NCHRP 08-36, Task 107
Synthesis of State DOT and MPO Planning and Analysis Strategies to Reduce Greenhouse Gas Emissions

Requested by:

American Association of State Highway and
Transportation Officials (AASHTO)
Standing Committee on Planning

Prepared by:

Tiffany Batac, Guido Schattanek, and Michael D. Meyer Ph.D., P.E.
Parsons Brinckerhoff, Inc.
303 2nd Street, Suite 700N
San Francisco, CA 94107

October, 2012

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Acknowledgements

This study was conducted for the AASHTO Standing Committee on Planning, with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 08-36, Research for the AASHTO Standing Committee on Planning. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 08-36 is intended to fund quick response studies on behalf of the Standing Committee on Planning. The report was prepared by Tiffany Batac, Guido Schattanek, and Michael D. Meyer, Ph.D., P.E. of Parsons Brinckerhoff. The project was managed by Lori L. Sundstrom, NCHRP Senior Program Officer.

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ACRONYMS

AASHTO	American Association of State Highway Transportation Officials
AMPO	Association of Metropolitan Planning Organizations
ARC	Atlanta Regional Council
ArcGIS	Geographic Information System
CACP	Clean Air & Climate Protection
CAFE	Corporate Average Fuel Economy
CalSEEC	California Statewide Energy Efficiency Collaborative
CAPPA	Climate and Air Pollution Planning Assistant
CARB	California Air Resources Board
CCAP	Center for Clean Air Policy
CEQ	Council on Environmental Quality
CLIP	Climate Leadership in Parks
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CH_4	Methane
COG	Council of Government
CUTR	Center for Urban Transportation Research
DLCD	Department of Land Conservation and Development
DOE	Department of Energy
DOT	Department of Transportation
EDMS	Emissions and Dispersion Modeling System
EERPAT	Energy and Emissions Reduction Policy Analysis Tool
EF	Emission Factor
EPA	Environmental Protection Agency
EV	Electric Vehicle
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
g/mi	Grams per mile

GDP	Gross domestic product
GHG	Greenhouse Gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GreenSTEP	Greenhouse Gas Strategic Transportation Energy Planning Model
GVWR	Gross vehicle weight rating
GWP	Global Warming Potential
HAP	Hazardous air pollutant
HC	Hydrocarbon
HDV	Heavy-Duty Vehicle
HFC	Hydro fluorocarbons
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HPMS	Highway Performance Monitoring System
I-PLACE3S	Planning for Community Energy, Economic, and Environmental Sustainability
ICLEI	International Council for Local Environmental Initiatives
IDAS	Intelligent Transportation Systems Deployment Analysis System
IPCC	Intergovernmental Panel on Climate Change
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System
LDV	Light-Duty Vehicle
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
LEM	Lifecycle Emissions Model
LRTP	Long-Range Transportation Plan
MEPA	Massachusetts Environmental Policy Act
MMT	Million Metric Tons
MOVES	Motor Vehicle Emissions Simulator
MPG	Miles per gallon
MPO	Metropolitan Planning Organization
MTC	Metropolitan Transportation Commission

MY	Model Year
MWCOG	Metropolitan Washington Council of Governments
N_20	Nitrous Oxide
NEMS	National Energy Modeling System
NEPA	National Environmental Policy Act
NH_3	Ammonia
NHTSA	National Highway Traffic Safety Administration
NMIM	National Mobile Inventory Model
NO_x	Oxides of nitrogen
O&M	Operations & Maintenance
ODOT	Oregon Department of Transportation
PAYD	Pay-As-You-Drive
PHEV	Plug-in Electric Vehicle
PMT	Person miles traveled
QA/QC	Quality Assurance and Quality Control
RTP	Regional Transportation Plan
SACOG	Sacramento Area Council of Governments
SAGE	Systems for the Analysis of Global Energy Markets
SCS	Sustainable Communities Strategy
SED	State Energy Data
SHRP	Strategic Highway Research Program
SIP	State Implementation Plan
SIPT	State Inventory Projection Tool
SIT	State Inventory Tool
SJCOG	San Joaquin Council of Governments
SO_2	Sulfur dioxide
STS	Statewide Transportation Strategy
TAZ	Transportation Analysis Zone
TCM	Transportation Control Measure
TDM	Transportation Demand Management
TEM	Transportation Energy Model

TERMS	Transportation Emission Reduction Measures
Tg	Tera-grams
TIP	Transportation Improvement Program
TPB	Transportation Planning Board
TRIA	Trip Reduction Impact Analysis
TRIMMS	Trip Reduction Impacts of Mobility Management Strategies
TSM	Transportation System Management
UNFCC	United Nations Framework on Climate Change
USDOT	United States Department of Transportation
VHT	Vehicle Hours of Travel
VMT	Vehicle Miles Traveled
WEPS	World Energy Protection System
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

This report describes the current state-of-practice in analyzing strategies aimed at reducing transportation-related greenhouse gas (GHG) emissions. The focus of the research was on state department of transportation (DOT) and metropolitan planning organization (MPO) analysis efforts, the types of analysis tools used, the range of GHG reduction strategies considered, and the challenges faced by those undertaking the analyses.

This research effort reviewed the most current literature and practices in GHG analysis. A web-based survey was sent to state DOTS and MPOs in collaboration with the Association of Metropolitan Planning Organizations (AMPO) and the American Association of State Highway and Transportation Officials (AASHTO). The sample size was 278 agencies and 57 agencies responded. The intent was to gather information about the planning process with respect to GHG analysis and strategy consideration. A more select group of state DOTs and MPOs was identified based on their experience with GHG analysis, the state of practice in data collection and model application, and plans for improving their practices and estimation methods. These agencies became the focus of more detailed data collection and interpretation on their GHG analysis experience.

The transportation sector is a major contributor to GHG emissions in the U.S. and around the world. Approximately 27 percent of total U.S. GHG emissions come from the transportation sector, with carbon dioxide (CO_2) accounting for 95 percent of transportation GHG emissions (virtually all of the energy consumed by the transportation sector came from petroleum products). Light-duty vehicles account for approximately 58% of the transportation share. GHG emissions from transportation have increased by about 19% since 1990 (with vehicle miles traveled –VMT- increasing 34%), while the total US GHG emissions increased approximately 11% during this 20-year period. However, VMT growth rates have dropped in the last decade, which could dampen future growth in transportation GHG (for example, 2011 VMT was lower than VMT in 2005). Economic conditions during this period (such as the recession and spikes in gasoline prices) contributed to reduced VMT, but experts in VMT trends cite evidence that demographic factors and other developments are also contributing to slower VMT growth.

A few states have passed laws or adopted policies that require consideration of GHG emissions in transportation planning and decision making. In most cases, these laws have been accompanied by emission targets or goals that establish a benchmark against which progress can be measured. Some of these policies have adopted "CO_2 emissions" or GHG emissions as the policy metric, but one (in the form of legislation in Washington state) adopted VMT as a surrogate measure. A handful of the states that have GHG laws and policies have taken the next step in integrating GHG analysis into the project development process, in particular in environmental analysis. In such cases, specific methodologies are recommended by the environmental agencies for conducting such an assessment.

The results of the state DOT and MPO survey indicated that approximately 15% of the survey pool, or about 41 total respondents, have estimated GHG emissions as part of their baseline and future planning scenarios or expect to in the near future (23 or 8% have already conducted some level of GHG analysis). For state DOTs and MPOs reporting that GHG emissions were considered under a state or local mandate, policy, or climate action planning effort, 13 agencies reported having a GHG reduction goal or target. Most emission targets were generally compared against a base year of 2005 or 1990 – consistent with either state goals or the Kyoto Protocol, with medium term goals in the range of 7-25% reductions by 2020, and longer term goals of 30-80% reductions by 2035 or 2050. For the majority of agencies not performing GHG analysis the reasons varied from public skepticism about climate change, awaiting guidance or regulatory requirements from the state or federal level, and unclear expectations from the governor or state legislature.

Categorizing GHG emission reduction strategies varies from one analysis to another. However, the individual strategies themselves are often similar. Changes in vehicle and fuel technology are pointed to by every study as the major source of GHG reductions from the transportation sector. Most studies then acknowledge that pricing can be an important influence in changing vehicle purchases and travel behavior to reduce GHG emissions. More efficient operations (Transportation System Management-TSM) and efforts to influence travel demand are also mentioned in most studies as important components of an overall strategy. For MPOs in particular, land use strategies that lead to higher densities are often part of the analysis, as is investment in more transit options. Finally, some rather innovative strategies, such as location transfers[1] and eco-driving, have surfaced in a few locations. However, many of the studies also acknowledge the challenges such strategies face in actually being implemented, and most agencies with established targets have found the targets to be unachievable without additional federal actions to improve fuel economy, reduce carbon content of fuel, or adopt economy-wide pricing.

Ranging from improving system efficiency to eco driving to changes in urban form, the different types of strategies that need to be analyzed presents a challenge to the suite of analysis tools available to transportation analysts. The tools need to have a breadth of capability as well as sufficient depth to provide credible and defensible answers to the question of, "what benefit in reduced GHG emissions are we likely to get if we implement a combination of the strategies?" Moreover, long range GHG forecasting is complicated by the wide range in future vehicle technology and fuels that may unfold over the next two to four decades. In particular, continued significant improvements in fuel economy and lower-carbon fuels could cut GHG/mile driven to half compared to today's levels – which significantly lowers the GHG reduction potential of VMT reduction strategies and other strategies.

For direct operations of transportation vehicles (for example, vehicle driving and idling), transportation-related CO_2 is emitted in direct proportion to fuel consumption, with some variation by type of fuel, either consumed directly by the vehicles, or indirectly thru the electrical grid that powers electrified transport. As a result, estimating the GHG implications of transportation projects primarily involves estimating the amount of fuel—gasoline, diesel, and other fuels—used by motor vehicles and other transportation sources. Although conceptually simple, this calculation in practice is quite complex, since vehicle fuel consumption depends on a variety of factors (vehicle type, model year, technology, fuel type; driver operating characteristics - such as speeds and accelerations, air conditioning use, tire inflation, etc.).

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1 A location transfer in this context refers to incentivizing existing residences or buildings currently within designated environmentally sensitive zones to move closer to the urban core. Examples of incentives may include parcel exchange and/or increase in number of parcels at a set ratio.

In the context of regional emissions estimation, most MPOs use a combination of a travel demand model and an emissions factor model. Advancements have been made in both types of models over the past decade, in essence developing models that better reflect the phenomena being analyzed. For example, the use of simulation models allows the analyst to examine vehicle flow conditions that contribute to tailpipe emissions. The introduction of EPA's MOVES emissions model also represents a step forward in better representing the CO_2 consumed in proportion to vehicle operating conditions (horsepower used under different modes of operation), type of fuel (gas, diesel, and others), mileage driven by different vehicle technologies and model years, and future effects of CAFE fuel economy standards. Over half of the agency responses indicated that they are still using MOBILE6.2 for their GHG analysis.

The introduction of EMFAC2011 by the California Air Resources Board (CARB) is also another step forward, since it includes the latest data on California's car and truck fleets and travel activity, and the emissions benefits of CARB's recent rulemakings including on-road diesel fleet rules, clean car standards, and a low carbon fuel standard. Again, several California agencies are still using EMFAC2007. All agencies are expected to be using MOVES2010[2] or EMFAC2011 for air quality inventories - conformity determinations, and hopefully for GHG analysis, within one year.

Scenario planning tools are being used to assess the GHG effects of the emission reduction strategies under consideration, particularly at the MPO level. To varying degrees, these tools can account for GHG emissions from buildings, energy consumption, water usage, land use changes, transit, bicycle lanes expansion, and other sources not accounted for in the traditional travel demand and emission models, which produce VMT and CO_2 by VMT roadway type and vehicle class. Many scenario planning tools have been developed in response to growth challenges and the need for more comprehensive vision planning. They are often used in the development of Regional Transportation Plans, integrated

[2] For GHG analysis and energy consumption, MOVES2010a (or later version) should be used instead of MOVES2010, as MOVES2010a and later versions include car and light truck GHG emission standards affecting model years 2012-and-later (standards published May 7, 2010) and update the effects of CAFE standards for model years 2008-2011. The latest GHG/fuel economy standards enacted on August 28, 2012 will be included in next model version.

transportation - land use processes, regional visioning, and forecasting efforts to reach GHG emission reduction targets. These tools are often linked with other MPO models, like travel demand models and emission factor models (MOBILE 6.2, MOVES or EMFAC).

These tools continue to evolve and offer a wide range of analytical sophistication. The tools used by the agencies studied in this research are representative of this range---from spreadsheet-based tools like Rapid Fire and TRIA to spatial analysis as in I-PLACE3S to comprehensive statewide GHG analysis as in GreenSTEP.

In terms of the scope of GHG analysis, this research found that: GHG analyses were focused primarily on direct transportation emissions (with no consideration of full life-cycle emissions); the primary mode of transportation analyzed in GHG estimation efforts was light-duty vehicles; and GHG estimation methods were most commonly based on VMT data. Fleet and fuel efficiency benefits such as CAFE standards and state regulations (such as the Pavley GHG tailpipe emissions standards adopted by approximately 15 states) were seldom included in the analysis.

The variety of scenario planning tools are being used to evaluate and test possible GHG effects of local and state level policy actions, but they fall short in forecasting the changes to the motor vehicle fleet characteristics and the future effect of fuel economy standards on the local fleet. However, once the majority of DOTs and MPOs acquire the familiarity and expertise with MOVES and EMFAC2011, future scenario forecasting methods will be able to better evaluate the full spectrum of transportation emissions. However, the uncertainty of technological breakthroughs or economic conditions that may significantly change fleet fuel economy, technology, and fuel characteristics over the next 20 to 40 years (such as 2050 a common GHG target year), poses great challenges for current modeling tools.

This project identified several research needs:

- Improvements in local GHG inventories and models to more accurately reflect future vehicle technologies and fuel economies;

- Better tools for lifecycle analysis to evaluate and compare all GHG strategies based on their full GHG effects (infrastructure construction, materials extraction and disposal process, and maintenance operations);

- Better understanding of the GHG effects of hybrid, plug-in and battery powered electrical vehicles (how changes to electric power generation and grid would affect the emissions of these vehicles);

- More comprehensive tools for assessing freight GHG emissions from supply chains (which are expected to become a larger share of the transportation emissions);

- Better understanding of sensitivities in GHG analysis, to support greater focus on the variables of greatest consequence; and

- More coordinated planning efforts among state DOTs, MPOs, and federal agencies (EPA and USDOT) in normalizing and/or standardizing analytical procedures and protocols.

In addition, research is needed to monitor and evaluate the real-world results of GHG policies, programs, and projects, to enable adjustments in current GHG models and assumptions based on post implementation measurement.

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Background

The primary greenhouse gases (GHGs) produced by the transportation sector are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFC). Carbon dioxide, a product of fossil fuel combustion, accounts for 95 percent of transportation GHG emissions in the United States. National inventories estimate that the transportation sector contributed approximately 27% of the nation's GHG emissions in 2010, with highway vehicles constituting 82% of the transportation-related GHG emissions. (These are national percentages, with significantly higher transportation shares in states that rely heavily on hydro-power and other low-carbon electricity and, conversely, significantly lower shares in states that rely heavily on coal-powered electricity.) Most importantly, the GHG emissions from the transportation sector have been growing at a much faster rate than those from other sectors, like the power industry. Within the transportation sector, freight has experienced the fastest growth. Freight movement represents nearly a quarter of transportation sector GHG, and the freight sector's GHG emissions have increased over 58% since 1990 (USDOT, "Transportation's Role in Reducing U.S. GHG"). This increase is double that of passenger travel (27%), which has significantly more regulations aimed at improving vehicle efficiency, lowering emissions and mandating cleaner fuels.

In the absence of climate change legislation, federal agencies have made efforts to incorporate climate change consideration in transportation planning, grant awards, research, vehicle regulations, and outreach. Moreover, many states have developed climate action plans having transportation elements, and a handful of states have enacted legislation mandating transportation actions to reduce GHG emissions. Experience under the Clean Air Act and contemporary GHG analyses indicate that federal/national policies will have the greatest impact in reducing transportation GHG emissions (through vehicle efficiency, fuel, and carbon pricing policies), but that state and metropolitan transportation agencies also have a role to play. This is primarily so because the magnitude of needed GHG reductions is so large that a broad range of transportation strategies will be needed to come close to GHG targets that aim for 60-80% reductions below 1990 (or 2005) levels by 2050.

As owners, operators, and regulators of much of the nation's transportation system, transportation agencies are well-positioned in the public policy arena and in public infrastructure decision making to contribute to efforts at reducing GHG emissions. Although many of the most effective strategies for reducing such emissions will likely come from national vehicle and fuel standards, many agencies and groups are looking at the use and performance of the transportation system as another opportunity for emission reductions.

