multiple factors – transportation investments, land use, vehicle

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[44] Center for Climate and Energy Solutions, http://www.c2es.org/us-states-regions/policy-maps/emissions-targets.

technologies, fuels, transportation operations, etc. – in reaching targets, since it may be impossible for transportation investment strategies alone to reach the target.

"Target zero" initiatives focused on eliminating roadway fatalities have brought together a wide range of stakeholders involved in traffic safety, including transportation agencies, law enforcement, and public health, to address the causes of crashes. Similarly, an aspirational target for reducing GHG emissions may help to encourage greater partnership among transportation planning agencies, operating agencies, environmental agencies, and policy-makers to consider the wide range of strategies needed. For instance, the Denver Regional Council of Governments (DRCOG)'s board has set a per capita GHG reduction target of 60% below 2005 levels by 2035 from the transportation sector, as well as reduction in "drive alone" commutes and per capita VMT. The GHG reduction target was based on the State GHG reduction targets, but not on a systematic analysis of what was feasible.

- **Analytically-based – Accounting for available resources, trends, policies or strategies in consideration, and other factors that may affect performance, and setting a target that is believed to be attainable**. Developing analytically-based targets requires conducting analyses of potential strategies, understanding available funding, and considering the various factors that influence emissions. This analysis may find that it is not realistic to reduce GHG emissions in the short-term but that long-term policies, such as land use changes and technological changes, can have more notable effects. For instance, the Metropolitan Transportation Commission (MTC) of the San Francisco Bay Area included a set of ambitious targets in its 2035 Transportation Plan, adopted in 2009. These targets were aspirational, and among others, included a target "to reduce carbon dioxide emissions to 40% below 1990 levels by 2035." The Plan clearly identified gaps between aspirational targets and expected outcomes. In the subsequent development of Plan Bay Area, MTC worked with the State of California to develop analytically-based targets in relation to State requirements. These targets call for MTC to demonstrate that its long range plan will reduce per-capita CO_2 emissions from cars and light-duty trucks 7% by 2020 and 15% by 2035, compared to 2005 levels. As was the case in California in the preceding example, realistic targets are often constrained by the decisionmaking status quo and the technical and/or political resources available to set policies or implement strategies.

States and regions that are assessing GHG emissions and setting reduction targets for the first time can refer to existing studies that discuss the magnitude of emissions reduction they might be able to expect as the result of some common strategies before setting targets. There will be an opportunity later in the planning process to revise these targets based on any significant changes in policy, technology, or demographic forecasts, but setting a strong target at the outset helps provide direction for strategy implementation.

The Genesee Transportation Council (GTC) is the MPO that includes nine upstate New York counties and the City of Rochester. The GTC includes fifteen performance measures in its Long Range Transportation Plan (LRTP). Of these fifteen performance measures, one is directly related to GHG emissions reduction (e.g. CO_2e) and one related to direct energy use. Additionally, the LRTP includes four mobility and three accessibility measures, all of which are focused on managing future travel demand. GTC has adopted directional targets in its performance measurement process based upon benchmarks established for each measure. For example, there are estimated to be 11,385 tons/day of CO_2e in the region with a goal of decreasing that amount. These emissions were estimated by post-processing volume and speed data from the GTC Travel Demand Model using methodologies developed in conjunction with NYSDOT. Another example of a directional target in the GTC LRTP is the transit on-time performance measure where the goal is to increase the current 84% on-time performance on transit.

See GTC's LRTP for more information: http://www.gtcmpo.org/docs/LRTP.htm.

Choosing a Timeframe for Analysis

Identifying a timeframe for targets helps determine the target's level of achievability. Analysis periods to be considered include:

- Long-range – twenty or more years in the future
- Mid-range – ten years in the future
- Short-range – three to five years in the future

Determining the time horizon over which outcomes are measured is also important. Given the long lag time for many strategies to take effect – particularly land use changes and large scale transportation investments – a long-term outlook may be particularly useful for GHG emissions and fits within the long range planning process. However, mid-range or short-range timeframes could also be considered. For instance, MPOs addressing conformity might wish to set targets in relation to milestone years. Given the important role of exogenous factors, such as fuel prices and economic growth, which are volatile and have important impacts on GHG emissions, short-range targets may not be as helpful. Thus, it is important to ensure that short-term expectations are not derived in a linear fashion from long-term targets, since programs may take several years to implement and their impacts can increase over time.

7. Identifying Strategies, Analyzing Alternatives, and Developing Investment Priorities

In a PBPP process, performance measures and targets are used to inform decisions on investments and policies. To do so, an agency needs to identify and analyze strategies to assess their anticipated benefits relative to established targets. This information will be valuable to inform decisions on investments and policies that are incorporated into the LRTP and TIP and STIP, as well as potentially to inform broader policy decisions (e.g., related to vehicle technologies and fuels).

Approaches for Using GHG Performance Information in Planning

There are two primary approaches that can be used to integrate GHG performance measures in the plan development process: analyzing GHG performance along with other performance measures during LRTP development, or conducting a focused analysis of GHG reduction strategies that supports the LRTP.

Analyze GHG Performance Together with a Range of Other Performance Measures within LRTP Development

As part of LRTP development and analysis, MPOs will frequently develop alternative investment packages and then conduct modeling analysis to compare the performance of different alternatives across several metrics. For instance, an MPO may develop alternative packages with different emphasis areas, such as increased investments in transit, highway preservation, or management & operations strategies, together with alternative land use policies, and compare the performance across multiple metrics, including mode share (e.g., transit, walk/bike, drive alone), congestion (e.g., vehicle hours of delay), and emissions of criteria pollutants and GHGs. This analysis will inform policy makers of what future GHG emissions are expected to be under different investment scenarios, and allow decision-makers to make informed choices while considering the range of performance outcomes of importance to the region.

Conduct a Focused Analysis of GHG Reduction Strategies that Supports the LRTP

Another approach that a State DOT or MPO could apply is to conduct a focused analysis of transportation GHG reduction strategies to understand key factors affecting GHG emissions and effective strategies, in order to feed into decisionmaking for the LRTP.

Transportation agencies can consider a wide range of GHG reduction strategies, including land use planning, promoting advanced vehicle technologies, encouraging the use of alternative fuels, improving transportation system operations, implementing transportation demand management programs and reducing the carbon footprint of transportation agencies themselves.[45] Specific strategies could