A review of state and metropolitan transportation plans in 2009 showed that for those plans that addressed climate change, reducing the rate of growth of vehicle miles traveled (VMT) was the most often stated road-related strategy for slowing GHG emissions (Schmidt and Meyer, 2009). Examples found in these plans included pricing (such as congestion charges, higher parking rates, pay-as-you-drive insurance, high occupancy toll (HOT) lanes, and parking cash out), commuter benefits, and ridesharing services. Expanded transit service and improved non-motorized travel options were also identified as strategies in most plans. In the long run, influencing urban form and land use patterns were also identified as possibly important strategies for decreasing the rate of VMT increase, although the national literature on this is unsettled and shows mostly modest GHG reductions, even by 2050.

1.2 Research Objectives

The goal of this research project was to: 1) identify which state DOTs and MPOs have conducted analyses of GHG emission reduction strategies and have considered incorporating these strategies into their transportation plan, and 2) produce a synthesis of the types of analyses used in these efforts, identifying GHG methodologies, common elements and approaches, and those that differ.

1.3 Research Approach

The research effort was divided into five tasks.

Task 1: Identify States and MPOs that are Considering GHG Emissions Strategies as Part of the Transportation Planning Process and/or for Implementation

This initial task identified where states and MPOs are either implementing GHG emission reduction strategies, or where they are at least being considered in the context of meeting GHG reduction targets. Relatively few states and MPOs were considering GHG emission reduction strategies as part of a targeted climate change program or for that matter in their general planning effort. Some MPOs, like those in California, Oregon and Washington, are doing so because of state legislative, policy, or mandates, and thus these states and the MPOs in them were part of those contacted about current practice.

Task 1 included several efforts to develop a "universe" of potential state- and MPO-level GHG emissions reduction strategies and the analysis methods used to assess their effectiveness. The research team conducted a literature search, including examining other relevant research projects that were underway. The research team also contacted the Association of Metropolitan Planning Organizations (AMPO) and the American Association of State Highway and Transportation Officials (AASHTO) to identify which states or MPOs should be considered as part of the synthesis effort. A web survey was developed and sent to AMPO and AASHTO members requesting information on what was being done in their agency or planning process with respect to GHG analysis and strategy consideration.

Surveys were distributed online to 278 association members from December 2011 through January 2012 (see survey questions in Appendix A). In total, 57 participants responded to the survey, including 14 DOTs and 43 MPOs (a 20% response rate). The estimated 8% of the survey pool that reported conducting GHG analysis reveals the small share of DOTs and MPOs actively pursuing this analysis as part of their project or planning processes.

Task 2: Synthesize Results from Task 1

Task 1 identified and categorized states and MPOs with respect to what they had been doing in GHG emissions analysis. Based on the results of the Task 1 survey, Task 2 conducted a series of structured telephone interviews with selected states and MPOs to understand their approach to GHG emissions strategies and the methods used to analyze their potential reductions (see Table 1-1 for the states and MPOs contacted). The selected state DOTs and MPOs reflected diversity in geography, size, and level of engagement in GHG planning. An interview template was developed to organize the information from these targeted agencies (see appendix B for the template).

Table 1-1: State DOTs and MPOs Contacted

State DOTs	MPOs
Maryland DOT	Atlanta Regional Commission
Minnesota DOT	Boston Regional MPO
Oregon DOT	Denver Regional Council of Governments
	Metropolitan Washington Council of Governments
	Sacramento Area Council of Governments
	San Joaquin Council of Governments
	Tahoe Metropolitan Planning Organization

Task 3: Compare and Contrast Analysis Methods

This task compared and contrasted the different analysis methods used by states and MPOs. The intent was to describe the state DOT and MPO efforts with respect to different types of analysis approaches. For example, the research team identified the assumptions included in the analyses, limitations in the approach and additional analysis capabilities desired by the agency staff. Another focus of this task was to describe the context within which the analysis tools were used. Thus, for example, some tools are often used within a scenario-based methodology, which examined the likely variation in GHG emissions given differing input assumptions.

The comparison of the different approaches also included the opinions of the transportation practitioners contacted concerning the GHG analysis methodology, including what were the perceived advantages of using a particular analysis method, the disadvantages, and what they would do differently.

Task 4: Prepare a Final Report

This final report describes the results of the synthesis and the methodology used to produce these results.

Task 5: Develop an Educational Webinar to Disseminate Synthesis Results

An educational webinar was developed to disseminate the results of this research to state DOTs and MPOs in particular, but also to other agencies and transportation professionals interested. The webinar focuses on what selected states and MPOs are doing with respect to GHG emission reduction analyses.

1.4 Intended Audiences

The research results are important to three primary audiences. The first is the technical staff of state DOTs and MPOs who are tasked with conducting the analyses and evaluations that provide input into transportation planning and decision making. The research provides a “snapshot” of best practices with respect to GHG analyses, and an assessment of the limitations associated with the methodologies.

The second audience is the public official who is often involved in developing or making the decisions regarding transportation systems and networks and who consider a wide range of issues, including in some cases GHG emissions. Although it is not likely that public officials will want to know the specifics of how individual models work, it is important for them to know the general approach for modeling, the underlying assumptions and the level to which the results can credibly represent what is likely to happen if GHG emission reduction strategies are actually implemented.

The third audience is the research community. To some extent, the first two audiences above represent the current transportation professional and decision making community. Given the state of practice in GHG emissions modeling, this project can provide some useful directions to research that will improve the quality of the information presented to decision makers. This project will help define where more research and new/improved models are needed.

1.5 Report Organization

The remainder of this report is organized in the following manner.

- Chapter 2 describes the transportation sector's role as a source of GHG emissions, and provides examples of how some states and regions have laws, regulations and policies that require officials to consider the potential for transportation strategies and actions to reduce such emissions.
- Chapter 3 reviews transportation-related GHG emissions reduction strategies that have been considered as part of transportation planning and policy. This chapter includes a review of the most recent studies, and the results of the survey performed as part of this study.
- Chapter 4 presents an overview of the analytical tools and methods to estimate GHG emissions, and types of transportation and emissions factor models that are commonly used today.
- Chapter 5 describes the models and approaches that were used by those interviewed, along with the results of the national survey with respect to analysis tools and models.
- Chapter 6 synthesizes the results of the research to answer the following questions: What is the state of the practice? What analytical tools are being used by the different entities? What shortcomings exist and why? What needs to change or improve? And what are some recommendations on how should this be done?

CHAPTER 2: TRANSPORTATION-RELATED GHG EMISSIONS AND POLICY MOTIVATION FOR THEIR ANALYSIS

2.1 Introduction

This chapter provides a background on transportation's contribution to climate change and GHG emissions. Policy and agency motivation for considering transportation-related GHG emissions in decision making is also discussed.

2.2 Transportation's Contribution to GHG Emissions

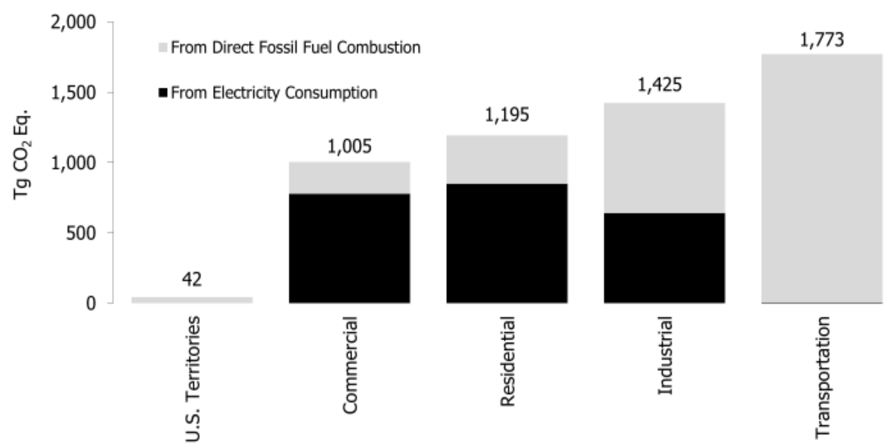
The U.S. Environmental Protection Agency's (EPA) *Inventory of Greenhouse Gas Emissions and Sinks* provides historical data on GHG emissions from transportation and other sectors (Environmental Protection Agency 2010). As noted in chapter 1, the transportation sector (including all modes of transportation) contributes approximately 27 percent of the nation's GHG emissions, where such emissions come primarily from the burning of fossil fuel such as petroleum. About 92 percent of transportation fuel is petroleum-based, with the rest divided between natural gas, renewable fuels (e.g., biofuels) and electricity that powers transit systems (Environmental Protection Agency, 2012).

The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of CO_2 are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through natural processes (i.e., sources). When in equilibrium, carbon fluxes among these various reservoirs are roughly balanced. Since the Industrial Revolution (circa 1750), global atmospheric concentrations of CO_2 have risen about 39 percent (IPCC 2007 and NOAA/ESLR 2009), principally due to the combustion of fossil fuels.

Globally, approximately 30,313 Tera-grams (Tg) or million metric tons (MMT) of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2009, of which the United States accounted for about 18 percent.

CO_2 is the primary greenhouse gas emitted by human activities in the U.S., representing approximately 84 percent of total greenhouse gas emissions. The largest source of CO_2, and of overall greenhouse gas emissions, is fossil fuel combustion, with such combustion accounting for 94 percent of CO_2 emissions in 2010 (Environmental Protection Agency, 2012). Transportation activities (excluding international maritime bunker fuels) accounted for 32 percent of CO_2 emissions from fossil fuel combustion. Virtually all of the energy consumed by the transportation sector came from petroleum products, with almost 65 percent of the CO_2 emissions resulting from gasoline consumption for personal vehicle use (defined by EPA as light duty vehicles). This is not surprising given that passenger cars account for over 50 percent of highway vehicles and over one-third of all the energy consumed in the transportation sector. Light trucks, sport utility vehicles (SUVs), and vans comprise almost 40 percent of all highway vehicles and consume around 39 percent of energy in the sector (U.S. Department of State 2012). Figure 2-1 provides the comparison of the GHG emissions from fuel combustion by economic sector in 2010.

Figure 2-1 GHG Comparison from Fuel Combustion by Economic Sector (2010)

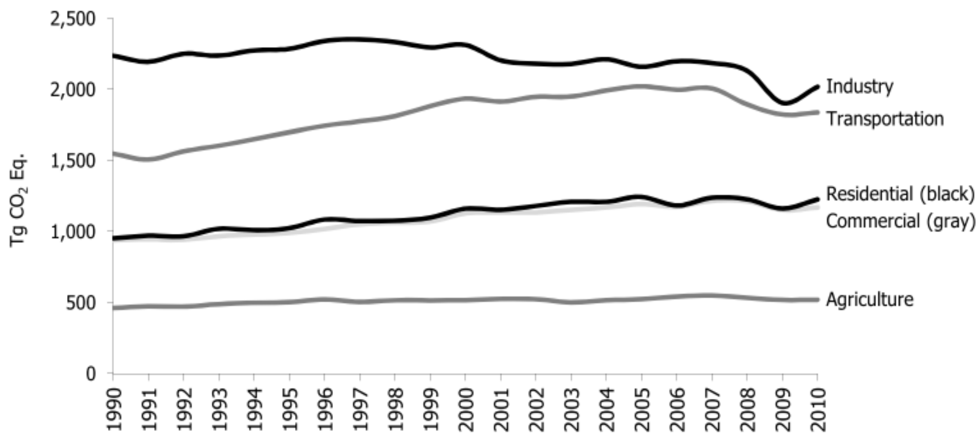


Source: (Environmental Protection Agency 2010)

In 2010, total U.S. greenhouse gas emissions were 6,821.8 Tg or MMT of CO_2e. Total U.S. GHG emissions increased by 10.5 percent from 1990 to 2010. GHG emissions from transportation have increased by about 19% since 1990. This historical increase is largely due to increased demand for travel and a general flattening of fuel economy in the U.S. vehicle fleet (although recent changes in fuel efficiency standards should show improvements in future years). The number of vehicle miles traveled by passenger cars and light-duty trucks increased by 34% from 1990 to 2010. Figure 2-2 illustrates the growth in

CO_2e emissions by economic sector from 1990 to 2010. As can be observed, transportation emissions growth rate out-paced the other sectors. It should be noted, however, that although VMT has increased over the 20-year period, in the most recent decade VMT has grown at a slower pace. VMT in 2011 compared to VMT in 2005 decreased due to a variety of economic, technological and behavioral factors.

Figure 2-2 Growth in CO_2 Emissions (1990-2010)



Source: Environmental Protection Agency, 2010.

Most reported transportation GHG emissions are direct emissions, that is, those that result from the combusting of gasoline and diesel fuel in engines. However, a life cycle perspective of transportation would include the GHG emissions that are generated in the process of constructing and maintaining road, rail, port, and airport infrastructure, manufacturing and maintaining vehicles, and extracting and refining transportation fuels; the overall GHG emissions attributed to this sector could be 20% higher or more. Chester and Horvath, for example, estimated that direct emissions from vehicle operations account for only 60 percent of the total GHG emissions associated with light-duty vehicles (Chester, M. and A. Horvath 2008). In their analysis, the extracting and refining of fuels accounted for 10 percent of emissions, vehicle manufacturing for 12 percent, and constructing and maintaining roads used by these vehicles for an estimated 17 percent. Therefore, only 60 percent (rounded up) of a vehicle's total GHG emissions (including fuel production and vehicle operations) was estimated to be directly proportional to distance driven (VMT).

GHG emissions not directly associated with vehicle operation are not included in the figures for transportation sector GHG emissions provided earlier in this section; therefore, the overall contribution of the transportation sector is most likely much larger than its estimated direct emissions contribution of 27 percent.

Best case analysis should account for life-cycle emissions when comparing different GHG strategies. Certain strategies, like pricing, eco-driving, and traffic smoothing, have little to no life-cycle GHG emissions, whereas capital intensive strategies, such as building new rail transit or highway facilities, have very high life-cycle GHG from construction equipment and activities, the processing and disposal of materials, and maintenance operations.

One of the best sources for estimating future transportation-related GHG emissions comes from the Department of Energy's *Annual Energy Outlook*. The most recent version of this annual report looks at recent policy and technology advances and incorporates expected factors that could influence future energy consumption and GHG emissions into a forecast (e.g., new fuel economy standards) (Department of Energy, 2012). A "reference case" or scenario is developed representing the most likely scenario for future energy consumption based on what can reasonably be expected from what we know today. Different scenarios are then analyzed based on potentially changing factors, such as more stringent corporate average fuel economy (CAFE) standards. For example, the federal government enacted GHG emissions and fuel consumption standards in 2011 for medium- and heavy-duty engines and vehicles. For the first time, GHG emissions and fuel consumption standards were established for on-road, heavy-duty trucks with a gross vehicle weight rating (GVWR) above 8,500 pounds. These standards were assumed in the DOE reference case. The reference case assumed that fuel economy standards rise slightly to meet the requirement that LDVs reach 35 mpg by model year 2020 as mandated in the law.

Additional scenarios, one called the "Extended Policies Case," modified the reference case by incorporating even more stringent standards proposed by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA), which include a 3.9-percent annual average increase in fuel economy for new light duty vehicles (LDVs). Fuel economy standards after 2025 were assumed to increase at an average annual rate of 1.5 percent through 2035 (Department of Energy, 2012).

One of the key assumptions in the DOE analysis is the penetration of alternative fueled and/or hybrid electric vehicles. The reference case assumed about 35 percent of new car sales will be alternative fueled vehicles in 2035 (whereas the "Extended Policies" scenario assumed almost an 80 percent level). Not surprisingly, energy LDV energy consumption in the "Extended Policies" scenario is about 20 percent less than that in the reference case.

The reference case estimates that transportation sector energy consumption grows at an average annual rate of 0.1 percent from 2010 to 2035, slower than the 1.2 percent average from 1975 to 2010. The slower growth results primarily from improvements in fuel economy and an assumed slower-than-historical growth in travel demand. LDV energy demand falls by 3.2 percent from 2010 to 2035. The assumed energy consumption due to an increase in personal travel demand is offset by existing GHG standards for model years (MY) 2012 to 2016 and by fuel economy standards for MY 2017 to 2020. Energy demand for heavy duty vehicles (HDVs), however, increases by 21 percent from 2010 to 2035, resulting from increased vehicle miles traveled (VMT).

The reference case estimates that the total U.S. energy-related CO_2 emissions grow by just over 2 percent from 2010 to 2035 due to "assumed modest economic growth, growing use of renewable technologies and fuels, efficiency improvements, slow growth in electricity demand, and increased use of natural gas, which is less carbon-intensive than other fossil fuels" (Department of Energy, 2012).

In sum, for 2010, the transportation sector comprised 27% of the nation's GHG emissions inventory, and it has been the fastest growing emission sector since 1990. Moreover, the AEO estimates for 2010-2035 are that transportation energy/GHG will continue to outpace the rate of growth in other sectors (<2.5% for transportation vs. 2% for all sectors). Given this significant and growing contribution, any effort to form a GHG reduction policy, whether at a national, state or regional scale, will have to include transportation strategies if it is to be effective. What is also evident from the DOE analysis is that technology–related strategies, such as new vehicle fuel economy and emissions standards, are an important contributor to efforts at reducing GHG emissions.