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[45] http://www.ops.fhwa.dot.gov/tdm/index.htm http://www.ops.fhwa.dot.gov/publications/fhwahop12035/index.htm.
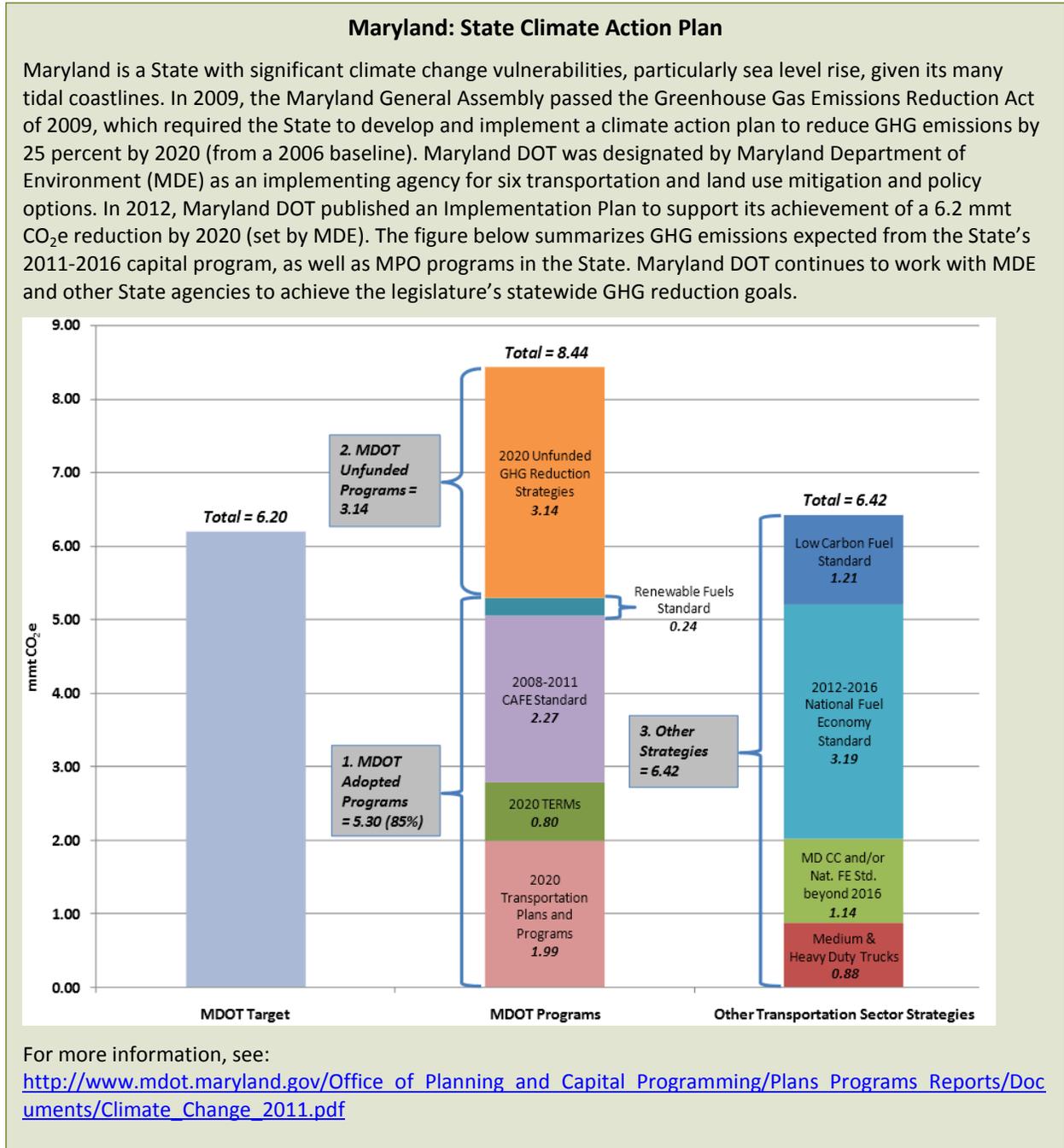
incorporate alternative fuel vehicle infrastructure investment, pricing programs, improved transit services, investments in improved vehicle operations such as through Intelligent Transportation Systems (ITS), accessibility/mobility strategies, walkable communities, provision of transportation alternatives to driving and transit oriented development. Freight strategies might include truck climbing lanes, truck-stop electrification or other projects.

There are a number of resources to help practitioners assess potential strategies. These include the following:

- The U.S. DOT has developed a Transportation Climate Change Clearinghouse that provides information on GHG mitigation strategies and how to evaluate them, as well as links to a wide range of studies and other resources. http://climate.dot.gov/ghg-reduction-strategies/index.html
- FHWA has developed the Energy and Emissions Reduction Policy Analysis Tool to assist States and regions in estimating the impact of transportation strategies. http://www.planning.dot.gov/FHWA_tool/
- FHWA has developed a *Handbook for Estimating Transportation Greenhouse Gases for Integration into the Planning Process*. This resource provides summary information on techniques, methods and models that can be used by planners to estimate GHG emissions impacts of different transportation strategies. http://www.fhwa.dot.gov/environment/climate_change/mitigation/resources_and_publications/ghg_handbook/chapter01.cfm
- EPA has developed the report Analyzing Emission Reductions from Travel Efficiency Strategies: A Guide to the TEAM Approach http://www.epa.gov/otaq/stateresources/policy/420r11025.pdf

A focused analysis of GHG reduction strategies may be particularly helpful to State DOTs, since their LRTPs often set out a key policy direction and strategies, but traditionally have not involved identifying and modeling specific project investments. Although not required by law, this approach could be similar to the approach used in the development of a Strategic Highway Safety Plan (SHSP). In developing an SHSP, a focused safety analysis is conducted, using a data-driven process to understand the source of problems at a detailed level, identify potential solutions (i.e., safety countermeasures), assess the effectiveness of alternative strategies, and prioritize strategies. By bringing together a wide range of stakeholders that play a role in safety – transportation agencies, law enforcement, emergency medical services, etc. – and focusing broadly on the sources of problems, this approach helps support collaborative efforts. If implemented effectively, a transportation-focused Climate Action Plan or sustainability planning effort could function in a similar way. This approach can help to support informed investment decisionmaking and may serve as a catalyst for dialogue between decision-makers at the State and local levels to consider strategies (e.g., land use, incentives, pricing) that may not be traditionally considered in transportation planning by State DOTs.

An example of a State DOT led climate strategy analysis is work conducted by Maryland Department of Transportation in developing its Climate Action Plan.

Maryland: State Climate Action Plan

Maryland is a State with significant climate change vulnerabilities, particularly sea level rise, given its many tidal coastlines. In 2009, the Maryland General Assembly passed the Greenhouse Gas Emissions Reduction Act of 2009, which required the State to develop and implement a climate action plan to reduce GHG emissions by 25 percent by 2020 (from a 2006 baseline). Maryland DOT was designated by Maryland Department of Environment (MDE) as an implementing agency for six transportation and land use mitigation and policy options. In 2012, Maryland DOT published an Implementation Plan to support its achievement of a 6.2 mmt CO_2e reduction by 2020 (set by MDE). The figure below summarizes GHG emissions expected from the State's 2011-2016 capital program, as well as MPO programs in the State. Maryland DOT continues to work with MDE and other State agencies to achieve the legislature's statewide GHG reduction goals.

For more information, see:
http://www.mdot.maryland.gov/Office_of_Planning_and_Capital_Programming/Plans_Programs_Reports/Documents/Climate_Change_2011.pdf

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At the MPO level, the National Capital Region Transportation Planning Board (TPB) at the Metropolitan Washington Council of Governments conducted a "What Would it Take?" analysis in 2010 to evaluate

the types of strategies that would be required to meet regional climate change mitigation targets, including GHG emission reductions.[46] The analysis required a GHG inventory and forecast, which was created using a travel demand model to forecast vehicle miles traveled (VMT) for the years 2005, 2010, 2020, and 2030, and applied MOBILE6.2-generated CO_2 emissions factors to generate CO_2 emissions totals.[47] The analysis addressed a wide range of strategies, including transit investments, eco-driving, and operations strategies.

The Atlanta Regional Commission (ARC), Atlanta's MPO, performed a scenario analysis to compare the long range plan forecasts with various transportation investments and vehicle technological improvements in an effort to understand what actions would be required to reduce on-road GHG emissions to 1990, 2000, or 2010 levels.[48] ARC's analysis used a 4-step travel demand model and MOBILE6, the previous EPA emissions model, to model land use scenarios that described different potential growth patterns.[49] Other examples are provided by California MPOs, which have conducted extensive analysis to show which strategies can be implemented and investments made to reduce light-duty GHGs above and beyond what will be achieved through vehicle technologies and fuels.[50]

An important element of this approach, however, is that it should not be just a stand-alone analysis. The GHG analysis and strategy assessment should directly inform and support investment decisions in the LRTP.