2.3 Considering GHG Emissions in Decision Making

The motivation for considering GHG emissions in planning and policy decisions can come from a variety of sources. In some states, the governor's office has initiated an effort to develop a state climate action plan. This has been done in numerous states (often with minimal input from transportation officials), with the effort usually examining a wide range of strategies for reducing GHG emissions. In other cases, governors have issued an executive order that requires certain activities and efforts on the part of state agencies. In yet other cases, state legislatures have passed laws that mandate the consideration of GHG emissions reduction in state-related activities, such as in the purchase of hybrid vehicles for an agency's vehicle fleet.

At the federal level, executive orders and guidance have been issued relating to federal agency operations and activities. Draft guidance was developed in 2010, but has not been finalized, by the White House Council on Environmental Quality (CEQ) to consider both GHG mitigation and climate adaptation under the National Environmental Policy Act (NEPA) As of the date of this report, U.S. DOT encourages, but does not require, consideration of GHG emissions in statewide and metropolitan transportation planning. It is beyond the scope of this report to examine all of the plans, policies and mandates that relate to GHG emissions analysis. The following sections simply illustrate some of the requirements that currently serve as the policy foundation for the GHG analyses found in the U.S.

2.3.1 GHG Requirements and Reduction Targets for Planning

Many states have developed multi-sector climate action plans (Parsons Brinckerhoff 2009), although it appears that a significant number of them are not being actively implemented and some have been quietly shelved. Nonetheless, included in a majority of these plans are state adopted GHG reduction goals for 2020 (or other near term goal) and 2050 (or other long term goal). In some cases, these reduction targets have also been mandated by a Governor's Executive Order. The goals are often statewide and cover multiple sectors, but vary in terms of application requirements (e.g., per capita reductions, absolute reductions, light-duty vehicles only, all transportation modes, CO_2 or all GHGs, etc.). For instance, in Washington and Oregon, statewide GHG reduction targets have been adopted specific to transportation; however, Washington requires a per capita VMT reduction while Oregon requires an absolute GHG reduction by all transportation modes.

The results of the survey distributed to MPOs and state DOTs for this research indicated that 10% of survey respondents consider GHG emissions in agency planning efforts. Six of the state DOTs also reported having short-, mid-, or long-term percent reduction targets. Of the MPO survey respondents, 12 also reported having short-, mid-, or long-term GHG emission reduction targets in place. A summary of state DOT and MPO reduction targets and deadlines reviewed as part of this research is shown in Table 2-1.

Table 2-1 State DOT and MPO GHG Reduction Targets

AGENCY	TARGET REDUCTIONS	METRIC
State Departments of Transportation		
Maryland DOT	• 25% below 2006 levels by 2020	• CO_2e all modes
Minnesota DOT	• 15% below 2005 levels by 2015 • 30% below 2005 levels by 2025 • 80% below 2005 levels by 2050	• Absolute reductions, all modes • Fuel consumed, all modes
Oregon DOT	• No growth in emissions by 2010 • 10% below 1990 levels by 2020 • 75% below 1990 levels by 2050	• MPOs – per capita; LDVs • DOT – absolute; all modes • Covers CO_2, CH_4, and N_2O
Metropolitan Planning Organizations		
Atlanta Regional Commission	• No targets, simply comparison to 1990 conditions	• CO_2 • CO_2e
Boston Region MPO	• Reduce to 1990 levels by 2010 • 10% below 1990 levels by 2020 • Reduce GHG emissions sufficiently to eliminate any dangerous threat to climate; current science suggests reductions as much as 75-85% below current levels required	• CO_2; absolute reductions • Targets are multi-sector
Denver Regional COG	• 60% below 2005 levels by 2035[3] • (4.5 tCO_2 to 1.8 tCO_2 per capita)	• CO_2; per capita • Transportation specific
Metropolitan Washington COG	• 2005 levels by 2012 • 20% below 2005 levels by 2020 • 80% below 2005 levels by 2050	• Targets are currently multi-sector; Transportation targets underway • CO_2; absolute reductions

A number of states have enacted legislation or provided policy guidance for GHG consideration in state and regional transportation planning.[4]

[3] Metro Vision Plan (2011): http://www.drcog.org/documents/2011%20MV%202035%20Plan%20for%20Web5-12-11.pdf

[4] For an overview, see http://www.fhwa.dot.gov/environment/climate_change/adaptation/resources_and_publications/integrating_climate_change/page05.cfm

California Senate Bill (SB) 375 requires the state's metropolitan planning organizations (MPOs) to develop a Sustainable Communities Strategy (SCS) that lays out a plan to meet the region's transportation, housing, economic and environmental needs in a way that enables the area to meet the statewide greenhouse gas emission reduction targets set by the California Air Resources Board (CARB) under Assembly Bill (AB) 32. Region-specific per-capita GHG targets for light-duty vehicles have been established (see Table 2-2). Other vehicle technology and fuel strategies exist under AB 32, but California's SB375 GHG reductions represent targets to be achieved through land use and transportation planning. The final emission reductions, across all the MPOs in California, amount to 3 million metric tons (MMT) in 2020 – out of projected statewide GHG emissions of 596 MMT in 2020 – ½ of 1% of projected GHG emissions in California.

Table 2-2: Summary of California Regional Reduction Targets (Per Capita)

Group	MPO	2020	2035
4 Largest MPOs	MTC	7%	15%
	SANDAG	7%	13%
	SCAG	8%	13%*
	SACOG	7%	16%
San Joaquin Valley (8 MPOs)		5%	10%
6 Remaining MPOs	TMPO	7%	6%^
	SCRTPA	0%	0%
	BCAG	0%	1%
	SLOCOG	8%	8%
	SBCAG	6%^	4%^
	AMBAG	13%^	14%^

Notes:
^ indicates percentage increase in per capita emissions
* Subject to change

The *Massachusetts DOT's GreenDOT policy,* adopted in June 2010, establishes GHG emission reduction as one of three mutually-reinforcing goals, and establishes policies to achieve those goals (Massachusetts DOT 2010). The policy requires that statewide and regional transportation planning documents, including MPO long-range transportation plans, integrate the GreenDOT goals, and that statewide and regional transportation improvement programs (TIPs) include GHG emissions reduction as a project selection factor.

Minnesota has passed numerous laws relating to GHG emissions for a range of sectors in the state. The *Next Generation Energy Act* established a state goal of reducing statewide greenhouse gas emissions across all sectors to a level at least 15 percent below 2005 levels by 2015, to at least 30 percent below 2005 levels by 2025, and to at least 80 percent below 2005 levels by 2050 (State of Minnesota 2007). The levels shall be reviewed based on a climate change action plan study. This action plan must:

- "Estimate 1990 and 2005 greenhouse gas emissions in the state and make projections of emissions in 2015, 2025, and 2050;

- Identify, evaluate, and integrate a broad range of statewide greenhouse gas reduction options for all emission sectors in the state;
- Assess the costs, benefits, and feasibility of implementing the options;
- Recommend an integrated set of reduction options and strategies for implementing the options that will achieve the goals in subdivision 1, including analysis of the associated costs and benefits to Minnesotans;
- Estimate the statewide greenhouse gas emissions reductions anticipated from implementation of existing state policies;
- Recommend a system to require the reporting of statewide greenhouse gas emissions, identifying which facilities must report, and how emission estimates should be made; and
- Evaluate the option of exempting a project from the prohibitions if the project contributes a specified fee per ton of carbon dioxide emissions emitted annually by the project, the proceeds of which would be used to fund permanent, quantifiable, verifiable, and enforceable reductions in greenhouse gas emissions that would not otherwise have occurred."

The *New York State Energy Plan* requires MPOs to conduct a greenhouse gas analysis of their transportation plans, although it does not require them to meet any reduction targets (New York State Energy Board 2009).

In *Oregon*, two main pieces of legislation drive the consideration of GHG emissions in the state—House Bill 2001 (2009) and Senate Bill 1059 (2010). HB 2001, also known as the Oregon Jobs and Transportation Act, is the transportation funding plan adopted by the state legislature in 2009. While the act has many provisions addressing various elements of Oregon's transportation system and economy, it also calls for state support to finance the development of scenario plans in two of Oregon's Metropolitan Planning Organizations (MPOs). In accordance the Oregon Transportation Commission has set aside funding.

A statewide, comprehensive bill aimed at reducing greenhouse gas emissions from transportation, SB 1059, was passed by the Oregon Legislature in 2010. SB 1059 names the

Oregon Department of Transportation (ODOT) and the Oregon Department of Land Conservation and Development (DLCD) as the lead agencies in implementing many of its requirements. ODOT and DLCD are charged with the following actions:

- Coordinate and consult with stakeholders, local governments, Metropolitan Planning Organizations (MPOs) and other state agencies to develop a state-level strategy to reduce greenhouse gases from transportation;
- Develop a toolkit to assist local governments and MPOs in reducing greenhouse gases from transportation;
- Develop guidelines for scenario planning, and provide information to LCDC to set transportation-related greenhouse gas reduction targets for areas served by metropolitan planning organizations;
- Conduct outreach and education to the public; and
- Work with local governments within areas served by an MPO to consider what actions they might take, transportation-wise, to reduce greenhouse gases in the short-term.

Washington has set per-capita VMT-reduction targets of 18 percent by 2020, 30 percent by 2035, and 50 percent by 2050, compared to a 2020 baseline. These benchmarks are set statewide, with no directives on regional target setting. However, Executive Order 09-05 ("Washington's Leadership on Climate Change") directs the Secretary of the Department of Transportation to work collaboratively with other state agencies, local and regional governments and others to estimate current and future statewide levels of VMT, evaluate potential changes to VMT benchmarks to address low- or no-emission vehicles, develop additional strategies to reduce emissions from the transportation sector, and cooperatively develop and adopt regional transportation plans that will reduce greenhouse gases and achieve the statutory benchmarks to reduce annual VMT per capita.

2.3.2 State Practice on Considering GHGs in State Environmental Review

Four states, in particular, California, Massachusetts, New York and Washington, have been involved with GHG analyses at the environmental review stage for many years. These four states pursue largely similar approaches, but also show important differences.

California: California revised the state's environmental law to introduce GHGs into the environmental review process. State guidance does not establish criteria for setting thresholds of significance, although such guidance was to be developed. The Caltrans' environmental checklist for satisfying the state environmental law has listed under greenhouse gas emissions two questions that should be addressed in the environmental document. Does the project, (Caltrans 2011)

- Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?
- Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?

Caltrans then recommends the following statement be placed in environmental documents with respect to how GHG emissions should be considered,

> "An assessment of the greenhouse gas emissions and climate change is included in the body of environmental document. While Caltrans has included this good faith effort in order to provide the public and decision-makers as much information as possible about the project, it is Caltrans determination that in the absence of further regulatory or scientific information related to GHG emissions and CEQA significance, it is too speculative to make a significance determination regarding the project's direct and indirect impact with respect to climate change. Caltrans does remain firmly committed to implementing measures to help reduce the potential effects of the project. These measures are outlined in the body of the environmental document."

In the context of Senate Bill (SB) 375 and other efforts in the state to reduce GHG emissions, this approach essentially links project assessment to local or regional blueprint plans, sustainable community strategies, climate action plans, or other policies to reduce emissions.

Massachusetts: In 2007, Massachusetts released a policy on GHGs for all new Massachusetts Environmental Policy Act (MEPA) reviews (Executive Office of Energy and Environmental Affairs 2010) . The MEPA policy only deals with CO_2 emissions analysis. For transportation emissions, it requires project sponsors to calculate net new VMT resulting from the project, and multiply that VMT by CO_2 emissions factors – using individual factors for each vehicle type, or using the Massachusetts fleet-wide emission factor provided in the guidance. To calculate VMT reduction from travel demand management strategies, MEPA recommended the use of the EPA COMMUTER and CUTR Work Trip Reduction models.

The MEPA policy requires calculation of transportation emissions not just from transportation projects, but from any development that has VMT impacts. The policy allowed for carbon offsets as a mitigation tool, but gives priority to on-site mitigation. It also allowed project sponsors who propose “exceptional measures” to reduce GHGs to opt-out of doing the GHG analysis.

New York State: the New York State DOT *Environmental Technical Manual* includes procedures for project-level energy and GHG analysis. The approach, based on fuel usage, only considers CO_2 emissions. The analysis employs carbon emission coefficients for motor vehicle fuel (based on MOVES) to calculate the carbon equivalent of CO_2 emissions from the operations of each alternative.

Washington: Washington State DOT’s (WSDOT’S) *Guidance for Project-Level Greenhouse Gas and Climate Change Evaluations* provides guidance on how GHG emissions are to be considered in transportation project environmental review (Washington State Department of Transportation 2012). In one of the few instances found among states, the guidance separates emissions into three categories: operational, construction, and embodied/lifecycle. WSDOT defines the level of analysis required by the type of environmental documentation being prepared – e.g., no analysis is done for categorical exclusions, qualitative analysis is done for Environmental Assessments (EA), and quantitative analysis is done for Environmental Impact Statements (EIS), and the analysis varies by type of emission. For quantitative analyses, WSDOT recommends the use of EPA's MOVES model for operations emissions and the Energy Discipline Report for construction emissions.

2.4 Summary

The transportation sector is a major contributor to GHG emissions in the U.S. and around the world. Approximately 27 percent of total U.S. GHG emissions come from the transportation sector, with road travel constituting the largest source. Any serious attempt at reducing GHG emissions in the U.S. will have to deal with emissions from transportation. Both national fuel economy and GHG emissions standards are the most effective strategy for achieving any substantial level of emissions reduction (outside a pricing scheme that would likely be politically difficult).

A few states have passed laws or adopted policies that require consideration of GHG emissions in transportation planning and decision making. In most cases, these laws have been accompanied by emission targets or goals that establish a benchmark against which progress can be measured. Some of these laws have adopted a metric of CO_2 emissions (or CO_2-equivalent which represents total GHG) as the policy metric, whereas a few others (e.g., Washington and Massachusetts) have adopted vehicle miles traveled (VMT) as a surrogate measure. Some of the states that have GHG laws and policies also do GHG analysis at the project level during the environmental analysis step. In such cases, specific methodologies are recommended for conducting such an assessment. The next chapter discusses the types of strategies and actions that can result from such analyses.

CHAPTER 3: TRANSPORTATION GHG REDUCTION STRATEGIES

3.1 Introduction

This chapter provides an overview of typical transportation-related GHG emission reduction strategies that are found in the literature and in practice. The results of a survey of state DOTs and MPOs and answers from case study interviews conducted for this research are included at the end of the section.

3.2 GHG Emission Reduction Strategies in the Literature

Many national, state/regional and think tank studies have examined the GHG emission reduction potential of transportation strategies. Many of these studies have been top-down, aspirational or "scenario" estimates of potential travel activity and system efficiency benefits. This section describes some of the studies that have been conducted over the past five years simply to illustrate the types of transportation strategies that are being considered as part of GHG emissions analysis. This description is not intended to judge whether the analysis results are correct or even plausible. Most of the studies are based on assumptions that to a large extent logically lead to the study conclusions---assumptions relating to the effectiveness of individual strategies, effectiveness of combined strategies, extent and enforcement of the deployment of particular strategies, degree of political feasibility of implementing actions that directly affect individual travel or land use decisions, and in the case of cost effectiveness estimates, assumptions underlying what is meant by both effectiveness and costs.

Several national studies have been commissioned by the federal government or national professional organizations that have attempted to establish boundaries on what GHG emissions reductions could be reasonably expected from transportation sources.

EPA's Wedge Analysis: The Environmental Protection Agency (EPA) conducted a study in 2007 that examined the relationships among strategies for advanced vehicle technologies, low-greenhouse-gas fuels, and/or reducing vehicle miles traveled (Mui and J. Alson 2007). The analysis was based on scenarios of assumed future conditions including deployment of alternative fueled vehicles. The analysis concluded that individual strategies on vehicle technologies, fuels, or transportation demand management approaches could "moderately" reduce GHG emissions up to 2050. The analysis also concluded that with "aggressive" combined improvements in vehicle technologies and fuels as well as a reduction in vehicle miles traveled, transportation-related contribution to national GHG emissions could be significantly reduced. The analysis noted that limiting GHG emissions reduction strategies to only passenger vehicles constrains the extent of emissions reduction. It recommended including commercial trucks, marine vessels, railroads, airplanes, and non-road vehicle sources as part of a national strategy.

Moving Cooler: This report was commissioned by numerous professional and advocacy groups (Urban Land Institute 2009). The report excluded vehicle technology enhancements (making vehicles more energy efficient through better technology) and fuel strategies (reducing the carbon content of fuels by using alternative fuels, such as natural gas, biofuels, and hydrogen) from analysis. Instead of considering a full range of strategies, *Moving Cooler* chose to focus on pricing strategies, travel activity strategies (reducing the number of miles that vehicles travel) and operational strategies (such as eco-driving and traffic management). With specific regard to those actions aimed at influencing travel activity and improving driving conditions, the report considered the following strategies: pricing and taxes; eco-driving[5]; land use and smart growth; non-motorized transportation; public transportation improvements; ride-sharing, car-sharing, and other commuting strategies; and regulatory strategies that would moderate vehicle travel or reduce speeds to achieve higher fuel efficiency; operational and intelligent transportation system (ITS) strategies; capacity expansion and bottleneck relief; and multimodal freight sector strategies. The study found that individual strategies showed modest reductions in GHG emissions (0.5 to 5 percent) over the baseline depending on the extent of deployment. When combined into strategy packages, the study estimated a national percent reduction in GHG emissions (not including economy-wide pricing) of less than 4% to up to 25% in the

[5] Eco-driving refers to a style of driving that reduces the impact of gasoline on the environment by reducing fuel consumption and improving the automobile's efficiency.

year 2050 compared to a 2050 baseline. However, some important caveats apply to these estimates:

- The 25% estimate is based on aggressive assumptions of economic and political feasibility (such as all intercity interstate highways are tolled in 2010 at a minimum of $0.05/mile; by 2015 there is a national speed limit of 55 MPH; parking fees of $400 are imposed in residential neighborhoods starting in 2010; truck-only toll lanes are in place for 40% of large area urban interstate VMT by 2025; at least 90% of all new development from 2010-2050 occurs in compact neighborhoods; and $1.2 trillion is invested in expanding transit over 40 years).
- In contrast to the assumptions for travel behavior changes, *Moving Cooler* limited expected improvements in vehicle technology to only 43 MPG fleetwide in 2050 (versus an ongoing federal rulemaking to achieve 54.5 MPG for new cars in 2025).

NCHRP 20-24 (59): This report used a scenario approach to examine transportation GHG emissions through 2050 (Burbank and Kassoff 2009). This study summarized existing information, and tested a GHG scenario for passenger vehicles based on reduced carbon intensity of the vehicle fleet (58 to 79 percent reduction in carbon emissions per vehicle-mile), reduction in growth of vehicle-miles traveled (to 0.5 to 1.0 percent annually), and improvements in system operating efficiencies (a 10 to 15 percent GHG reduction). The resulting GHG emissions were compared against 2050 goals as established in various national and international climate change proposals or initiatives. The various scenarios resulted in transportation GHG emissions levels from 44 to 76 percent below a 2005 baseline.

USDOT Report to Congress: The study evaluated four groups of strategies to reduce transportation GHG emissions: low-carbon fuels, vehicle fuel economy, transportation system efficiency, and reducing carbon-intensive travel activity (U.S. Department of Transportation 2010). The types of strategies found in the system efficiency and travel activity categories included:

System Efficiency

Highway Operations and Management

- Traffic management
- Real-time traveler information
- Highway bottleneck relief
- Reduced speed limits

Truck Operations and Management

- Truck idling reduction
- Truck size and weight limits
- Urban consolidation centers

Freight Rail and Marine Operations

- Freight modal diversion
- Rail and intermodal terminal operations
- Ports and marine operations

Air Traffic Operations

- Air traffic management in U.S. airspace

Infrastructure Construction and Maintenance

- Construction materials
- Other transportation agency activities alternative fuel DOT fleet vehicles, and LEED-certified DOT buildings

- Reduce Carbon Intensive Travel Activity

Pricing

- VMT fees
- Intercity tolls

- Pay-as-you-drive insurance
- Congestion pricing
- Cordon pricing

Alternative Modes

- Transit expansion, promotion, and service improvements
- Intercity passenger bus and rail
- Non-motorized travel

Land use and parking

- Land use strategies, such as 60-90% of new urban growth in compact, walkable neighborhoods
- Parking management

Commute Travel Reduction

- Demand management such as widespread employer outreach and alternative mode support
- Flexible work schedules
- Compressed work week
- Tele-working
- Ride-matching, carpool, and vanpool

Public Information Campaigns

- Marketing campaigns
- Information on vehicle purchase
- Driver education/eco-driving

The report highlighted the lowering of speed limits on national highways (up to 2 percent GHG reduction) and strategies such as traffic management and bottleneck relief that could "modestly" reduce GHG emissions. It was noted that these strategies would have co-benefits associated with reduced fuel consumption given less congestion and stop-and-go traffic. The report also noted that it is difficult to estimate numerically the GHG reductions with such strategies because of induced demand. With respect to reducing carbon-intensive travel activity, the report estimated that the collective impact of all the strategies studied could result in a 6 to 21 percent reduction in GHG emissions nationally in the year 2050.

Reason Foundation Study of 48 Regions: This study examined 48 major U.S. regions, quantifying "how much CO_2 cars, light trucks and commercial trucks currently emit (base year 2005) in each region, how much CO_2 would have increased with prior CAFE standards, how much the new CAFE standards will reduce, and how much CO_2 might be reduced by other commonly suggested policies" (Hartgen, Fields, Scott, and San Jose 2011). On the transportation system side, the policies included signal timing and speed controls, capacity increases, high-occupancy or priced lanes, travel reduction polices, transit use increases, carpooling, telecommuting and walking to work.

The study concluded that vehicle technology improvements resulting in higher fuel economy, along with traffic signal harmonization, speed harmonization and shifts to smaller vehicles, provide the most significant reductions in surface transportation CO_2 emissions. It further noted that these individual strategies can generally reduce modest amounts of CO_2 emissions at a cost of around $180/ton reduced….and that "other policies such as expanded HOV-HOT lanes, carpooling, capacity improvements, VMT reductions and transit service improvements are likely to be considerably less cost-effective, although of course there are other reasons for doing them."

FHWA Reference Source Book: The most recent reference on GHG-reduction strategies was produced by the FHWA in 2012 (Federal Highway Administration 2012b). The source book examines a wide range of transportation and land use strategies that could be used to reduce GHG emissions. Expected GHG emission reductions are presented as well as information on implementation feasibility and how a particular strategy might interact and complement others. Figure 3-1 shows the types of strategies examined in this reference. Conclusions relating to the GHG reducing potential of individual strategies included:

1. There is a wide range of potential GHG emissions reduction outcomes for individual strategies simply because the contexts of their implementation are so different.
2. Some strategies could have a potentially significant impact on transportation-related GHG emissions, but these (such as pricing) tend to be the most challenging to implement.
3. Emission reductions attributable to individual strategies are most often modest compared to emission reductions from the entire transportation sector.
4. Serious policy consideration of transportation-related GHG reduction strategies will have to consider a multi-strategy (or bundled) approach to program development. However, there is very little research on the impact of jointly implemented strategies.
5. The net GHG effect of many strategies is unknown because they have "multiple and complex effects that have rarely been studied."

In addition, FHWA is developing a *Handbook for Estimating Transportation GHGs for Integration into the Planning Process,* but has not yet been released at the time of writing.

National Clearinghouses: In addition to these national studies, national clearing houses have been established as central points of reference for transportation GHG reduction strategies. Two in particular, one by the U.S. DOT (U.S. Department of Transportation 2010) and another by the American Association of State Highway and Transportation Officials (AASHTO n.d.), provide information on transportation GHG-reduction strategies. FHWA has also published a review of literature that examines a wide range of such strategies (Federal Highway Administration 2012a).

Figure 3-1: Strategies Considered in FHWA's Reference Sourcebook

Transportation Demand Management Strategies	Transportation System Management Strategies	Vehicle Improvement Strategies
• Road Pricing (including distance-based fees and cordoning) • Parking Management and Parking Pricing • Car Sharing • Pay-as-You-Drive Insurance • Ridesharing and HOV Lanes • Transit Incentives • Transit Improvements • Telework	• Traffic Signal Optimization • Ramp Metering • Incident Management • Speed Limit Reduction and Enforcement • Roundabouts • Capacity Expansion • Resurfacing Roads • Alternative Construction Materials	• Feebates • Scrappage Programs • Tax Incentives for Cleaner Vehicles • Heavy-Duty Vehicle Retrofits • Eco-Driving Education and Training and Dynamic Eco-Driving • Truck Stop Electrification and Auxiliary Power Units • Anti-Idling Regulations and Campaigns

Source: (Federal Highway Administration 2012b)

Numerous metropolitan/regional transportation/GHG emission studies have been completed as well, many of them in western states where state laws or policies require them to be done. In addition, over 30 states have completed climate action plans that have in varying degrees of sophistication addressed the role of transportation and land use strategies in reducing GHG emissions. However, in many states these action plans are not being actively implemented. Moreover, a 2012 review of state climate action plans found that *"…nearly all of the transportation GHG reductions estimated in state Climate Action Plans would require new legislation or state agency rulemaking. Half of the reductions would require major new funding. One third of state CAP GHG reductions rely on assumptions about the future price of transportation. … Some of the greatest uncertainty stems from strategies that are quantified using goals, rather than empirical data, and are not supported by a feasibility study"* (Schmidt and Meyer 2009).

As an example of a metropolitan resource document, the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area looked at transportation and land use strategies that would help reduce GHG emissions in the region (Metropolitan Transportation Commission 2009). The resource guide looked at 45 potential strategies, divided into five categories:

- Part I: Improve Vehicles and Fuels
- Part II: Improve Infrastructure
    - Travel Options
    - Streets and Roads
    - Freight
- Part III: Focus Growth
- Part IV: Shift Transportation Behavior
    - Voluntary Actions
    - Pricing
- Part V: Other Strategies
    - Cap and Trade
    - In-house emissions reduction
    - Adaptation

Figure 3-2 shows the type of information provided by this guide.

In summary, many plans and studies have been written on transportation's role in reducing GHG emissions. The strategies seem to be similar from one locale to another, with the biggest GHG emission-reducing strategies being those relating to vehicle technology and fuel composition, followed by strong pricing strategies. After these strategies are presented, however, the emphasis in the strategy list often varies by the type of organization doing the study. Thus, for example, metropolitan planning organizations (MPOs) place more emphasis on land use and development policies than do national or state plans. This is not surprising given that MPOs are much more involved with land use than higher level agencies, and are closer to implementation challenges than national organizations. Organizations more oriented toward environmental concerns tend to rely more on strategies that influence individual travel behavior (e.g., pricing and land use) than more traditional transportation agencies [see, for example, (Bishins, Sandwick and Neelakantan 2011) (Kooshian and Winkelman 2011)].

Finally, it is worth noting that certain types of promising strategies tend to be overlooked or receive little attention because they lack strong interest group advocates -- such as eco-driving, ridesharing, speed management, and traffic smoothing – despite indications that they are as effective as other strategies in reducing GHG emissions, are relatively low in cost, engender little political controversy, and can be implemented in the near term.

The next section presents the results of a recently completed research project for the Strategic Highway Research Program, Part 2. This is the most recent research project that has examined the literature on transportation-related GHG emissions and thus provides a snapshot of the state-of-knowledge at this time.

Figure 3-2: Transportation, Land Use and GHG Emissions Guide Format, Metropolitan Transportation Commission

Potential Impact in 2020:

NOTE: Ratings are for single strategy only. *Impacts could be significantly higher when strategies are analyzed as packages.*

High	> 2% reduction in transportation CO_2
Medium	1-2% reduction in transportation CO_2
Low	< 1% reduction in transportation CO_2

Cost-Effectiveness:

High	< \$100 per ton of CO_2 reduced
Medium	\$100-\$500 per ton reduced
Low	> \$500 per ton reduced

Note: In the Cost Effectiveness column, the X means qualitative analysis only.

Strategy/Project	Potential Government Lead	Already implemented somewhere?	Technically possible in 5 years?	Potential Impact in 2020	Cost-Effectiveness	Page Index
Part I: Improve Vehicles and Fuels (Page 12)						
1. Passenger vehicle emission standards	Federal/State	Yes	Yes	High	High	Page 12
2. Heavy duty vehicle emission standards	Federal/State	Yes	Yes	Low	Unknown	Page 15

3.3 Typical Transportation GHG Emission Reduction Strategies as Found in Project SHRP2 C09

Recently completed Strategic Highway Research Program2 (SHRP2) Project C09, "Incorporating Greenhouse Gas Emissions into the Collaborative Decision-making Framework," examined a range of strategies that have been considered as part of GHG analyses. (Parsons Brinckerhoff, 2011) This section summarizes the results of this research.

As seen in the national literature, this project concluded that some of the most effective strategies for reducing GHG emissions include improvements in vehicle and fuel technologies. However, most state and local transportation agencies have little authority over such strategies, although state governments can exercise significant influence through taxation policies and potentially other mechanisms (e.g., alternative fuel infrastructure investment, fuel and/or vehicle standards). This report only focused on those strategies that state and local transportation agencies can directly influence via normal transportation planning, investment and operations, and others such as pricing that will remain specific to those jurisdictions willing to take such action.

GHG emission reduction strategies under the purview of transportation agencies were characterized in three major areas: (Parsons Brinckerhoff, 2011)

- Infrastructure provision, including the design, construction, and maintenance of highway, transit, and other transportation facilities and networks;
- Management and operation of the transportation system, for example, technologies and operational practices to improve traffic flow, or transportation facility/system pricing policies (such as managed lanes); and
- Provision of transportation services and demand management measures to encourage the use of less carbon-intensive modes, such as transit service improvements, rideshare and vanpool programs, and worksite trip reduction programs.

Other strategies that may be influenced by transportation agencies included:

- Land use planning, for which transportation agencies may provide regional coordination, funding, and/or technical assistance to support state and local efforts to evolve land use patterns considered more energy efficient and conducive to reductions in GHG emissions;
- Pricing strategies such as tax and insurance policies, mileage-based pricing, or registration fees, for which transportation agencies may provide analysis support and encourage state-level policy changes;
- Provision of alternative fuels infrastructure, as well as direct purchase of alternative fuel vehicles for agency fleets; and
- Eco-driving programs, which educate, train, and provide incentives and technology for drivers to drive fuel-efficiently, keep tires optimally inflated, avoid high speeds, etc.; as shown in *Moving Cooler*, even modest levels of eco-driving have greater GHG reduction potential than aggressive land use policies, but eco-driving tends to be overlooked due primarily to lack of institutional advocates.

Table 3-1 shows the many different types of strategies that fit into these categories (remembering again that these strategies only include those that can likely be influenced by state and local governments).

Which of these strategies will receive most attention in a particular jurisdiction will depend on the goals established for that jurisdiction or planning effort, the presence or absence of interest group advocates for them, and most likely some assessment of the political feasibility of strategy implementation. It is interesting to note that some of the most "aggressive" plans for reducing GHG emissions are found in MPO plans that have included measures to influence travel behavior. These have included a shift towards more compact and transit-oriented land use patterns, as well as other travel reduction measures such as improved transit service, extensive travel demand management (TDM) programs, and travel pricing. This emphasis appears to be driven by other goals or perceived “co benefits” as much or more than actual GHG reduction potential.

Table 3-1: State and Local Government Strategies that can Influence Transportation-Related GHG Emissions and Energy Use

Strategy	Governmental Action	Primary Responsibility
Transportation System Planning and Design	• Transportation network design • Modal choices/investment priorities • Roadway design standards (affecting traffic speed and flow, pedestrian & bicycle accommodation)	Transportation agency (state, metro, local)
Construction and Maintenance Practices	• Pavement and materials – reduced energy consumption materials, durability and longevity, smoothness • Construction and maintenance equipment and operations – idle reduction, more efficient & alternative fuel vehicles, etc. • Right-of-way management - vegetation management (maximize vegetation as carbon sinks, minimize mowing); alternative energy capture (solar, wind)	Transportation agency (state, local)
Transportation System Management and Operations	• Traffic management and control (signal optimization & coordination, integrated corridor management, etc.) • Speed management (speed limits, enforcement) • Idle reduction policies and enforcement • Real-time travel information • Incident management • Preferential treatment for vehicle types (e.g., HOV lanes, bus priority) • Pricing - HOT Lanes, congestion pricing	Transportation agency (state, metro, local)
Vehicle and Fuel Policies	• Vehicle emissions standards (possibly) • Feebates or carbon-based registration fees • Provision of low-carbon fuel infrastructure • Subsidies for low-carbon fuels • Transit vehicle fleet purchases or retrofits • State/local government fleet purchases • Older/inefficient vehicle scrappage	State government, transportation agency (fleet purchases)

Strategy	Governmental Action	Primary Responsibility
Transportation Planning and Funding	• GHG consideration and analysis in planning • GHG emission reduction targets • Funding incentives tied to GHG reduction • Multi-agency working groups	Transportation agency (state, metro, local)
Land Use Codes, Regulations, and other Policies	• Integrated regional transportation and land use planning and visioning • Funding incentives and/or technical assistance for local policies for compact development, walkable communities, mixed-use development, reduced parking requirements, etc. • Infrastructure investments to support in-fill and transit-oriented development	Local government (mostly), state government, state and metro transportation agency (incentives, technical assistance)
Taxation and Pricing	• State or local tax policies that discourage low-density development • Congestion pricing • Pay-as-You-Drive Insurance • Parking pricing • Mileage-based transportation user fees • Vehicle registration fees based on fuel efficiency, carbon emissions, or miles driven	State government (mostly), local government (development fee policies, parking pricing), transportation agency (congestion pricing)
Other Travel Demand Management and Public Education	• Commute/worksite trip reduction programs • Telecommuting and alternative work schedules • Ridesharing and vanpooling incentives and services • Individualized marketing campaigns	Transportation agency (state, metro, local)
Public Education	• Eco-driving information, training, & in-vehicle feedback • Information on fuel economy, cost, and GHG impacts of vehicle purchase and travel decisions	State and local government; transportation agency

Source: (Parsons Brinckerhoff, 2011)

SHRP2 C09 made the following observations on the transportation-related strategies that can be considered for GHG emissions reductions. They are repeated here because this research has confirmed what was found in that project.