Identifying the Most Appropriate GHG Reduction Strategies

A wide suite of strategies are available to reduce GHG emissions from transportation. It is important that States and MPOs identify the key drivers of GHG emissions in their areas and then analyze potential GHG reduction strategies to assess potential effectiveness in their specific State or regional circumstances. Some of the types of transportation-related GHG reduction strategies that may be advanced by States and MPOs are briefly described below.

VMT Reductions - Light-duty Vehicle Strategies

GHGs from light-duty vehicles can be further reduced beyond what will be achieved through technological developments and regulatory programs, primarily through reductions in VMT influenced by strategies and programs that support travel alternatives. These strategies include:

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[46] MWCOG, "What Would It Take?" Available at: http://www.mwcog.org/clrp/elements/scenarios.asp.

[47] FHWA, "Handbook for Estimating Transportation Greenhouse Gases for Integration into the Planning Process."

[48] Atlanta Regional Commission's PLAN 2040 and associated documents. Available at: http://www.atlantaregional.com/plan2040/documents--tools.

[49] In the time since ARC conducted the scenario analysis using MOBILE6, the EPA has developed an updated model, MOVES. FHWA, "Handbook for Estimating Transportation Greenhouse Gases for Integration into the Planning Process."

[50] Metropolitan Transportation Commission's Climate Change website. Available at: http://www.mtc.ca.gov/planning/climate/.

- **Carpooling and vanpooling programs** that provide an option for motorists to split the costs and externalities of driving alone
- **Bicycling and pedestrian improvements** that encourage greater multi-modal road use
- **Transit improvements**, which provide greater options for motorists to leave their cars at home
- **Teleworking programs**, which give employees the choice to work from home or choose an alternate travel schedule
- **Pricing strategies,** including road pricing, parking pricing, and including Pay as You Drive insurance, influence motorists to drive less and use alternative modes more
- **Land use planning and urban design**, which can reduce trip length, and increase use of transit and non-motorized modes
- **Outreach and education** to increase awareness about the use of alternative modes, the option of teleworking, and other choices that reduce personal costs and GHG emissions from light-duty vehicle travel
- **Incentive programs** to influence more motorists to drive alone less often

By creating more transportation options and influencing travel behavior, these strategies also support other objectives in most regions including improving mobility and travel choices, reducing emissions, developing livable communities, improving access for bicyclists, and improving pedestrian safety. Therefore, such strategies complement and support other regional and/or State objectives.

Vehicle/Systems Operations Strategies

There are a number of actions that State DOTs and MPOs and local communities can take to reduce GHG from transportation system operations. These include the following strategies:

- Managing speed (35-55 MPH is optimal)
- Speed limits/enforcement
- Eliminating bottlenecks
- Smoothing traffic flow
- Improving signal timing
- Roundabouts
- Reducing car and truck idling
- Work zone management to smooth flow
- Congestion pricing
- Encouraging eco-driving

Several of these strategies are routinely included in MPOs' and State DOTs' long range plans because they support other regional and/or State goals and priorities. While these strategies reduce GHG emissions, it is important to recognize that some of them, such as eliminating bottlenecks and improving traffic flow, may facilitate additional vehicular travel that may offset GHG reductions in the long term.

Freight Strategies

Heavy-duty truck GHG emissions are growing faster than other sources of transportation GHGs, and constitute a significant portion of total on-road emissions. An evaluation of GHG emissions from heavy-duty vehicles in seven States found that while the heavy-duty VMT accounted for a relatively small share of total in-state VMT, heavy-duty CO_2 emissions accounted for 20 to 37 percent of total on-road emissions in these States.[51]

MAP-21 established a national freight policy that requires the U.S. DOT to establish a primary freight network of up to 300,000 miles, and requires the development of a National Freight Strategic Plan. With this new focus on freight planning, there may be additional opportunities to address freight-related GHG emissions. Freight strategies that have been identified in various State climate action plans (and some of which are routinely included in State and/or MPO Long Range Plans) are listed below.[52]

- Anti-idling programs
- Truck-stop electrification
- Speed limit enforcement
- Freight villages/consolidation centers
- Feeder barge container service
- Bottleneck reduction
- Traffic flow improvements
- Pre-clearance at scale houses
- Truck driver training
- EPA SmartWay upgrade kits, loans and diesel retrofits
- Improvements to highway grade crossings
- Efficient intermodal facilities
- Incentives to retire older trucks
- Freight logistics improvements
- Shifting freight from truck to rail
- Technologies (Hybrid power trucks; low-viscosity lubricants; single side-base tires; automatic tire inflation systems)

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[51] An evaluation of VMT and on-road CO_2 was conducted for seven states (Michigan, California, Nevada, Maryland, South Carolina, Pennsylvania, and Idaho) and eight metropolitan regions (Atlanta, Denver, Salt Lake City, Chattanooga, Washington, DC, San Francisco, Youngstown, OH, and Burlington, VT). The evaluation found that in the seven states, heavy-duty vehicles accounted for 7%, 8%, 9%, 10%, 10%, 11%, and 18% of total VMT in Michigan, California, Nevada, Maryland, South Carolina, Pennsylvania, and Idaho, respectively. The evaluation also found that heavy-duty vehicle travel accounted for 20%, 21%, 28%, 22%, 26%, 28%, and 37% of total on-road CO_2 emissions in Michigan, California, Nevada, Maryland, South Carolina, Pennsylvania, and Idaho, respectively. This analysis was conducted by ICF International using data from FHWA and these states.

[52] Detailed information on strategies is available in NCHRP 20-24(59) Appendix C, available at: http://climatechange.transportation.org/pdf/nchrp_2024_59_final_report_031309.pdf.

Fuel Efficient Vehicle Technologies and Alternative Fuels

The introduction of more fuel efficient vehicles and alternative fuels can reduce GHG emissions. While vehicle fuel efficiency standards have been primarily implemented at the Federal level to date, California has the legal authority to adopt more stringent vehicle technology standards to reduce air emissions. Other States may adopt California standards. States can influence the adoption of new vehicle by purchasing these vehicles for their own fleets. Tax breaks or subsidies for new vehicle technologies may also be adopted at the State or regional level. New vehicle technologies may also be given other special preferences. For instance, California law allows single-occupant use of high occupancy vehicle (HOVs) lanes by certain qualifying clean alternative fuel vehicles.

The use of low carbon fuels is another important strategy that can be promoted at the State or regional level to reduce GHG emissions. States and localities have been involved in promoting a range of alternative fuels, including natural gas (CNG, LNG), propane, biofuels (ethanol, biodiesel) and electricity. States and regions can promote the installation of alternative fuel filling stations or electric vehicle charging stations. A number of agencies have prepared electric vehicle readiness studies to plan for electric vehicle use. Alternative fuel mandates in some States have been used to require the mixture of biofuels, such as biodiesel, into the fuel supply. Lower fuel tax rates on alternative fuels may also provide an incentive for their use. California has adopted a low carbon fuel standard that provides a fuel-neutral mechanism to promote lower carbon fuel use.

Developing an Investment Plan: Analyzing GHG Emissions to Inform Investments and Policy Priorities

As noted earlier in the section on developing a baseline, GHG emissions forecasts are typically developed using a combination of travel demand forecasting models and emissions models. Scenario planning is a tool that can also be important for emissions forecasts, and allows for the comparison of different investment plans on State and/or regional objectives and goals. Scenario planning is fairly common at the MPO level, as MPOs use their travel demand models to assess alternative packages of investments. In general, scenario planning is more useful when sub-area performance measures are also reported because the more flexible the model, the easier it is to use as a tool for answering particular questions that arise during the public involvement process.

At the State level, a challenge is that many LRTPs are largely policy-documents or corridor-based, and even if investments are identified, forecasting models may not be available to analyze investments. Still, State DOTs could conduct analyses of alternative policies and strategies, much like the analyses that have been conducted by States as part of Climate Action Plans.

The Puget Sound Regional Council (PSRC) developed its Long Range Regional Plan using five different scenario alternatives. Climate change was a factor considered in developing scenarios, but there were also many other components. Through the public participation process, climate change became such an important priority that GHG reduction strategies were included in the final scenario plan, and GHGs were used in the prioritization criteria. The most recent long range plan, Transportation 2040, has a four part strategy that includes Land Use, Transportation Pricing, Transportation Choices, and Technology. The results of the investments and strategies contained in Transportation 2040 are illustrated in the figure below. The combination of the four-part strategy results in a range of emissions reductions (between 5 percent likely technology scenario and 28 percent aggressive technology scenario) below 2006 modeled emissions. As compared to the 2040 Baseline trend, the preferred alternative results in emissions reductions between 31 percent and 48 percent.

FIGURE 18. Greenhouse Gas Emissions (CO2 Emissions in Millions of Tons)
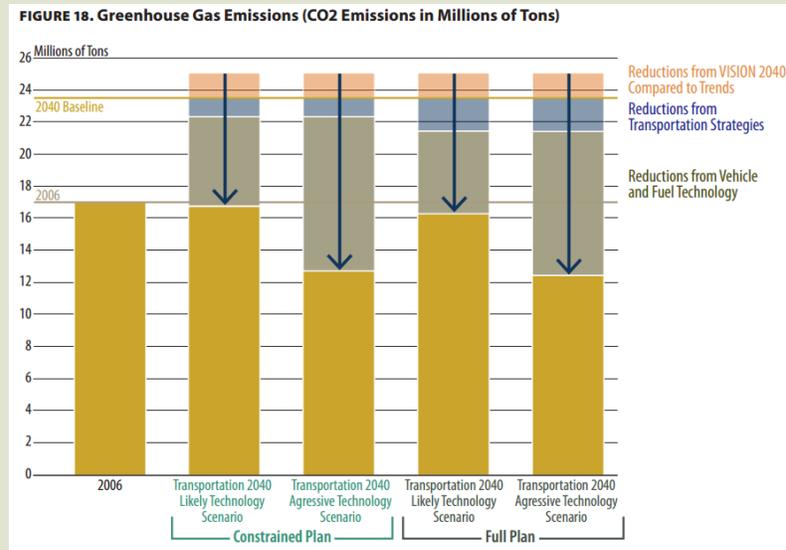
Source: Puget Sound Regional Council, *Transportation 2040,* Chapter 3 and Appendix L, available at:
http://www.psrc.org/transportation/t2040/t2040-pubs/final-draft-transportation-2040

Recognizing the limitations of most travel models to address strategies such as demand management and incentives, Oregon DOT developed the GreenSTEP Model to test various scenarios for reducing transportation sector GHG emissions. This tool is the basis for the Energy and Emissions Reduction Policy Analysis Tool (EERPAT) tool, which is being promoted by FHWA as a statewide GHG policy analysis tool for providing rapid analysis of many scenarios that combine effects of various policy and transportation system changes. EERPAT is an open source tool and is designed to be adapted and used by other States. EERPAT is sensitive to a variety of different policies, including carbon taxes, policies that incentivize the introduction of low carbon vehicle technology, public policies that incentivize fleet turnover, policies to increase transit capacity and ridership, policies to promote intercity rail and bus transport, policies that improve walkability and transit access, urban growth boundaries and household and business transportation demand management programs.

The impacts of these policies may overlap each other and in many cases the benefits of individual strategies may not be additive when used together. The EERPAT model accounts for this, and incorporates various secondary effects of policies. For instance, the model accounts for the rebound effect when fuel economy improvements are implemented. By re-calculating household budgets to

include fuel economy savings due to new vehicle technologies, EERPAT incorporates potential increases in demand for VMT caused by lower travel costs.

Metropolitan GHG Reduction Targets and Scenario Planning
Portland Oregon

In 2007, the State of Oregon adopted a goal to reduce all GHG emissions to 75% below 1990 levels by 2035. The State Land Conservation and Development Commission (LCDC) adopted GHG reduction targets in 2011 to help guide the State's MPOs as they conduct scenario planning which is required in the Portland and Eugene/Springfield areas, as part of the statewide effort. The other MPOs are not required to conduct scenario planning but may do so on a voluntary basis. Targets were set based on an assessment of what is possible to be accomplished at the metropolitan level. These targets call for a 17-20% reduction in transportation-related GHGs in each metropolitan area by 2035 in order for the State to meets its 2050 goal. State law (HB 2001) requires Metro and the Portland metropolitan area local governments to develop and select a preferred land use and transportation scenario that achieves the GHG emissions reduction targets. Portland Metro's Climate Smart Communities scenario planning process includes six desired regional outcomes which serve as guiding principles for the Climate Smart Communities Project. Metro's scenario planning process identified evaluation criteria that could assess scenario performance on all of the region's six desired outcomes. Climate Smart Communities Scenarios Project: Strategies Toolbox discusses the scenario planning process in detail and the various strategies researched.

www.oregonmetro.gov/index.cfm/go/by.web/id/36945

Assessing Tradeoffs and Understanding Co-benefits

A challenging part of PBPP is to consider how an agency will weigh tradeoffs among different goals areas. For example, how will GHG reductions be weighted in comparison to criteria pollutant emissions reductions? Or more broadly, how important is GHG reduction in comparison to safety or economic development? Are there strategies that generate a win-win for multiple goal areas? This balancing of goals and priorities is achieved through qualitative and quantitative analysis and most importantly through the decisions made by policy makers about relative priorities within a region.

One of the advantages of many GHG reduction strategies is that they tend to support other regional and State goals that are typically included in LRTPs. For example, transit investments support mobility, access to jobs, increasing travel choices, reducing emissions and reducing VMT and GHGs. Another example is improving rail-freight grade crossings. These investments may improve traffic flow, reduce particulate matter (PM) emissions, encourage rail freight, and reduce energy consumption and GHGs. Many of the other types of investments that State DOTs and MPOs traditionally make also can support

reducing GHGs. There are also co-benefits in that many strategies reduce multiple pollutants of concern (e.g. VOCs, NOx, CO, PM-10, PM2.5, etc.).[53] Other examples of co-benefits include:

- Increase in physical activity,
- Improvement in roadway safety,
- Reduction in household transportation costs,
- Economic development, and
- Cost savings for local agencies.

The Sacramento Area Council of Governments (SACOG) tested seven policy scenario options as part of the GHG target setting required by State law. The work was done to inform SACOG and others of the GHG reduction potential of various scenario options, each of which was focused on expanding a policy bundle. The scenarios included land use enhancements, transit enhancement, system and demand management enhancement and pricing. Two scenarios assessed the possibility of combining elements of these policy bundles.

SACOG staff have made a concerted effort to ensure that various considerations are being measured from a consistent base so that each scenario is evaluated using the same data. The decision makers do not use a scoring system, but they do look at all of the possible outcomes and assess what strategies do and do not work well together. SACOG highlights the co-benefits of its strategies as a way to convince decision makers how to get the best return on transportation investments. SACOG addresses trade-offs by creating scenarios that revolve around specific priorities so that decision makers and the public can develop their own opinion of the best scenarios. The final plan includes just one scenario that is a combination of the best elements from 3 or 4 other near-final scenarios.