1. The largest absolute GHG benefits in the transportation sector are likely to come from advancements in vehicle and fuel technologies. Particularly promising technologies in the short to mid-term include advancements to conventional gasoline engines, truck engine improvements and drag reduction, and hybrid-electric vehicles. In the longer term, ethanol from cellulosic sources, battery-electric vehicles, plug-in hybrid electric vehicles, and hydrogen fuel cell vehicles all show great promise for reducing GHG emissions, but only if the technologies can be advanced to the point of being marketable and cost-competitive. Most of these strategies show the potential for net cost savings to consumers.
2. Pricing strategies – especially those that affect all or a large portion of VMT, such as VMT-based fees or congestion pricing – have been shown in studies to provide significant GHG reductions, but only by pricing at levels that significantly influence travelers' trip and location choices, levels that might be politically unpalatable.
3. Transportation infrastructure capital investments, like transit systems, multi-modal facilities, or park and ride lots, from a program perspective are usually shown over the long run to have larger impacts on travel behavior than other strategies (except for pricing). In addition, if one considers the co-benefits of such investment, the overall cost effectiveness of such investment might be very appealing.
4. Transportation system management (TSM) strategies that reduce congestion and improve traffic flow may provide modest GHG reductions at lower cost than capacity/system expansion. As with highway capacity strategies, however, there is uncertainty in the GHG reduction estimates for these strategies because of the magnitude and treatment of induced demand. However, the synergies needed for effective reductions should be kept in mind, e.g., any effective pricing system will need a companion ITS component to be viable, traveler advisories can increase

transit use, etc. As with #3 above, there are significant potential co-benefits (in this case in the form of time savings, reliability improvement, lower travel costs, energy savings, and safety benefits).

5. The GHG reduction benefits of a transit project will be proportional to the degree to which riders are attracted from more GHG-producing travel. This is particularly true if one takes a life cycle analysis perspective on both the transit and non-transit travel options.

6. Land use strategies can potentially provide modest GHG reductions over the long term at very low public-sector cost. Modest to moderate changes in land use patterns can probably be accomplished with strong growth policies and/or market incentives, but more far-reaching changes may be unpopular and be difficult to achieve in the current political and economic environment. To the extent that light duty vehicle fuel efficiency improves dramatically in the long run, the effects of land use (or other strategies affecting VMT) on GHG will be lessened.

7. Travel demand management (TDM) strategies have modest GHG emissions reduction potential at moderate public cost unless implemented in such a way that incentives/disincentives can influence traveler choices over a large area. Telecommuting and compressed work week strategies have primarily been driven by private initiatives.

8. Bicycle and pedestrian improvements are relatively low cost strategies, but there is little evidence that these improvements will provide significant GHG emissions reductions.

9. Speed limit reductions can provide GHG emissions benefits at modest cost, although are not likely to be popular, and require strong enforcement to achieve these benefits. EPA's own test data show the optimal speeds for the least GHG produced is 30-40mph, with GHG emissions increasing with each mph above 40.

10. While rail and marine freight is considered more energy-efficient than truck travel on average, the absolute magnitude of reductions from freight mode-shifting is

limited by the fact that only certain types of goods (particularly long-haul, non-time-sensitive goods) can be competitively moved by rail.

11. Truck operations strategies, in particular idle reduction, can provide modest total benefits with a low public investment cost while yielding net cost savings to truckers. One of the most effective strategies is to require on-board idle reduction technology, such as auxiliary units to power air conditioning and basic services while not running.

12. Studies such as *Moving Cooler* have suggested that eco-driving may have significant GHG reduction potential while providing a net savings to travelers. However, these results are based on European experience and there is limited experience with eco-driving programs in the U.S., due in part to lack of institutional advocates.

13. The impacts of any single transportation system strategy (system efficiency and travel activity) are generally modest, with most strategies showing impacts of less than (and usually considerably less than) 1 percent of total transportation GHG emissions in 2030. A few strategies show larger impacts (greater than 1 percent), including reduced speed limits, compact development, various pricing measures, and eco-driving. However, the ability to implement these strategies at sufficiently aggressive levels to reach a significant emissions reduction is uncertain due to institutional and/or political barriers. Despite the modest individual strategy impacts, analyses of the combined effects of all transportation system strategies shows that such packages could provide on the order of 5 to 20 percent reduction in transportation GHG emissions in 2030 as compared to what 2030 emissions would be without the strategies.

3.4 GHG Emission Reduction Strategies Being Considered by State DOTs and MPOs: Survey Results

As part of this research, a survey was distributed to state DOTs and MPOs asking which types of strategies were being considered to reduce transportation-related GHG emissions. Strategies identified by the respondents can be categorized as follows:

- Transportation system planning and design;
- Construction and maintenance practices;
- Transportation system management and operations (e.g., speed limit reductions, signalization);
- Vehicle and fuel policies;
- Land use codes, regulations, and other land use policies;
- Taxation and road pricing;
- Travel demand management (passenger);
- Travel demand management (freight);
- Transit strategies;
- Public education; and
- Bicycle and pedestrian.

Table 3-2 summarizes the number of respondent organizations considering the various strategies. The most common GHG reduction strategies considered by MPOs were bicycle and pedestrian strategies in addition to transit strategies. These two strategies were followed by transportation system management strategies, such as idling reduction, signalization, and speed or traffic flow management. Survey respondents also had the opportunity to identify other strategies not listed but under consideration. These other strategies included airport-related emission reductions and building energy efficiency and conservation measures.

In the long run, influencing urban form and land use patterns was also identified as a possibly important strategy for decreasing the rate of VMT increase. The means of implementing such strategies would be to modify local land use ordinances to encourage compact development patterns (i.e. smart growth), which over time would be expected to result in less driving and fewer GHG emissions. As noted earlier, the national literature on this is unclear and shows mostly modest GHG reductions, even by 2050. For example, the middle of the three scenarios analyzed in the 2009 TRB Special Report 298 on "Driving and the Built Environment" found the effect of more compact land use on household passenger GHG in 2050 to be in the range of 1.3% to 1.7% (Transportation Research Board, 2009).

In addition to the survey of state DOTs and MPOs, the research team interviewed DOT and MPO officials in selected locations because of their experience and record in considering GHG emissions in policy, planning and decision making. The types of strategies reflected the results of the national overview, although in some cases at a much higher level of application. For example, the Oregon DOT mentioned the importance of pricing, both parking and congestion pricing, as a lever for reducing GHG emissions. Widespread adoption of electric vehicles and more transit options were identified as well.

Among the MPOs, the Atlanta Regional Commission (ARC) looked at higher land densities and more transit options. The major conclusion from ARC's analysis was that vehicle and fuel technology was the primary driver for reducing GHG emissions, and that increasing land use density helps but it is not a panacea (and had little influence on travel behavior according to the travel demand model). For the Tahoe MPO, because of its unique authority over land use, one of the innovative strategies being considered is encouraging existing land owners in environmentally sensitive zones to locate buildings and/or residences closer to downtown through a variety of incentives. The Washington Metropolitan Transportation Planning Board placed considerable emphasis on eco-driving.

Table 3-2: GHG Reduction Strategies Being Considered by State DOTs and MPOs

Strategy	Number of Respondent Organizations Reporting Strategy Considered as Part of Planning Process	
	DOTs	MPOs
Total number of respondents	14	43
Total Number of Respondents Who Have or Will Consider GHG Emissions in Planning Process	11	30
Transportation system planning and design	3	15
Construction and maintenance practices	2	4
Transportation system management and operations	3	20
Vehicle and fuel policies	3	15
Land use codes, regulations, and policies	2	18
Taxation and road pricing	3	7
Travel demand management (passenger)	3	19
Travel demand management (freight)	2	5
Transit strategies	3	23
Public education	2	12
Bicycle and pedestrian	3	23

In sum, the results of the survey and to some extent the case study interviews reflect the experience reported in the national literature. Much weight is given to the role that technology will play in reducing transportation-related GHG emissions. This was reported in national studies as well as in state and MPO analyses. As shown in Table 3-2, the top four strategy types for MPOs were pedestrian/bicycle, transit, transportation system management (TSM) and travel demand management (TDM) strategies. There was no discernible preferred state DOT non-vehicle/non-fuel strategy either in the literature or in the survey/interviews.

3.5 Summary

This chapter examined the types of transportation-related GHG reduction strategies that have been analyzed in national, state and regional studies. Although the manner of categorizing the strategies is sometimes different, the individual strategies themselves are often similar. Changes in vehicle and fuel technology are pointed to by every study as the major source of GHG reductions from the transportation sector. Most studies then acknowledge that pricing can be an important influence in changing travel behavior towards using strategies that reduce GHG emissions. However, many of the studies also acknowledge the challenges such strategies face in actually being implemented. More efficient operations (TSM) and efforts to influence travel demand (TDM) are also mentioned in most studies as important components of an overall strategy. For MPOs in particular land use strategies that lead to higher densities are often part of the analysis, as is investment in more transit options. Finally, some rather innovative strategies, such as development rights transfer and eco-driving, have surfaced in a few locations.

The diversity in GHG reduction strategies poses a significant challenge to the models and tools used in analysis. Ranging from enhancing system operations to eco driving to changes in urban form, the suite of analysis tools available to transportation analysts needs to have a breadth of capability as well as sufficient depth to provide credible and defensible answers to the question of, "what benefit in reduced GHG emissions are we likely to get if we implement a combination of the strategies listed in Table 3-2?" Also posing a significant challenge to GHG models and tools is the need to speculate about new vehicle technology and fuels, economic conditions, and fuel prices that will influence travel behavior 20-40 years into the future. The next chapter summarizes the types of models and tools that are available to analysts in answering this question.

CHAPTER 4: ANALYTICAL METHODS AND TOOLS FOR CONSIDERING GHG EMISSIONS IN PLANNING EFFORTS

4.1 Introduction

Approaches to calculating GHG emissions vary in sophistication depending on the models or tools used, input assumptions, degree of causality between model variables and outcome measures, and data availability. The primary approaches to calculating surface transportation GHG emissions are based on estimating fossil fuel consumption or vehicle miles traveled, with some variations in the approaches. This chapter describes some of the leading models and analysis tools for estimating GHG emissions.

The starting point for GHG analysis is the development of a GHG emissions inventory. This provides a baseline composed of those activities that constitute the bulk of the emissions, and thus what opportunities exist for GHG reduction strategies. Besides national EPA emissions inventories, state GHG emission inventories have often been compiled in conjunction with state Climate Action Plans (CAPs). These inventories typically covered all sectors that were a source for GHG emissions, not just transportation. Many of these state CAPs were one of the first attempts at the state level to analyze GHG emissions and provide information on GHG reduction strategies. GHG emissions reductions from the baseline inventory is usually one of the performance metrics used to evaluate the effectiveness of alternative courses of action.

This baseline reduction metric is often calculated in reference to a historic or current baseline year inventory, but sometimes it is calculated in terms of a projected future baseline, such as a 2050 baseline. The metric and reference baseline of measurement is important, particularly for analysts and decision-makers, to fully understand the significance of reductions.

When examining the impacts of transportation policies, investments, or programs on GHG emissions, the methodology for calculating direct operational GHG involves two steps:

1) Determining the impacts on vehicle travel (e.g., VMT, speeds, distances), fuel economy, or fuel type used; and

2) Calculating the GHG emissions impact based on conversion factors that relate the change in these factors to GHG emissions reduction (e.g., grams/VMT).

This chapter discusses the methods for estimating transportation-related GHG, and the various types of supportive analytical models, including models relating to travel demand and emissions. Independent of the estimation methods used, an emissions inventory should be consistent with the quality assurance and control (QA/QC) principles established by the IPCC and EPA guidelines. The U.S. emissions inventory prepared annually by EPA uses methodologies consistent with those recommended in the *Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), the IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), and the IPCC *Good Practice Guidance for Land Use, Land-Use Change, and Forestry* (IPCC 2003). Additionally, the U.S. emissions inventory has continued to incorporate new methodologies and data from the 2006 IPCC *Guidelines for National Greenhouse Gas Inventories* (IPCC 2006).

Using a pragmatic means of building inventories that are consistent, comparable, complete, accurate and transparent improves inventory quality over time. To assist in these efforts, EPA implemented a systematic approach to QA/QC for the latest national GHG inventory, formalized in accordance with the QA/QC plan and the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines.

4.2 Fuel-Based Estimation and Supporting Analytical Tools

The most accurate method for estimating direct CO_2 emissions from mobile fuel combustion is to estimate the volume of fuel used, the measured carbon content of the fuel per unit of energy (or per unit of volume or mass), and the measured heat content (or density) of the fuel used. This is represented mathematically as:

CO_2 = F x R x K x (44/12)[6], where

CO_2 = emissions of CO2 [kg]

F = fuel use [gal]

R = heat content [Btu/gal] (or fuel density [kg/gal])

K = carbon content [kg C/Btu] (or [kg C/kg fuel])

CH_4 and N_2O emissions can be estimated by multiplying the amount of fuel used by the vehicle fuel economy, and a distance-based emission factor, represented as:

CH_4 = F x M x G, where

CH_4 = emissions of CH_4 [g]

F = fuel use [gal]

M = vehicle fuel economy [miles/gal]

G = emission factor [g CH_4/mile]

Carbon content varies by fuel, and some variation within each type of fuel is normal. EPA and other agencies use the following average carbon content values to estimate CO_2 emissions:

- CO_2 emissions from a gallon of gasoline: 8,887 grams CO_2/ gallon[7]
- CO_2 emissions from a gallon of diesel: 10,180 grams CO_2/ gallon[8]

[6] Carbon dioxide emissions per barrel of crude oil were determined by multiplying heat content times the carbon coefficient times the fraction oxidized times the ratio of the molecular weight of carbon dioxide to that of carbon.

[7] This gasoline factor is from a regulation establishing GHG standards for model year 2012-2016 vehicles (75 FR 25324, May 7, 2010).

[8] This diesel factor is from the calculations that vehicle manufacturers use to measure fuel economy (40 C.F.R 600.113).

Vehicles that use diesel fuel generally have higher fuel economy than comparable gasoline vehicles. However, when comparing carbon dioxide emissions, the higher CO_2 emissions from diesel fuel partially offset the fuel economy benefit.

The major limitation of this method is that transportation agencies (and primarily MPOs) do not typically collect data to track vehicle fuel consumption by fuel type (such as from fuel purchase data), and in many states a large portion of those driving could have purchased their fuel outside the study area (e.g., states with numerous pass-through trips). In a limited number of cases, fuel data are available and can be used directly in calculating CO_2.

Transportation GHG modeling generally focuses on estimating vehicle miles of travel (VMT) for motor vehicles, or person miles traveled (PMT) for transit and non-road modes as well as for highway-based vehicles. Given the primary use of VMT as a metric for transportation activity, the other key factor necessary to estimate vehicle fuel consumption is vehicle fuel economy (miles per gallon).

4.2.1 Energy/Economic Forecasting Analysis Tools

These tools are designed to forecast energy consumption, typically based on economic factors such as economic growth and fuel prices. Most of these tools are designed for national-level analysis, and cannot be readily used for metropolitan area or project-level analyses. Although these tools have strengths in terms of examining the implications of economic factors on transportation energy consumption, they typically are not geared toward analyzing the impacts of transportation investments and rely on data inputs that are not typically used in the transportation planning process. These tools include:

- *National Energy Modeling System (NEMS)* – Developed by the Energy Information Administration (EIA) in the U.S. Department of Energy (DOE), NEMS models the behavior of energy markets and their interactions within the U.S. economy to develop annual projections and evaluate national energy policies. A transportation demand module (TRAN) within the model forecasts the consumption of transportation sector fuels, which can be used to calculate CO_2 emissions.

- *VISION* – Developed by the Argonne National Laboratory (sponsored by DOE), VISION is an Excel-based model that estimates the potential energy use, oil use, and carbon emission impacts of advanced light- and heavy-duty highway vehicle technologies and alternative fuels up to 2050.
- *World Energy Protection System (WEPS) Transportation Energy Model (TEM)* – Developed by DOE as a component of WEPS (a world energy consumption model), the Transportation Energy Model (TEM) forecasts transportation sector energy use by transport mode at a national and multi-national region level. The WEPS accounting framework incorporates assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]), and about the rate of incremental energy requirements met by different energy sources. Projections produced by WEPS are published in the annual report, *International Energy Outlook*.
- *Systems for the Analysis of Global Energy Markets (SAGE)* – Developed by the DOE to replace WEPS, SAGE projects energy consumption to meet energy demand, estimated on the basis of each region's existing energy use patterns, the existing stock of energy-using equipment, and the characteristics of available new technologies, as well as new sources of primary energy supply.