See a description of SACOG Scenario Testing:
http://www.arb.ca.gov/cc/sb375/mpo/sacog/sacog.rtac.scenarios.pdf

Prioritizing Projects for Funding

Performance information can be used to prioritize projects for funding. Although project-level emissions analysis is not typically conducted in relation to performance measures, States and MPOs can use quantitative or qualitative information to assess how different projects or more likely, groups of projects, contribute to different goals. For instance, DRCOG in Denver, CO estimates emissions impacts of transit passenger facilities projects, bus service projects, new bicycle and pedestrian projects, and air quality improvement projects, and uses this information as part of a scoring matrix to prioritize projects.[54] High scores are awarded to those projects that aim to reduce the largest amount of emissions as a percentage of the regional total. The Puget Sound Regional Council in Washington State has

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[53] See FHWA, Multipollutant Emissions Benefits of Transportation Projects, While CO_2e was not investigated as part of this effort, many of the transportation emissions reduction strategies available to State DOTs and MPOs would also reduce CO_2e. https://www.fhwa.dot.gov/environment/air_quality/conformity/research/mpe_benefits/mpe01.cfm

[54] Denver Regional Council of Governments. Policy on Transportation Improvement Program (TIP) Preparation. 2010. Available at: http://www.drcog.org/agendas/DRAFT%202012-2017%20TIP%20Policy-MVIC%20Version.pdf.

discussed the concept of creating approaches, such as monetizing benefits, which allow projects to be prioritized using criteria that are relatively comparable and also allow for cost-benefit analyses. Monetizing benefits would also be useful because State officials have limited funding for transportation, and monetizing benefits could provide a mechanism to raise the priority of GHG reduction projects relative to other traditional transportation improvements that can be monetized.

Another approach is to designate specific funding for transportation climate change initiatives and prioritize funding based on estimated GHG reduction potential or cost-effectiveness. The MTC in the San Francisco Bay Area has developed a Climate Initiatives Program, which specifically was designed to fund programs that reduce GHG emissions, and have other co-benefits.

Integrating greenhouse gases into planning and programming in Massachusetts - In 2008 Massachusetts passed the Global Warming Solutions Act that requires the State to set a goal for reduction and create transportation plans that are consistent with that goal. The goal has been set at a 25 percent reduction by 2020 in GHG emissions from a 1990 baseline.

Long-range planning documents, including statewide planning documents (e.g. the Strategic Plan, State Freight Plan, and MassDOT Capital Investment Plan), as well as the long-range Regional Transportation Plans from the Metropolitan Planning Organizations (MPO), must address MassDOT's three sustainability goals and plan for reducing GHG emissions over time. Similarly, the shorter-range regional and State Transportation Improvement Programs (TIPs and STIP), under which particular projects are chosen for funding in the coming four years, must be consistent with the Commonwealth's GHG reduction target. This will require that the MPOs and MassDOT balance highway system expansion projects with other projects that support smart growth development and promote public transit, walking and bicycling. In addition, the project programming mix included in the RTPs, TIPs and STIP can contribute to GHG reduction through prioritizing roadway projects that enable improved system operational efficiency, without expanding overall roadway system capacity. Currently the TIPs provide a numerical ranking for projects on several different factors, including their contribution to GHG emissions.

MassDOT and the MPOs have developed approaches for identifying the anticipated GHG emission impacts of different project types. All TIP projects have been sorted into two main categories for analysis: projects with quantified impacts and projects with assumed impacts. Projects with quantified impacts consist of capacity-adding projects from the LRTP and projects from the TIP that underwent a CMAQ spreadsheet analysis. Projects with assumed impacts include projects that would be expected to produce a minor decrease or increase in emissions and projects that would be assumed to have no CO_2 impact.

For more information see Appendix C: Greenhouse Gas Monitoring & Evaluation.
http://www.ctps.org/Drupal/data/html/plans/TIP/FFYs_2014_2017_Draft_TIP.html#appc

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Since the transportation planning process is continuous, transportation plans and TIPs are updated periodically and State DOTs and MPOs routinely adjust program priorities based upon changing circumstances and resource constraints. As the new performance requirements included in MAP-21 are implemented, State DOTs and MPOs are expected to begin setting clear performance targets and using those targets to inform investment decisions in the required areas. If an MPO or State DOT chooses to adopt GHG reduction targets as part of their PBPP and as a means to support the environmental sustainability goal under MAP-21, then GHG reductions can be considered as an additional return on potential project investments.

8. Monitoring, Evaluating, and Reporting on GHG Performance

The goal of PBPP is to use performance data to inform and influence decisionmaking, especially with respect to the allocation of scarce resources. *Monitoring system performance* and *evaluating programs and projects* are the two key activities involved in the feedback loop that is part of a PBPP process. In the context of PBPP, it is important to distinguish between monitoring system-level performance and evaluating performance of investments, given the limited control that transportation agencies have over some outcomes. Reporting is the process through which performance is conveyed to various constituencies including policy- and decision-makers and the general public.

Monitoring GHG Emissions Performance

Monitoring provides information on actual conditions on a periodic basis and allows for periodic assessment of whether targets have been or are likely to be attained. Data collected informs transportation decision-makers about progress made toward goals and targets. Monitoring plans address issues such as what is being tracked, what data need to be collected, who will collect it, how it will be collected, where it will be stored, and how it will be reported back to the end user.

For GHG emissions, one key challenge is that monitoring requires some form of calculation or modeling since emissions are not directly "measured." If using fuel consumption as a more direct measure to calculate GHG emissions, it is important to recognize that fuel consumption data may not align well with VMT data used for forecasting and analysis within the planning process. However, on-going development of GHG inventories will provide a useful context both for overall State and regional performance, changes in the contributions of different sources to emissions, and for understanding factors that have influenced those changes.

Monitoring system performance is an ongoing process. For certain metrics, such as those related to safety and congestion, data may be compiled annually, quarterly, or even monthly or more often. For GHG emissions, annual reporting, or reporting in relation to each LRTP update, is likely the most appropriate reporting cycle.

Evaluating Performance

Evaluating performance is the process of taking information and drawing inferences as to why performance on various measures changed; in other words, interpreting the results. It goes a step beyond monitoring and tracking and attempts to understand whether implemented strategies have been effective in contributing toward positive performance outcomes. Two types of evaluation may be conducted:

- **System-level performance evaluation** - Regional analysis to assess the extent to which transportation investments and policies have contributed toward a target;
- **Project-level or program-level analysis** to assess impacts of specific strategies.

System-level Evaluation

Identifying the system-wide effects of transportation agency programs and activities is difficult, and requires modeling a "business as usual" or counterfactual scenario to see what GHG emissions would have been absent the implementation of GHG reduction strategies. System level evaluation incorporates the impacts of many different specific projects and programs. Ideally system level performance evaluation should focus on the outcomes achieved by the transportation system. For instance, the Central Lane MPO in Oregon uses internal VMT/capita, average trip length and % of person trips under one mile to evaluate the sustainability of its transport system performance and its long range plan. Mode shares for walking, bike, transit, or shared ride auto are also used. System characteristics such as bikeway miles, transit service hours per capita and percent of households within ¼ mile of a transit stop are included in their evaluation process. These measures are only indirect measures of GHG emissions, since changes in technology have reduced GHG emissions per VMT.

Some agencies have assessed the air quality and GHG emissions impacts of reductions in congestion on a system-wide basis using the MOVES model. More direct measures of transportation GHG emissions include total transportation GHG emissions for a region or transportation GHG emission per capita. These measures are less directly linked to specific transportation policies. System level evaluation can be more challenging since there are so many different policy, technology, and economic factors that affect GHG emissions at the system level, and transportation agencies may have only indirect influence over many of these factors. More commonly, evaluation focuses on a specific set of strategies or programs.

Project or Program-level Analysis

A State DOT or MPO can fund studies to measure the effectiveness of particular strategies or projects by examining conditions before and after, or with and without, a strategy of interest. For instance, a study could be conducted to quantify VMT reductions or mode shifts of a transportation demand management (TDM) program, to quantify the speed improvements associated with traffic flow improvement projects, to examine the reduction in vehicle delay associated with operational strategies, or other similar types of impacts. Projects and programs can be evaluated in terms of their emission reduction cost effectiveness, co-benefits, and on other criteria. The specific methods for determining impacts will vary from project to project; however, a common analytical framework can be applied to ensure an "apples to apples" comparison. This section describes a basic framework for evaluation and some of the concepts and components that should be considered. These include:

- Transportation Impacts
- Emissions Impacts
- Costs and Cost-Effectiveness
- Co-Benefits
- Lessons Learned

Transportation Impacts

The two most common types of impacts for projects or programs that reduce GHG emissions are reduced VMT and reduced emissions per mile (from cleaner vehicles, or eco driving for example). Some projects may not fit neatly in either of these two categories and may require tailored approaches.

VMT Reduction Projects / Programs - The methods for determining VMT reduction will vary by project. In general, these projects are more difficult to evaluate than clean vehicle projects because they require measurement of behavior change.

A preferred approach is to measure travel behavior before and after the project or program implementation. This can be done through a survey – by telephone, by mail, by internet, online, and/or in person. The appropriate data collection methodology (or combination of methods) will depend on the nature of each project. In general, the respondent is asked about their travel behavior (trip frequency, mode, trip distance, etc.) before the project occurs, and then is asked similar questions after the project. For some projects like bicycle or pedestrian projects, counts of pedestrian and bicycle activity before and after the project may be sufficient to estimate changes in vehicle trips and therefore VMT.

A major challenge with the before and after survey approach is that it is resource intensive. Another challenge is that, in some cases, the target population (e.g., users of a new bikesharing station) will not be known until the project has been implemented, so conducting a "before project" survey is not possible.

Evaluation of some projects may require the use of a control group – a similar population that is not subject to the project activities and is surveyed and monitored for behavior change like the target population. An alternative approach is to survey participants to ask how they traveled prior to the new project/service, or how they would have traveled in the absence the project/service. This "retrospective surveying" has been the approach taken in several evaluations of bikesharing programs, for example. Accuracy may be a challenge with this approach, particularly if respondents are asked to speculate about hypothetical travel or recall travel that occurred more than several weeks in the past.

A challenge with either approach is a bias toward what is perceived as the socially desirable answer. Some respondents will overstate their reduction in automobile use, for example, knowing that it is a goal of the project and considered more acceptable by society. This potential source of bias is a chief concern – and it may dictate the use of split-sample and/or more complicated questionnaires in order to minimize or mitigate its impact.

An additional challenge when sampling to estimate the impacts of a project or program is that sample size will determine, to some degree, the ability of the research to measure statistically reliable changes in behavior. The smaller the program impacts, all other things being equal, the larger the sample needed to measure the impacts. For each project, therefore, the appropriate sample size needed to evaluate the program will depend, in part, on the expected magnitude of impact needed for the project to be deemed "successful".

When determining VMT impacts, it is important to account for all vehicle activity affected by a project/program. In some cases, a reduction in automobile VMT may be offset by an increase other vehicle activity. For example, evaluation of a new shuttle service should account for the travel and emission of the shuttle itself. A bikesharing program may generate new VMT from the vehicles required to redistribute bicycles among stations.

Reduced Emissions per Mile (Clean Vehicles, etc.) - Some project evaluations will focus on the introduction of cleaner vehicles. In general, these types of projects require the collection of data on vehicle activity (VMT) as well as the fuel source used. For electric vehicles, charging information (charge duration, time of day, metered energy use) would be collected. It may also be important to account for the differences in emissions per kilowatt hour for base load and peak power usage for vehicle charging. In general, it may be important to account for life-cycle emissions for different types of fuels, including conventional fuels. For instance, fugitive emissions from natural gas vehicles or pipeline transmission may add significantly to the tailpipe emissions of natural gas vehicles. It is typical to assume that a low emission vehicle project would not change the demand for travel, unless project data suggests otherwise.

Emissions Impacts

Impacts on GHG emissions can be calculated by applying emissions factors to estimates of vehicle travel. The factors used to calculate GHG emissions impacts should be consistent across evaluations while at the same time reflecting the specific nature of the transportation activity changes. As discussed earlier, the MOVES model is one national source for emissions factors. It may be important to develop factors specific to a project in some cases. For example, if a project is replacing travel by older vehicles, emission factors could be created that reflect only vehicles of the relevant model years. If a project is eliminating only highway travel, emission factors could be created that reflect highway speeds.

Costs and Cost-Effectiveness

Project or program evaluations should consider evaluating the cost-effectiveness of program expenditures. Project cost-effectiveness can be determined by dividing the project costs by the emission reduction. Project costs can include multiple components. For example, costs could include only the regional agencies public expenditure, agency expenditures plus other State and local government costs, all government and private sector costs, or all costs from a societal perspective. Ultimately, the appropriate cost definition depends on how the cost effectiveness metric will be used.

For calculations of cost effectiveness, consider evaluating cost in two ways:

- Total public cost – Sum the public expenditures (including Federal, State or local government match). This measure of cost effectiveness allows for "apples to apples" comparison across projects and identifies what are the most cost effective ways for public agencies (as a whole) to reduce GHGs.
- Total cost – Sum public expenditures, in-kind costs used as a local match, and private funding.

Costs to users, such as a reduction in automobile ownership costs, can be assessed as a co-benefit.

A key concept in cost-effectiveness analysis is the "lifetime" of the emission reduction. For projects that provide an on-going service, like support for a ridematching program or a new shuttle service, it can be assumed that the emissions benefits last only as long as the program is in place. Thus, one year of funding buys one year of emission reduction. But other types of projects may have emissions benefits that remain after the grant funds have been expended. This is true of most infrastructure projects, for example.

There are a variety of approaches for addressing this issue in a cost-effectiveness calculation. In general, they seek to determine the average annual cost over the lifetime of the emission reduction. For instance the methodology typically used by the California Air Resources Board (CARB) for determining emission reduction cost-effectiveness[55] involves calculating an "annualized capital cost", which is the amortization of the one-time incentive grant amount for the life of the project. In effect, the annualized capital cost is the expected yearly return if the total capital cost were invested over the lifetime of the project.

It is important to select an appropriate discount rate for the cost-effectiveness calculations. Some State agencies use a 4% discount rate, which is intended to reflect the prevailing earning potential for State funds that could reasonably be expected by investing in various financial instruments. A lower rate may be needed to reflect current investment conditions. In San Francisco, MTC has used 2.2% discount rate for some analyses.

Some projects may also have annual operations and maintenance (O&M) costs in additional to an initial capital investment. If so, the average annual operating cost can be added to the annual capital cost.