Multi-Sector Inventory Tools

These tools are designed to develop GHG inventories or projections for all economic sectors, including transportation:

- *State Inventory Tool (SIT)* – Developed by the EPA, the SIT is designed to develop a comprehensive GHG inventory (CO_2, CH_4, N_2O, and HFCs) at the state level, using a combination of state-specific inputs and default data. It requires inputs of transportation fuel consumption and VMT.

SIT was used by the Maryland DOT to estimate on-road CH_4 and N_2O emissions based on the inputs of vehicle miles of travel (VMT) and SIT defaults for fleet characteristics and vehicle technology. VMT was based on available 2005-2006 Maryland State Highway traffic data and reported 2006 HPMS VMT. Off-road GHG emission analysis relied on the emission factors and methodologies provided in SIT. The SIT estimated off-road CO_2, CH_4 and N_2O emissions based on historical fuel consumption data. Inputs to the SIT tool for the 2006 baseline inventory were based on the EIA's State Energy Data (SED) and it is important to note that life cycle GHG emissions were not generated by SIT.

- *State Inventory Projection Tool (SIPT)* – Developed for the EPA, the State Inventory Projection Tool builds on inventory estimates from the SIT by allowing users to forecast GHG emissions through 2020. Projections are based in part on projected fuel consumption reported by the U.S. Energy Information Administration.

- *California Statewide Energy Efficiency Collaborative (CalSEEC)* – CalSEEC is a collaborative with ICLEI, Local Government Commission, Institute for Local Government, and energy companies like Pacific Gas and Electric, Southern California Edison, and Sempra Energy providing support to cities and counties to help them save energy and reduce greenhouse gas emissions across multiple sectors. Tools and support are provided to assist in the development of local government and community-wide GHG emissions inventories. The process and tools are typically used by smaller or more rural MPOs.

San Joaquin Council of Governments (SJCOG) used this tool to develop multi-sector GHG emissions inventory at the community scale for consistency with existing community action plans developed with this tool. Sectors included in the inventory were energy, transportation, solid waste, wastewater, and agriculture. On-road emissions, accounting for about 95% of total transportation emissions, were calculated using EMFAC2007 and VMT from the SJCOG RTP. Off-road emissions were calculated using CARB's OFFROAD 2007 model for San Joaquin County. All off-road vehicles were included with the exception of agricultural equipment (which was accounted for in the agricultural sector inventory). Overall, transportation accounted for about 44.7% of the total 2005 baseline inventory for SJCOG. As with virtually all such tools, CalSEEC does not account for life cycle emissions.

4.3 VMT-Based Estimation and Supporting Analytical Tools

If fuel usage data is unavailable for a particular vehicle type, CO_2 emissions may be estimated from VMT by dividing data for each vehicle type by its corresponding fuel economy using data from the U.S. EPA, which is typically included within emissions calculators. From this fuel usage estimate, CO_2 emissions can be calculated by:

CO_2 = (V/M) x R x K x (44/12)[9], where

CO_2 = emissions of CO_2 [kg]

V = VMT [miles]

M = vehicle fuel economy [miles/gal]

R = heat content [Btu/gal] (or fuel density [kg/gal])

K = carbon content [kg C/Btu] (or [kg C/kg fuel])

A range of VMT-based approaches and methods are used to estimate GHG emissions. Most of the more analytically based approaches use a travel demand model along with some form of emissions factor model. However, depending on the problem being studied and the resources available, one could also use traffic simulation models or even simple trend projections (often done for rural areas). This section provides an overview of the tools and methods that are commonly used today for GHG emissions analysis based on VMT.

In emission factor models like EMFAC or MOVES (the replacement of MOBILE6.2), one of the options for outputs is provided in grams per mile (g/mi). Using the VMT-based approach, the resulting CO_2 emissions can be calculated by:

CO_2 = V x EF, where

CO_2 = emissions of CO_2 [g]

[9] Carbon dioxide emissions per barrel of crude oil were determined by multiplying heat content times the carbon coefficient times the fraction oxidized times the ratio of the molecular weight of carbon dioxide to that of carbon.

V = VMT [miles]

EF = Emission Factor [g/mi]

There is a range in sophistication in calculating GHG emissions using VMT, depending on how VMT is derived. The *Practitioner's Resource Document on Calculations Methods and Data Sources* (SHRP CO9, 2009) describes the varying VMT-based approaches, when to apply different methods, and noting the data resources required to conduct an analysis.

When expressing total greenhouse gas emissions, the base unit is measured in CO_2 equivalents (CO_2e). The impacts of non-CO_2 greenhouse gas pollutants are calculated by multiplying by the pollutants' global warming potential (GWP). The GWP is the ratio of the warming that would result from the emission of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a fixed period of time, such as 100 years. For example, 1000 kilograms (one metric ton) of CO_2 is equivalent to one metric ton of CO_2e. One metric ton of CH_4, however, is equivalent to 23 metric tons of CO_2e. Table 4-1 outlines the GWP of various greenhouse gases per the various assessment reports by the Intergovernmental Panel on Climate Change.

As already mentioned, CO_2 is by far the most prevalent GHG emitted by transportation sources. According to the U.S. GHG Inventory, nationally over 95% of transportation GHG emissions are in the form of CO_2, when measured in terms of global warming potential (CO_2 equivalent emissions).

Table 4-1 Summary of Global Warming Potentials from IPCC's Second, Third, and Fourth Assessment Reports

Greenhouse Gas	Second Assessment Report GWP (1996)	Third Assessment Report GWP (2001)	Fourth Assessment Report GWP (2007)
CO_2	1	1	1
CH4	21	23	25
N2O	310	296	298

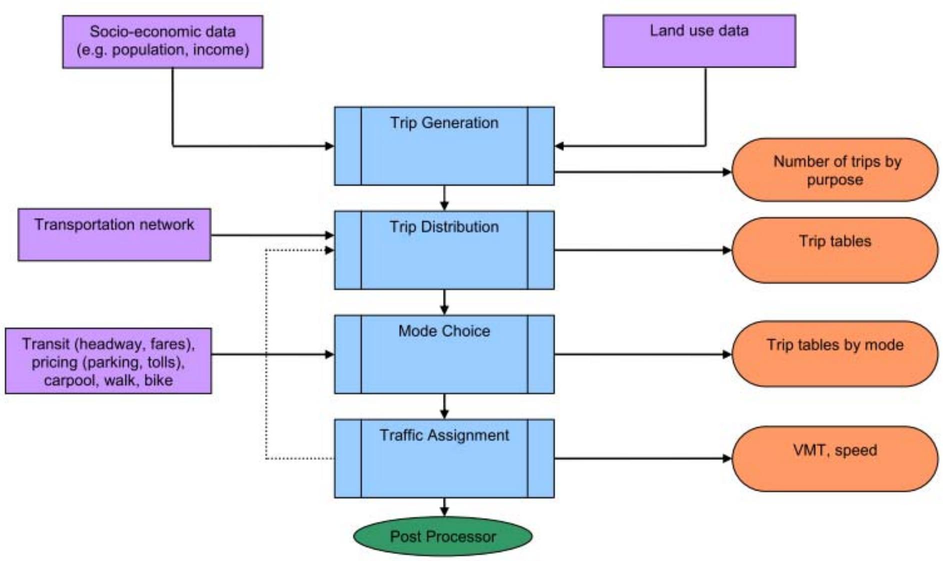
Source: Climate Change, 2007

4.3.1 Travel Demand Models

Travel demand models have varying capabilities for GHG analysis (Donnelly 2010). The usual product of model runs includes traffic volumes and speeds by network link, which are then used with an emission factor model to develop GHG emission estimates. These models are best suited for analyzing changes in the transportation network such as capacity expansion or new roadways. They have also been modified so as to analyze strategies such as road pricing. (DKS Associates 2007)

- **Traditional Travel Demand Models.** These models are the traditional 4-step travel demand models (e.g., typically using software packages such as EMME or VISUM) customized with local data forecast daily or peak period traffic demand for a state or region. The VMT outputs and associated operating characteristics are combined with emission models to develop GHG estimates. These models are the most common found in practice today (see Figure 4-1).

Figure 4-1 Basic Components of Typical Travel Demand Models



Source: CARB, Description of Methodology for Air Resources Board (ARB) Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies (SCS) Pursuant to SB 375July 2011

- **Micro-simulation and travel assignment models.** These models provide significantly more detail on travel demand (e.g., 15-minute demands, vehicle mix) and supply (e.g., signalization) and thus produce more accurate speed profiles, important in GHG emission estimates. These range from traffic simulation models (e.g., VISIM, Synchro) that typically cover a small geographic project area (e.g., facilities, network or corridor level) to dynamic traffic assignment models (e.g., Dynameq, VISTA, DynusT), which can be applied to larger regions.
- **Advanced Land Use and Transport models.** Many GHG analyses examine the emissions reduction potential of changing land use patterns and densities. More complex models can provide more accurate VMT estimates and sensitivity to land use and pricing GHG reduction strategies. In order to conduct such analyses, MPOs usually have some sort of land use forecasting model or method that is used for developing future projections of population and employment. Only a few areas, however, have developed integrated transportation and land use forecasting models (such as UrbanSim or PECAS) that are highly sensitive to transportation improvements as well as to a variety of land use policies. In many cases, land use scenarios are undertaken simply by manually changing the land use densities in traffic analysis zones subject to some overall control threshold for population and employment.
- **Freight Models.** These models are most commonly commodity flow models where freight movements are driven by economic transactions of industry type and use of particular goods (aided by the FHWA Freight Analysis Framework (FAF) dataset). These models are a significant improvement over the traditional employee trip-generated rates of truck trips. GHG analyses are increasingly including freight flows, after historically focusing only on auto travel (light duty vehicles).

The ability to estimate future traffic characteristics and travel activity accurately relies on the quality of the model inputs and assumptions. Table 4.2 outlines examples of travel model inputs. Data sources for these inputs may include but are not limited to the Census data for population household and household economic data, general plans, toll and transit operators, local agencies, energy surveys, and household travel surveys. (California Air Resources Board, 2011)

Table 4-2 Examples of Fundamental Travel Model Inputs

Category	Fundamental Model Input
Socio-Economic	Population by age, income, household and auto
	Migration rate
	Military population projection
	Household by household size and auto ownership
	Workers by household size
	Household vacancy rates
	Employment by industrial classification
	Unemployment rates
Land Use	Regional Comprehensive Plan assumptions
Highway Facilities	Highway capacity
	Highway network
	Lane miles by facility
	Facility free flow speed
	High occupancy vehicle (HOV) lane miles
	HOT lane miles
Transit Facilities	Transit route network
	Transit speed
	Transit route frequency
Transportation Costs	Gasoline prices
	Vehicle operating costs
	Toll prices
	Parking prices
	Transit fares
Travel Behavior	Trip generation rates
	Trip time distribution
	Trip distance distribution

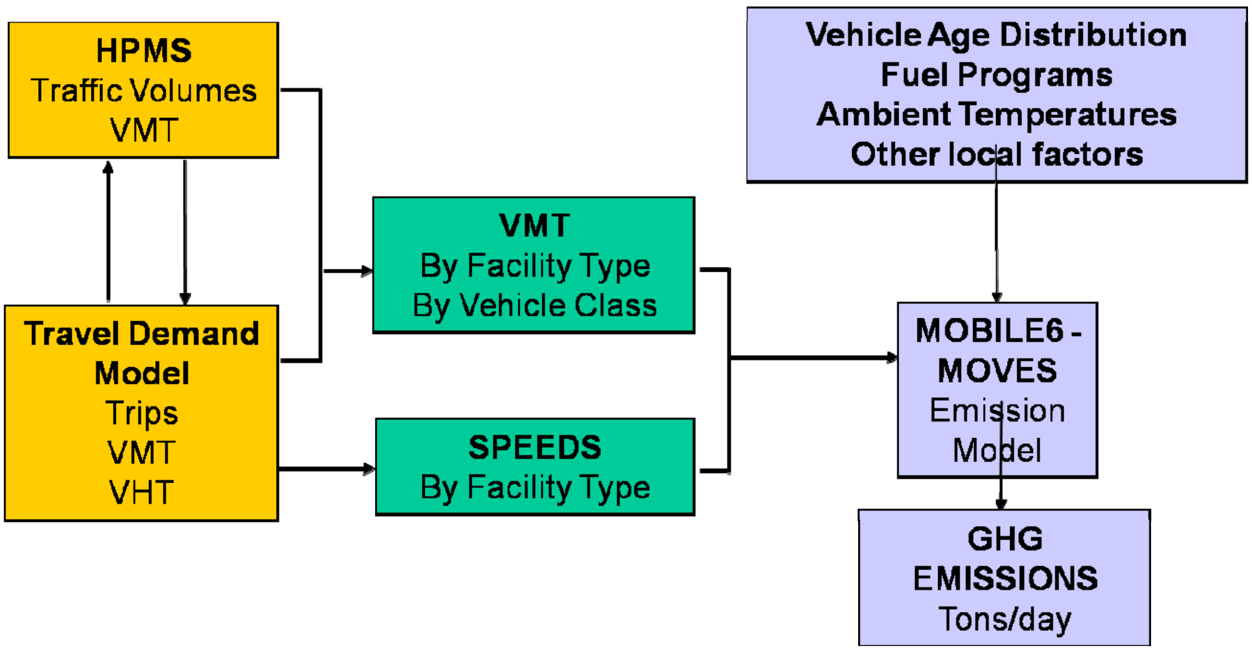
Source: California Air Resources Board, 2011

In most cases, these models have incorporated post processing modules for estimating changes in fuel use and pollutant emissions resulting from changes in traffic characteristics (speed and acceleration). While most do not currently produce GHG estimates directly, fuel CO_2 emission factors have been applied to changes in fuel use to determine changes in GHG emissions. The following section provides details on the most commonly used emission models and how they account for different CO_2 emissions by vehicle type, model year, and class.

4.3.2 Direct GHG Emission Calculation Models and Tools

The second major analysis tool for estimating GHG emissions based on VMT is an emission factor model. The three main types of emission factor models include those for on-road sources, off-road sources, and life-cycle analysis. Figure 4-2 illustrates the basic concept of emission estimation using travel demand and emission models.

Figure 4-2 VMT-Based Methods GHG Emission Estimation Process



Source: NHI Course 142044 – The Implication of Air Quality Planning for Transportation

4.3.2.1 On-Road GHG Emission Calculation Models and Tools

Three major emission models have been used in the United States: MOBILE6.2, its replacement MOVES, and EMFAC.

MOBILE6.2

EPA developed the first version of the MOBILE model in 1978 (MOBILE1) to estimate motor vehicle emission factors for the criteria air quality pollutants, and as a way to forecast current and future emissions. As vehicle technology evolved and better quantification of emissions was needed EPA updated the MOBILE model until MOBILE6.2 was released in 2002. MOBILE6.2 (the latest version) estimates "hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), exhaust particulate matter (which consists of several components), tire wear particulate matter, brake wear particulate matter, sulfur dioxide (SO_2), ammonia (NH_3), six hazardous air pollutant (HAP), and carbon dioxide (CO_2) emission factors for gasoline-fueled and diesel highway motor vehicles."[10] The model calculates emission factors for 28 individual vehicle types in low and high-altitude regions and varies the emission factors by such inputs as ambient temperatures, travel speeds, operating modes, fuel volatility, and mileage accrual rates. The model estimates emission factors for model year 1951 to 2050.

MOBILE6.2 considers all current and past model years, with the oldest vehicles lumped into a 25-years and older category. Although vehicle registration data and mileage accumulation rates, which provide a weighted average of the state or local vehicle fleet emissions, should be input at the state or metro area level, agencies that lack the resources to do this rely on national defaults built into the model. Normally the state environmental agency, in conjunction with the state DOT, compiles these data sets. The CO_2 emissions are estimated in a very simple fashion based on fuel economy performance estimates for each model year vehicle.

Its greatest limitation as a tool for GHG analysis is that CO_2 emission estimates are not adjusted for speed, temperature, fuel characteristics, or the effects of vehicle inspection maintenance programs. Thus, MOBILE 6.2 emissions are not sensitive to transportation strategies that could affect any of these factors. According to EPA guidance, this also means that these CO_2 emission estimates should only be used to model areas and time periods that are large enough to reasonably assume that variation in these parameters does not have a significant net effect (i.e. variations get averaged out at a large scale).[11] Another significant shortcoming for modeling CO_2 emissions is that MOBILE6.2 does not include any

[10] http://www.epa.gov/otaq/models/mobile6/420r03010.pdf

[11] http://www.epa.gov/otaq/models/mobile6/420r03010.pdf

data for the recent CAFE fuel economy standards or any alternative fuels program, i.e. the emission factors are based on the average of past fuel economy standards.