While cost-effectiveness calculations can often help to prioritize GHG emission-reducing projects for funding, it is important to note that co-benefits, which are not typically included in cost-effectiveness calculations, should supplement the dialogue. It is difficult to express through a cost-effectiveness calculation the more holistic benefits of emission reductions, and so it is recommended that cost-effectiveness serve as only one piece of the discussion about the need for emission-reducing program investments. A more complete discussion of co-benefits is given below.

Co-Benefits

Many GHG mitigation projects and programs have associated co-benefits in addition to GHG emission reduction. Such co-benefits might include congestion reduction, increased walkability, enhanced travel options, and reduced criteria pollutants, among others. Identifying these co-benefits, and, to the extent possible, assessing them in a quantitative or qualitative manner, can contribute significantly dialogue

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[55] See for example, Air Resources Board, The Carl Moyer Program Guidelines, 2008, available at:
http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm

about GHG emission reduction strategies. The specific co-benefits and methods for assessing them will differ from project to project.

In addition to identifying and perhaps quantifying the co-benefits of new GHG reduction strategies, it is important to highlight GHG emissions reductions as a co-benefit on many existing transportation projects and programs. As an example, policies or activities in place to reduce congestion or energy use have the added benefit of reducing GHG emissions. Doing so can help express to decision-makers the idea that GHG emissions reductions strategies are not new and not altogether unfamiliar.

Lessons Learned

Among the key objectives of an evaluation is to learn from the individual projects and programs that are being implemented in the field. One approach to creating lessons learned is to use a summary assessment approach to identify the key lessons learned from each project and program, and assess how replicable it is to expand the projects/programs on a much broader scale.

The specific questions and approach for determining lessons learned will vary from project to project. Some projects have no precedent in a region or State and an evaluation can provide a wealth of new lessons learned concerning every aspect of the project. Other project types may have a history of implementation and past evaluation. An evaluation in these cases will focus on understanding what changes could make such projects more effective in the future. In general, an evaluation of lessons learned could consider the following issues and questions:

Effectiveness - What are the project's keys to success? How did measured project impacts compare to forecasted impacts? What might be the reason for any differences? What changes would have made the project more effective? What changes would increase its adoption?

Replication - What factors need to be in place for the project to be successfully replicated? What is the extent of potential replication? If the project were replicated elsewhere, would we expect the cost effectiveness to change?

Scalability - To what extent could the project be increased in scale (e.g., to larger target populations or larger geographic areas)? If the project were scaled up significantly, would we expect the cost effectiveness to change?

Duration of Impacts - Will benefits persist once the project has ended? How long can they be expected to persist? What changes would help to maximize the duration of benefits?

Role of Technology - To what extent did the project contribute to deployment or adoption of new technologies? How will new and emerging technologies affect the project? Could new technologies make similar projects more effective in the future, or irrelevant or unnecessary in the future?

One example of a program evaluation is the Metropolitan Transportation Commission's (MTC) evaluation of their Climate Initiatives Program. In December 2009, MTC, the transportation planning commission for the nine-county San Francisco Bay Area, programmed $80 million over a three-year period for a number of initiatives meant to reduce GHG emissions associated with transportation. These initiatives included:

- The purchase of electric vehicles and charging stations, electrifying car sharing, a demonstration of battery electric vehicles for San Francisco neighborhood taxis and deploying bay area electric vehicle infrastructure;
- Demonstrating dynamic ridesharing technology in three counties, developing bike sharing programs, parking pricing pilot programs and various other TDM programs;
- Development of school transportation "green teams", funding for a bike repair and encouragement vehicle and other school transportation programs; and
- The Green My Ride Program, a TDM program that merges municipal fleet operations, electric vehicles, and carsharing into a Guaranteed Ride Home for employees.

MTC initiated an evaluation program to measure the costs and benefits of these programs. The focus of the effort was to determine the effectiveness of these programs and projects at reducing GHG emissions. Survey data was used to evaluate some of these projects, but other qualitative and quantitative methodologies were also used. The evaluation included the creation of a baseline scenario and an estimation of transportation impacts, emissions impacts, costs and co-benefits, and a description of lessons learned.

Another example of a program evaluation includes efforts by the National Capital Region Transportation Planning Board (TPB) at the Metropolitan Washington Council of Governments in the Washington, DC region to quantify the effectiveness of its Commuter Connections TDM program. TPB conducts a regional State of the Commute Survey, along with additional surveys such as a Guaranteed Ride Home Program survey and tracking of participation rates in programs, in order to analyze the vehicle travel reductions and air quality improvements associated with the program.[56]

Another approach is for the State DOT or MPO to develop guidance for evaluating strategies, and require local project sponsors to conduct evaluations of their projects and programs. Guidance can be provided on when an assessment should be done, what measures should be used, how data should be gathered, what methods should be used to analyze the data, and other aspects of evaluation studies. This approach is appropriate where partner agencies are responsible for implementation of strategies.

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[56] See the most recent State of the Commute Survey Report from 2010 available online at http://www.mwcog.org/store/item.asp?PUBLICATION_ID=415.

Reporting and Communicating Performance

The way in which information about system performance in comparison to targets is communicated to policymakers and the public can have significant implications for agency and program support. Effective reporting tells a story and explains the societal trends (e.g., land use changes, demographic changes) and other factors that may be influencing results. Transportation organizations communicate performance results to a number of different audiences. First, the organizations collect and analyze data and circulate performance results internally. In addition, they report results both to the general public and to leaders and policymakers. In the case of the public and policymakers, simple graphics, visuals, and dashboards can be useful for communicating information in ways that the public can understand. Moreover, it is important to not just present information, but also to provide context for trends to tell a story about why performance has changed. To the extent possible, visuals should show past performance to provide context for current results. In addition, where appropriate, the organization can also provide counterfactual information, for example, about performance that would have been expected without the investments that were made. This can be particularly relevant for GHG emissions, given the many factors affecting GHG emissions that are beyond the control of transportation agencies.

Additionally, effective communication regarding GHGs could serve as a catalyst for interagency partnerships to reduce surface transportation GHG emissions. State DOTs, MPOs, local governments, State legislatures, the private sector, developers, the auto industry, and other stakeholders play an important role in reducing GHG emissions based on their roles in land use decisionmaking, road use pricing (including consideration of strategies such as VMT-fees, pay-as-you-drive insurance, and fuel taxes), speeds limits and enforcement, and creating incentives for purchasing fuel efficient vehicles, among other strategies. Consequently, communicating information about GHGs could help to engage discussions among these partners.

> **Caltrans Regional Progress Report**
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> California DOT's Regional Progress Report is part of an ongoing State effort to understand the intersection between land use, mobility, housing, infrastructure and natural resources preservation as they relate to a region's economic vitality, quality of life, and environmental quality. In 2007, the first California Regional Progress Report introduced regional quality of life indicators based on Regional Blueprint Planning goals. The 2010 Report builds on the foundation laid in 2007, but expands upon it to help meet the State's need for coordinated sustainability planning and assessment.
>
> The Report is available at:
> http://www.dot.ca.gov/hq/tpp/offices/orip/Collaborative%20Planning/California_Regional_Progress_Report.html

9. Relevant Resources

This document builds on a wide range of resources that focus on specific issues in relation to this document. The references below may be helpful for further information.

Performance-based Planning and Programming References

AASHTO, *A Primer on Performance-Based Highway Program Management: Examples from Select States,* January 2008. Available at: http://www.ampo.org/assets/1012_primeronperforfmancebased.pdf.

AASHTO, *Executive Roundtable on Performance-based Planning and Programming*; held October 22-23, 2009, in Palm Desert, CA.

FHWA and FTA, *Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach – A Guidebook.* Prepared by ICF International and SAIC, February 2010. Available at: http://ops.fhwa.dot.gov/publications/fhwahop10026/index.htm.

FHWA and FTA, *Incorporating Performance Measures into Regional Transportation Planning: Peer Exchange*; held February 24, 2010 in Washington, D.C. Available at: http://planning.dot.gov/Peer/WashingtonDC/dc_2010.asp.

FHWA and FTA, *Performance-based Planning and Performance Measures: Peer Exchange;* held July 13, 2010 in Minneapolis, MN. Available at: http://planning.dot.gov/Peer/minnesota/minneapolis_2010.pdf.

FHWA, *Asset Management and Management of Highway Performance;* held August 17, 2009 in Washington, DC. Prepared by Cambridge Systematics. Available at: http://www.ampo.org/assets/1010_fhwapeerexhange.pdf.

FHWA, *Performance-Based Planning and Programming Guidebook* (forthcoming, 2013). Prepared by ICF International.

FHWA, *Performance-based Planning and Programming White Paper*, Prepared by Cambridge Systematics, May 2012. Available at: http://www.fhwa.dot.gov/planning/performance_based_planning/resources/white_paper/.

FHWA, *Roundtable on System Performance Measurement in Statewide and Metropolitan Transportation Planning: Peer Exchange;* held October 7-9, 2003 in Washington, DC. Prepared by the Volpe Center. Available at: http://www.planning.dot.gov/Peer/PerfMeasRT/PerfMeasRT.asp.

NCHRP 20-24(37), *Measuring Performance among State DOTs: Sharing Good Practices.* Project series available at: http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=543.

NCHRP 20-24(58), *National Forum on Performance-Based Transportation Planning and Programming*, held in Dallas, Texas, September 13-15, 2010. Prepared by Cambridge Systematics. Materials available at: http://planning.transportation.org/Pages/NationalForumonPerformance-basedPlanningandProgramming.aspx.

NCHRP 25-39: Environmental Performance Measures for State Departments of Transportation, http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3190 (forthcoming).

NCHRP Report 446, *A Guidebook for Performance-Based Transportation Planning*, Prepared by Cambridge Systematics, 2000. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_446.pdf.

NCHRP Report 666, *Target-Setting Methods & Data Management to Support Performance-Based Resource Allocation by Transportation Agencies: Volumes I and II; Volume III: Case Studies*. Prepared by Cambridge Systematics. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_666.pdf.

NCHRP Report 708, *A Guidebook for Sustainability Performance Measurement for Transportation Agencies*, Prepared by TTI, 2011. http://www.trb.org/Main/Blurbs/166313.aspx.

TRB, *Performance Measures to Improve Transportation Planning Practice: Peer Exchange;* held May 6, 2004 in Charleston, SC. Prepared by the Volpe Center. Available at: http://onlinepubs.trb.org/onlinepubs/circulars/ec073.pdf.

Integrating Climate Change Considerations and Analysis into Planning

California Air Pollution Control Officers Association, "Quantifying Greenhouse Gas Mitigation Measures," August 2010, http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf.

California Air Resources Board Regional Targets Advisory Committee "MPO Self-Assessment of Current Modeling Capacity and Data Collection Programs." 2009.

California Senate Bill 375, Chapter 732, Statutes of 2008, "Sustainable Communities and Climate Protection Act of 2008" http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.pdf.

California Transportation Commission, "2010 California Regional Transportation Plan Guidelines," April 7, 2010, http://www.dot.ca.gov/hq/tpp/offices/orip/rtp/index_files/2010%20RTPGuidelines_Jan2011_Technical_Change.pdf.

Center for Clean Air Policy, "Overview of GHG Planning Capacity Building and Technical Assistance Resources," for U.S. Federal Highway Administration, May 2011.

FHWA, "Climate Change – Model Language in Transportation Plans", Prepared by ICF International, 2010. http://www.fhwa.dot.gov/environment/climate_change/mitigation/resources_and_publications/model_language/index.cfm.

FHWA, *Handbook for Estimating Transportation Greenhouse Gas Emissions for Integration into the Planning Process*. Prepared by ICF International. Forthcoming, 2013.

FHWA. "Integrating Climate Change into the Transportation Planning Process", Prepared by ICF International, 2008. http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/integrating_climate_change/index.cfm.

Gallivan, Frank, Michael Grant, and John Davies, "Improving the Transportation Component of State Greenhouse Gas Inventories," paper developed for 17th Annual International Emission Inventory Conference, Portland, OR, June 4, 2008.

NCHRP 20-24 (64), "Assessing Mechanisms for Integrating Transportation-Related Greenhouse Gas Reduction Objectives into Transportation Decision Making," Prepared by ICF International, January 2010, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w152.pdf.

NCHRP 25-25 (58), "Greenhouse Gas Calculator for State Departments of Transportation (GreenDOT), "Prepared by ICF International.

NCHRP 25-25(17), "Assessment of GHG Analysis Techniques for Transportation Projects," Prepared by ICF International, May 2006.

NCHRP 25-25 (65), "Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments," Prepared by ICF International, July 2011, http://climatechange.transportation.org/pdf/NCHRPGHGGuidelinesJuly152011.pdf.

New York State Department of Transportation, "Air Quality Analysis of Transportation Improvement Programs, Regional Transportation Plans, and Capital Project programs – Technical Guidance to Assist Metropolitan Planning Organizations and Department of Transportation Regional Offices Meet the Objectives of the 2002 New York State Energy Plan," January 21, 2003.

Oregon Department of Transportation, "Greenhouse Gas Toolkit," http://www.oregon.gov/ODOT/TD/TP/GHGToolkit.shtml.

Schmidt, Nicholas and Michael Meyer, "Incorporating Climate Change Considerations into Transportation Planning," Transportation Research Record, No. 2119, 2009, pp. 66-73.

Southern California Association of Governments, "SCAG SB 375/SCS Technical Methodology and Related Processes for Estimating GHG Emissions – Draft," March 25, 2010, http://www.scag.ca.gov/sb375/pdfs/CEHD-TechMethodolgy032510_strikethrough.pdf.

Strategic Highway Research Program Project C09. *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-making Framework: Draft Final Report*. Prepared by Parsons Brinckerhoff, 2011. http://transportationforcommunities.com/shrpc01/cases/pdf/SHRP%202%20C09%20Draft%20Final%20Project%20Report.pdf.

U.S. Department of Transportation, "Estimating Transportation-Related Greenhouse Gas Emissions and Energy Use in New York State," Prepared by ICF International, March 2005, http://climate.dot.gov/documents/EstimatingTransportationRelatedGGE.pdf.

U.S. Environmental Protection Agency, "Potential Changes in Emissions Due to Improvements in Travel Efficiency – Final Report," Prepared by ICF International, March 2011. http://www.epa.gov/otaq/stateresources/policy/420r11003.pdf.

U.S. Environmental Protection Agency, "Smart Growth and Climate Protection Policy Analysis, Task 3 – Assessment of Tools," Prepared by ICF International, June 2010.

U.S. Environmental Protection Agency, "Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption – Final," November 2012. http://www.epa.gov/otaq/stateresources/ghgtravel.htm.

U.S. Environmental Protection Agency, *Guide to Sustainable Transportation Performance Measures*, Prepared by ICF International, 2011. http://www.epa.gov/dced/pdf/Sustainable_Transpo_Performance.pdf.

Urban Land Institute, "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions," Technical Appendices, Prepared by Cambridge Systematics, October 2009.

Washington State Department of Commerce, "Assessment of Greenhouse Gas Analysis Tools," prepared by Fehr & Peers, December 2009, http://www.commerce.wa.gov/site/1277/default.aspx.