Motor Vehicle Emission Simulator (MOVES)

EPA's Motor Vehicle Emission Simulator (MOVES) model replaces EPA's previous MOBILE6 and NMIM models. MOVES has the capability to estimate CO_2, N_2O, and CH_4 emissions from on-road vehicles. Of all the tools available, EPA's MOVES provides the most functionality and applicability for conducting different types of transportation GHG analyses.

EPA's MOVES model was designed for transportation emissions analysis and overcomes most of the limitations of these other tools when it comes to GHG analysis. Based on input from stakeholders, MOVES was envisioned and designed so that it could be used for a range of purposes including:

- National inventory development for EPA reports and regulations;
- Inventory development for regulatory requirements (e.g., SIPs, conformity);
- Policy evaluation (e.g., technologies, fuels, travel incentives);
- Hot spot and project level analysis; and
- Model validation and uncertainty analysis.

The tool also accounts for the effects of transportation investments and policies, including changes in levels of vehicle travel, mix of vehicles (classification and fuel type), activity patterns (e.g., VMT mix by road type and time of day), operating speeds (including congestion levels or idling times), state vehicle registration, and sales fraction by type of vehicle class. The tool includes vehicle registration data and mileage accumulation rates for all counties within the US. This aspect is very important when internally calculating the different fuel economy for specific vehicle types, classes, models, and model years. The model could be used with the internal default data sets at different levels of geography (e.g., nation, state, county, project level) and time spans, but also allows the input of localized data sets if needed for a specific scenario analysis. MOVES builds on the EPA 30-year experience with the MOBILE series of vehicle emission factors that started in 1978 with MOBILE1 until the development of MOBILE6 in 2002.

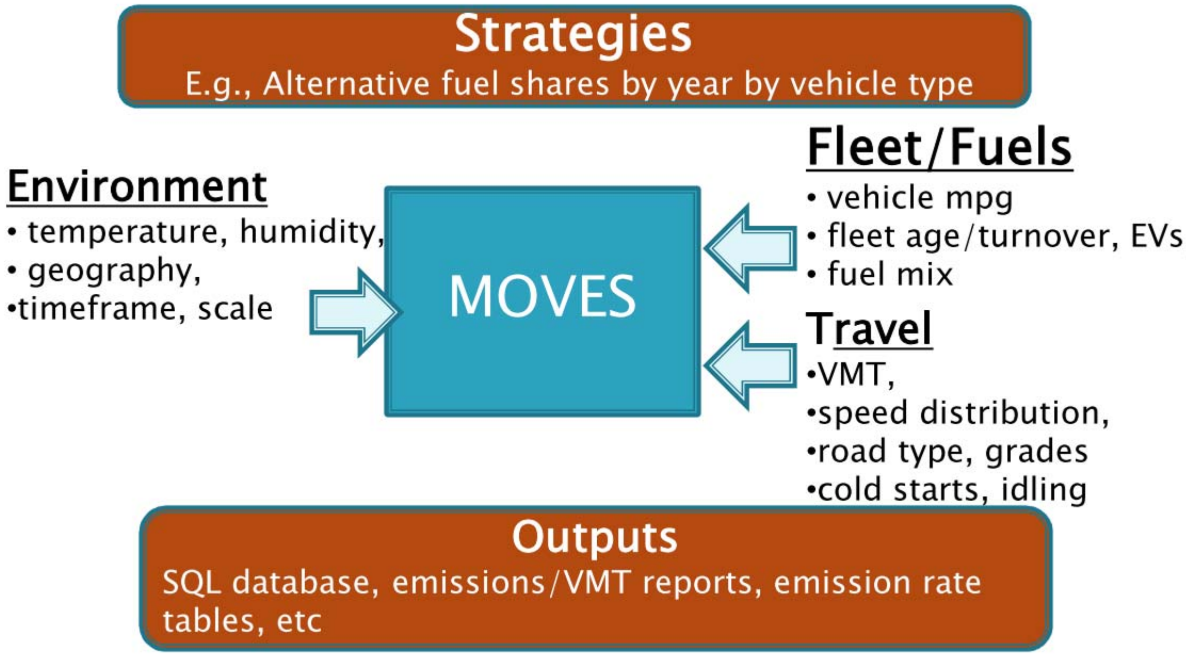
The following three versions of MOVES currently exist: MOVES2010, MOVES2010a, and MOVES 2010b. MOVES2010a and MOVES2010b are minor revisions to the MOVES2010 model. Neither of these revisions is considered to be a new emissions model for SIP and conformity purposes.

MOVES2010a was released in September 2010 to incorporate car and light truck greenhouse gas emission standards affecting model years 2012-and-later (published May 7, 2010) and updates effects of CAFE standards affecting model years 2008-2011. MOVES2010a includes reductions in greenhouse gases associated with those standards in future calendar years, and small reductions in refueling and sulfur-related emissions associated with the reductions in vehicle fuel consumption.

MOVES2010b was released in April 2012. Minor revisions include the 2010a improvements, more flexibility for varying inputs within a single custom domain, and relocation of the interface for entering data about Advanced Vehicle and Fuel Technologies from the main input panel to the County Data Manager. This latest version also contains internal data sets that can be used to project the market penetration of alternative fuels, and newer vehicle technologies. The most recent CAFÉ standards (model years 2017-2025) signed at the time of writing, however, will not be incorporated until MOVES2013.

Figure 4-3 outlines the basic components and inputs for the estimation of GHG emissions using MOVES.

Figure 4-3 MOVES Model Inputs



Source: Parsons Brinckerhoff, 2012

Emission Factor Model (EMFAC)

The California Air Resources Board (CARB) developed the EMission FACtors (EMFAC) model as the California counterpart to EPA's MOBILE (now MOVES) model. Using emission factors and vehicle activity inputs, EMFAC develops emission estimates for on-road vehicles to be used in developing emission inventories, projections, and other project level analyses. The CO_2 emission rates vary by vehicle speed.

EMFAC combines locally specific emission rates and vehicle activity to generate hourly or daily total emissions for geographic areas in California (statewide, air basin, air pollution control district, or county). EMFAC estimates fuel consumption for gasoline and diesel as well as emissions of CO_2 and CH_4, but not N_2O for vehicles model years 1970 to 2040. The model performs separate calculations for each of thirteen classes of vehicles by fuel usage and technology group. EMFAC contains local data for each county in California; however, the user can edit inputs such as VMT, vehicle population, technology fractions, speed fractions, and other factors.

EMFAC differs from MOVES in the way emissions are estimated. MOVES calculates emission rates associated with vehicle operating modes (e.g., cruise and acceleration). These emission rates are based on the second-by-second power demand placed on a vehicle when operating in various modes and at various speeds. The activity data in MOVES is vehicle operating time. In contrast, EMFAC like MOBILE calculates emissions estimates from trip-based travel activities. EMFAC quantifies running exhaust emission factors in grams per mile for a specific speed bin. The emission factors are composite emission rates aggregated from base rates by vehicle class, technology group and model year. The activity data used by EMFAC is vehicle miles travelled (VMT).[12] EMFAC2007 has been used for many project environmental impact assessments and alternatives analysis studies.

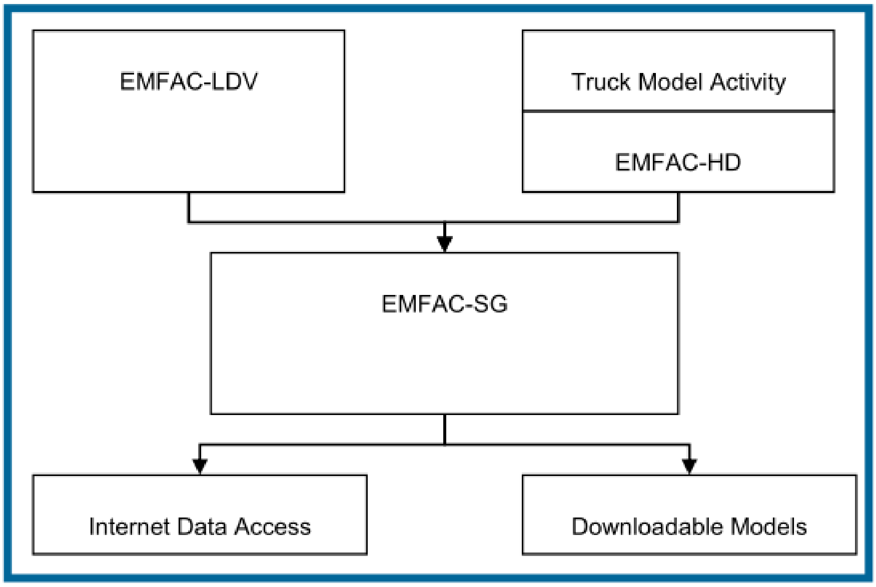
EMFAC2011was released September 19, 2011 to support CARB's regulatory and air quality planning efforts, and to meet the FHWA's transportation planning requirements. EMFAC2011 includes the latest data on California's car and truck fleets and travel activity. The model also reflects the emissions benefits of CARB's recent rulemakings including on-road diesel fleet rules, Pavley Clean Car Standards, and the Low Carbon Fuel standard. The most important improvement in EMFAC2011 is the integration of the new data and methods to estimate emissions from diesel trucks and buses.

In order to incorporate the new detailed data, CARB staff used a modular emissions modeling approach for EMFAC2011 that departs from past EMFAC versions. The first module, named EMFAC-LDV, estimates passenger vehicles emissions. A second module, called EMFAC-HD, estimates emissions from diesel trucks and buses. A third module integrates the output of EMFAC-LDV and EMFAC-HD and provides users with the ability to conduct scenario assessments for air quality and transportation planning, and is called EMFAC-SG. Together the three modules comprise EMFAC2011.

Figure 4-4 provides a schematic description of the EMFAC2011 components.

[12] http://www.arb.ca.gov/msei/onroad/latest_version.htm

Figure 4-4 EMFAC2011 Components



Source: CARB, Description of Methodology for Air Resources Board (ARB) Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies (SCS) Pursuant to SB 375, July 2011

As part of the Sustainable Communities and Climate Protection Act of 2008 (SB 375), a sustainable communities strategy (SCS) is now required for each region as part of the long-range regional transportation planning process to illustrate how the region will meet its assigned GHG targets. To facilitate the evaluation of GHG impacts in the SCS, the California Air Resources Board developed guidance and a review process for consistency across the 18 MPOs in the state. The methodology is intended to provide the framework for a transparent evaluation of associated reductions in GHG emissions, and focuses on a review of how well the region‘s travel demand modeling and related analyses provide for the quantification of GHG emission reductions associated with the SCS.

CARB staff examined each MPOs' modeling documentation in order to assess whether its model reflects both the existing conditions, and the likely traveler response to the SCS components. Model validation and calibration ensure that the model represents current or base year conditions, which are then reflected in travel forecasts. CARB staff also developed an EMFAC Post-Processor tool for MPOs to estimate the GHG emissions associated with their SCS while also considering the emission reduction benefits of California's vehicle and fuel standards.

4.3.3 Off-Road GHG Emission Calculation Models and Tools

Several models are available for estimating off-road GHG emissions.

- *Climate Leadership in Parks (CLIP) Tool* – Prepared for EPA, the CLIP Tool allows for GHG and criteria pollutant emissions estimation at the local level for all highway and non-highway transportation and mobile sources (including off-road sources such as construction equipment). Although default vehicle characteristics are geared toward travel situations at national parks, CLIP allows users to enter additional data to reflect local conditions.
- *EDMS (aircraft and airports)* – This is a well-established model developed by FAA and used for airport-related analysis.
- *NONROAD Model* – This EPA-approved emissions model is used to develop estimates of criteria pollutant and CO_2 emissions estimates for non-road sources, such as recreational vehicles, agricultural equipment, construction equipment, lawn and garden equipment, recreational boats, airport ground support equipment, railroad maintenance equipment and others. NONROAD does not address commercial marine vessels, locomotives, or aircraft.
- *National Mobile Inventory Model (NMIM)* – EPA developed NMIM to integrate the input data requirements, model runtimes, and post-processing requirements for MOBILE6.2 and NONROAD models into a single package.
- Rail and marine emissions are generally estimated on spread sheet-based platforms using a variety of fuel consumption and emission rates from EPA and industry sources.

4.3.4 Life-Cycle GHG Emission Calculation Tools

Although most GHG emission calculations by state DOTs and MPOs focus on direct operating emissions, there is value in conducting a life-cycle GHG emission analysis in order to capture "upstream" processes in addition to "downstream" processes. Upstream processes can refer to processes like the exploration and production, drilling, extraction, transport and refining of crude oil. Upstream processes also include the GHG and energy associated with constructing and maintaining infrastructure, as well as manufacturing of vehicles. Downstream processes typically cover oil disposal or recycling of oil and/or vehicles and vehicle products. Life-cycle analysis can be especially valuable when assessing GHG reduction strategies related to fuels and vehicles and for major capital investments, as in construction of new highway or transit capacity. The primary two life-cycle analysis tools include:

- *Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model* – Developed by the Argonne National Laboratory (sponsored by DOE), GREET is designed to evaluate the energy and emission impacts of advanced vehicle technologies and new transportation fuels (considering the fuel cycle from wells to wheels and the vehicle cycle through material recovery to vehicle disposal).
- *Lifecycle Emissions Model (LEM)* – Developed at the University of California, Davis, LEM estimates energy use, criteria pollutant emissions, and CO_2-equivalent greenhouse-gas emissions from transportation and energy sources. The revised (2003) Lifecycle Emissions Model (LEM) calculates energy use, air-pollutant emissions, and CO_2-equivalent emissions of CO_2, CH_4, N_2O, chlorofluorocarbons (CFC-12), nitrogen oxides (NO_x), carbon monoxide (CO), non-methane organic compounds (NMOCs) weighted by their ozone-forming potential, sulfur oxides (SO_x), hydrogen (H_2), and particulate matter (PM) from the lifecycle of fuels and materials for a wide range of transportation modes, vehicles, and fuels.

In addition to the two primary life-cycle analysis tools, NYSDOT has developed procedures for estimating construction and maintenance emissions at the planning and project levels. A spreadsheet tool developed for this same purpose through a FHWA research contract underway is expected to be completed in early 2013. Table 4-3 provides a summary of current energy and emissions modeling tools described in this chapter.

Table 4-3 Summary of Current Energy and Emission Factor Models

Energy/ Emission Factor Model	Geographic Level of Analysis				Type of Analysis		Transportation Mode						
	State	Region	Local	Project	Inventory Development	Projections	LDV	HDV	Bus	Rail	Maritime	Aviation	Other Non-Road
NEMS						x	x	x	x	x	x	x	x
VISION						x	x	x	x	x	x	x	x
WEPS					x	x	x	x	x	x	x	x	x
SAGE				x	x	x	x	x	x				
SIT	x				x		x	x	x	x	x	x	x
SIPT	x					x	x	x	x	x	x	x	x
MOBILE6.2	x	x	x	x	x	x	x	x	x				
MOVES	x	x	x	x	x	x	x	x	x				
EMFAC	x	x	x	x	x	x	x	x	x				
CLIP			x		x		x	x	x		x		x
EDMS		x	x	x	x	x						x	
NONROAD	x	x	x		x	x					x		
NMIM	x	x	x		x	x	x	x					x
GREET	x	x	x	x	x	x	x						
LEM				x	x	x	x	x	x	x	x		x

4.4 Survey Results

The most common approach used by MPOs and DOTs in the survey is the combination of travel demand models (or direct VMT data in rural areas) and emission factor models (MOBILE6.2, MOVES, or EMFAC). Most survey participants that do GHG analyses reported using a VMT-based approach to calculate direct GHG emissions. Survey participants who did not use VMT-based approaches relied on HPMS data (and then applied GHG emission factors), or used emissions calculators with built-in assumptions on emission factors. Vehicle emission models currently in use by survey respondents are summarized in Table 4-4.

Table 4-4 Vehicle Emissions Models Used by Survey Participants

Emissions Model	DOTs	MPOs	Total
Mobile6.2	1	7	8
MOVES	3	6	9
EMFAC	0	1	1

Note: Numbers reported are out of a total of 23 survey respondents who have conducted some level of GHG analysis to date.

The level of complexity and sophistication of the models and tools varies depending on the size, technical and economic resources of the MPO or DOT. No respondents in this study reported calculating life-cycle emissions; however, the Oregon DOT is planning to include a well-to-wheel component in its GHG analysis. Table 4-5 illustrates the common approaches being used by DOTs and MPOs interviewed as part of this study.

Table 4-5 Models, Tools, and Approaches Used by Case Study DOTs* and MPOs

	Oregon Dept. of Transportation	Maryland Dept. of Transportation	Sacramento Council of Governments	San Joaquin Council of Governments	Tahoe MPO	Denver Regional COG	Atlanta Regional Commission	Boston Region MPO	Metropolitan Washington COG
GHG Calculation Approach									
Fuel based approach		x							
Vehicle miles traveled approach	x		x	x	x	x	x	x	x
VMT trend extrapolation w VMT-based EFs		x							
Travel demand models		x				x	x	x	
Enhanced travel demand + off-model analysis	x				x			x	x
Traffic counts, forecasts + transit projections			x	x				x	
Traffic simulation models									
Integrated transportation-land use model			x			x		x	
Emission Model									
Motor Vehicle Emission Simulator (MOVES)		x							x
Mobile6							x	x	
EMFAC			x	x	x				
GHG Protocols									
ICLEI Clean Air & Climate Protection (CACP)			x	x					
Greenhouse Gas Regional Inventory Protocol			x					x	

*Note: Although GHG target reductions have been set in the state of Minnesota, Minnesota DOT does not yet have an established GHG estimation approach, and therefore is not listed in this table.

The results in Table 4-5 also reflect the familiarity with emissions modeling as required under the State Implementation Plan (SIP) and conformity requirements of the 1990 Clean Air Act Amendments, and the EPA conformity rule. Conformity requirements were designed to ensure that federal funding and approval were given to those transportation activities that were consistent with the objectives of a SIP. The Conformity Rule also requires MPOs and USDOT to conduct conformity determinations for long-range transportation plans and transportation improvement programs (TIPs). Most of these determinations have been based on the emissions models shown in Table 4-5.

At the time of this writing, MOBILE6.2 is still in use by many MPOs and DOTs since EPA has given a grace period for the mandatory transition to MOVES for regional conformity analyses until May 2013[13]. The use of MOBILE6.2 does not include CO_2 benefits from the new fuel economy standards (CAFE) on future scenarios (as described above MOBILE6.2 does not consider the effects of CAFE and is not sensitive to vehicle speeds).

In the case of California, the GHG procedures are more standardized due to the process implemented by CARB as a result of SB375. However, most of the current GHG analyses are still performed using EMFAC2007, which lacks the most recent effects of current truck and bus data collected by CARB and included in EMFAC2011.

4.5 Summary

This chapter provided an overview of the different estimation methods and tools for estimating transportation-related GHG emissions. Almost all methods begin with estimates of fuel consumption, or use VMT and fuel economy-based emission factors.

Transportation-related CO_2 emissions from vehicle operations are emitted in direct proportion to fuel consumption, with some variation by type of fuel, either consumed directly by the vehicles, or indirectly thru the electrical grid that powers electrified transport. As a result, estimating the GHG implications of transportation projects primarily involves estimating the amount of fuel—gasoline, diesel, and other fuels—used by motor vehicles and other transportation sources. Although conceptually simple, this calculation in practice is quite complex, since vehicle fuel consumption depends on a variety of factors (vehicle type, model year, technology, fuel type; vehicle operating characteristics - such as speeds and accelerations, air conditioning use, etc.), and fuel sales data is not commonly collected by MPOs.

[13] See Federal Register Notice 77 FR 11394.

In the context of regional emissions estimation, most MPOs use a combination of a travel demand model and an emissions factor model. Advancements have been made in both types of models over the past decade, in essence developing models that better reflect the phenomena being analyzed. For example, the use of simulation models allows the analyst to analyze better vehicle flow conditions that make such an important contribution to tailpipe emissions. The introduction of MOVES also represents a step forward in better representing the CO_2 consumed in proportion to vehicle operating conditions (horsepower used under different modes of operation), type of fuel (gas, diesel, and others) and the future effects of CAFE fuel economy standards.

The introduction of EMFAC2011 by CARB is also another step forward, since it includes the latest data on California's car and truck fleets and travel activity, and the emissions benefits of CARB's recent rulemakings including on-road diesel fleet rules, Pavley Clean Car Standards, and the Low Carbon Fuel standard.

The last decade resulted in a proliferation of sketch planning tools and software integration packages, developed by state DOTs, MPOs and consultants. As part of this study a series of sketch planning tools have been identified currently used by different agencies. The following chapter provides a summary of the tools reported during our survey and interview process, which agencies are using them and an assessment of the current state of GHG modeling practices.

CHAPTER 5: ANALYTICAL METHODS AND TOOLS FOR GHG ANALYSIS: CURRENT PRACTICE OF STATE DOTs AND MPOs

5.1 Introduction

In the survey distributed to 278 state DOTs and MPOs, a total of 57 agencies provided information about the greenhouse gas analysis methods and tools being used. Table 5-1 outlines the number of participating agencies and those reportedly considering GHG emissions in decision-making processes.

Table 5-1 Survey Respondents Who Have or Will Consider GHG Emissions in Near-Term Decision-Making Processes

	Total Respondents	Total Respondents Who Have or Will Consider GHG Emissions
DOTs	14	11
MPOs	43	30
Totals	57	41

Although a number of survey respondents reported considering GHG emissions in decision-making processes either currently or will in the near future, the number of agencies actually conducting an analysis that they could point to was about 8% of the survey pool. For those not considering GHG emissions analysis, the main reasons varied from lack of guidance to no legal or regulatory reason to do so.

When survey participants were asked whether a protocol was in place to conduct a GHG analysis, 15 survey respondents (about 26% of total survey respondents) had a defined protocol or approach for estimating GHG emissions reduction. Most agencies used a combination of approaches – mostly methods developed with or by other agencies, or as defined in technical literature. Five agencies reported actually using a protocol established by an international or national group (i.e., The Climate Registry General Protocol, World Resources Institute GHG Protocol, or ICLEI Local Government Protocol).

In DOT and MPO GHG planning efforts, the types of transportation modes considered as part of the GHG emissions analysis varied across the agencies. Light-duty vehicles were found in all GHG scenario analyses while heavy duty vehicles (primarily freight), marine, and aviation were less common. Transportation modes considered in GHG analysis as reported by survey participants and interviewed agencies are found in Table 5-2.

Table 5-2 Transportation Modes Considered in GHG Analysis by State DOTs and MPOs

	Oregon DOT	Minnesota DOT	Maryland DOT	Sacramento COG	San Joaquin COG	Tahoe MPO	Denver Regional COG	Atlanta Regional Commission	Boston Region MPO	Metropolitan Washington COG	DOT Survey respondents	MPO Survey respondents
Considered Transportation Modes												
Light-duty passenger vehicles	x	x	x	x	x	x	x	x	x	x	3	20
Transit buses	x	x	x			x	x	x	x	x	3	18
Heavy duty trucks	x	x	x				x	x	x	x	3	16
Transit rail	x	x	x				x		x	x	2	9
Intercity bus and passenger rail	x		x							x	2	9
Off-road freight (rail, intermodal, marine, air)	x		x								2	4
Airports and passenger aviation	x		x								2	3
Bicycling	x		x				x		x	x	2	15
Walking	x		x							x	2	15

Scenario planning tools were utilized in many cases to assess the GHG impacts of mitigation strategies under consideration, particularly at the MPO level. While some agencies used specific tools in their scenario approach to develop GHG analyses, others used some combination of tools and methods. Table 5-3 identifies the scenario planning tools used by agencies interviewed as part of this study.

Table 5-3 Scenario Planning Models and Tools Used by Interviewed DOTs and MPOs

	Oregon Dept. of Transportation	Minnesota Dept. of Transportation	Maryland Dept. of Transportation	Sacramento Council of Governments	San Joaquin Council of Governments	Tahoe MPO	Denver Regional COG	Atlanta Regional Commission	Boston Region MPO	Metropolitan Washington COG
Scenario-Based Planning Tools										
GreenSTEP	x									
I-PLACE3S				x						
Trip Reduction Impact Analysis (TRIA)						x				
Rapid Fire					x					
ICLEI Clean Air & Climate Protection (CACP)										
Other		x	x				x	x	x	x

Many scenario planning tools have been developed in response to high population growth rates; concerns about planning that merely extrapolates present trends into the distant future, as though those trends were fixed and unchangeable; and the desire to explore different future visions. For those DOTs or MPOs responding to GHG mandates or policies, scenario planning tools have also been developed from the need for more comprehensive vision planning. MPOs are one of the main users of scenario planning tools as they can cover larger geographic boundaries beyond individual cities or counties. They are often used in the development of RTPs, integrated regional land use and transportation plans, regional visioning, and plans to reach GHG reduction targets. These tools are often linked with other MPO models like travel demand models.

The following section describes the range of scenario planning models and tools used by the agencies contacted as part of this study, and their experience with these tools or approaches. A comparison of tools and approaches is also provided examining data requirements, analytical capabilities, outputs, benefits, and limitations.

5.2 Scenario Planning Tools and Approaches

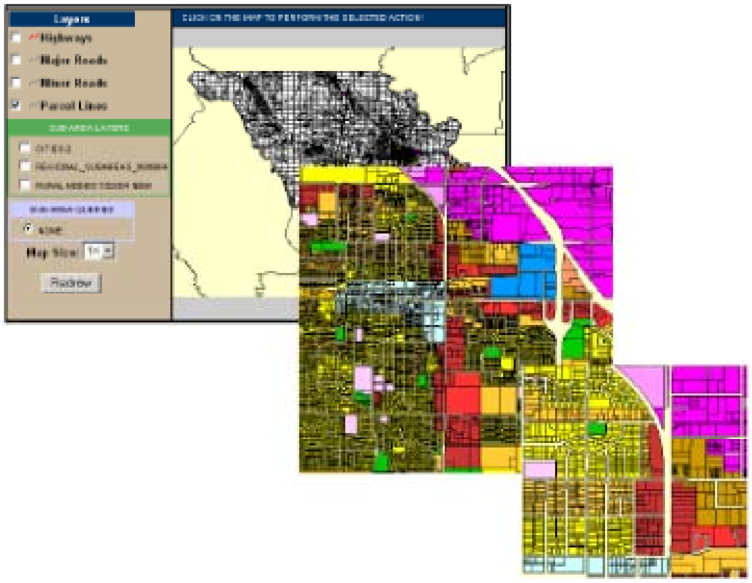
The first set of scenario planning tools and approaches presented below were those used by the case study agencies. These scenario planning tools include GHG emissions from buildings, energy consumption, transit, bicycle, and other sources not accounted for in the traditional travel demand model, which focus primarily on VMT and fleet characteristics.

5.2.1 I-PLACE3S [Sacramento Area Council of Governments (SACOG)]

I-PLACE3S (Planning for Community Energy, Economic, and Environmental Sustainability) is a web-based modeling platform for scenario planning. It can evaluate how alternative development patterns or transportation investments could impact a number of indicators, including transportation performance, energy usage, cost efficiency, and GHG emissions of the planning area being analyzed. I-PLACE3S analysis is conducted through a web-based map display. This strong visual component and interactivity supports scenario development and testing by non-technical users in settings such as public workshops, as well as in more technical settings. I-PLACES uses parcel level land use data for integrated, rapid analysis at county, regional, or neighborhood scales.

The Sacramento Area Council of Governments (SACOG) is one of the main users of I-PLACE3s. I-PLACE3s was initially chosen as the tool to conduct the regional scenario analysis for a variety of reasons including: ability to conduct parcel-level analysis, ability to assess a number of indicators including health benefits and GHGs, map visualizations, and facilitation in consensus building. Although parcel-level (as opposed to transportation analysis zone) data can be more cumbersome to work with, the benefits include the ability to provide more detailed analysis and look at broader planning issues, such as the environmental justice impacts of strategies.

Figure 5-1 I-PLACE3S Sample Map Interface



Source: Sacramento Area Council of Governments

I-PLACE3S also has 4D functionality. The 4D concept utilizes a post-processing approach where adjustments to VMT, and thus GHG emissions, are made as a result of land use-related changes characterized by the 4Ds (Density, Diversity, Design, Destination accessibility). The adjustments are derived from formulas that use elasticity values (a measure of the percentage change in a dependent variable [i.e., VMT] given a certain percent change in a related independent variable [i.e., density or design]). The elasticities are derived from the literature such as Ewing and Cervero's (2010) research focusing on this topic. The impact of other demand management strategies is often estimated by reducing expected reductions from the baseline in an additive manner after land use changes are analyzed.

In SACOG's scenario analysis, GHG reduction strategies included:

- Vehicle efficiency (plug-in electric vehicles are not included in the current Regional Transportation Plan but will be included in the update);

- Low carbon fuels;
- VMT reducing strategies like pricing, land use changes, passenger travel demand management, transit, increased bicycle/pedestrian access;
- Vehicle, system, and agency operations.

One of the limitations in using I-PLACE3S is the open-source nature of the program. Although the program has evolved from a desktop-only program to an open source web-based program, the data storage is not completely open source (there is a fee to maintain data storage externally) and assumptions are maintained in a single set. Where this can be a problem is when two neighboring MPOs are using the program and one MPO needs to change the trip generation rate assumption. By so doing, this same assumption is now incorporated into the analysis by the other MPO. SACOG is currently the only MPO user of I-PLACE3S in its region. As a result, it is considering other scenario planning tools to use in the future that enable more collaborative planning with neighboring MPOs.

Land use GHG reducing strategies are receiving the most planning emphasis, particularly development within corridors to change mode splits and reduce VMT. Through better corridor planning, SACOG believes it will be able to plan for better transportation alternatives, supporting land use, and thus a better regional transportation network.

5.2.2 GreenSTEP [Oregon DOT]

The Greenhouse Gas Strategic Transportation Energy Planning Model (GreenSTEP) was developed by the Oregon DOT (ODOT) to assess the effects of a variety of policies and other factors on travel and transportation sector GHG emissions. GreenSTEP is currently being used for state-level and metropolitan-level analysis. GreenSTEP uses inputs of household data, travel demand forecasts, fuel consumption, vehicle types (with a current focus on light duty vehicles), and a well-to-wheel component to estimate GHG emissions at a statewide or regional level for scenario plans and other long-range transportation plans. Components have been developed to model GHG emissions from ground transportation, long distance travel and freight.

In May 2012, ODOT released a draft Statewide Transportation Strategy (STS) outlining a path to reducing greenhouse gas emissions by 2050. The plan was the result of extensive statewide research and collaboration among state agencies, local governments, industry representatives, MPOs, and others. The STS includes strategies for land use, such as mixed use development and urban consolidation centers, and transportation systems, such as increased transportation options like transit and movement of freight by rail. Technology is a large part of the STS, as is the concept that future transportation users should pay the full price of travel decisions. The outcome of the STS vision was measured in terms of GHG emissions, as well as health impacts and changes in household costs. Through this process, it was determined that meeting a 75% reduction in GHGs could not be possible without substantial changes in vehicle technology and fuel prices. It was found that with extensive urban development, technology, pricing, and system optimization strategies, the GHG reductions could exceed the goal for the ground passenger and commercial service travel markets but not the freight and air passenger travel markets.

5.2.3 Rapid Fire [San Joaquin Council of Governments (SJCOG)]

Rapid Fire is a spreadsheet-based tool designed by Calthorpe Associates to produce and evaluate statewide, regional, and/or county-level scenarios across a range of metrics. It is well suited for regions where the sophistication in travel demand modeling and traffic data is limited.

Rapid Fire was developed as a result of the near-term need for a comprehensive modeling tool that could inform state, regional, and local agencies and policy makers about the likely impacts of climate, land use, and infrastructure investment policies. Results are calculated using empirical data and the latest research on the role of land use and transportation systems on automobile travel, emissions, public health, infrastructure cost, city revenues, and land, energy, and water consumption.

MPOs, like the San Joaquin Council of Governments (SJCOG) and others in the Central Valley may use this tool. The transparency of the model's structure of input assumptions makes it readily adaptable to different study areas, as well as responsive to data emerging from ongoing technical analyses by state, regional, and local agencies.

The model allows users to create scenarios at the statewide or regional scales. Results are produced for a range of metrics, including:

- GHG (CO_2e) emissions from LDVs and buildings
- Air pollution
- Fuel use and cost
- Building energy use and cost
- Residential water use and cost
- Land consumption
- Fiscal impacts (local capital infrastructure and O&M costs; city revenues)
- City revenues
- Public health impacts

5.2.4 Trip Reduction Impact Analysis (TRIA) [Lake Tahoe MPO]

TRIA (Trip Reduction Impact Analysis) is an Excel-based analytical tool that assesses the impacts of various policy decisions on VMT and GHG emissions at the regional level. The Tahoe Metropolitan Planning Organization utilized the TRIA method to assess impacts of VMT reduction strategies in the recently released draft sustainable communities strategy (SB 375 requirement for new regional transportation plans). Policies evaluated included parking management, employer vehicle trip reduction program expansion, transit service and facilities improvements, regional bike and pedestrian network, and dynamic ridesharing services. Additional off-model analysis of pedestrian/transit oriented development impacts was also conducted using trip generation rates from ITE (Institute of Transportation Engineers) to estimate total VMT and GHG impacts for four major alternatives.

One of the benefits of conducting the GHG analysis using the TRIA method is that there were no particular software requirements or fees. Only Microsoft Excel was needed to run the model; however, as with many Excel models, close attention to cell updates is essential to ensure integrity of linked formulas and outputs.

5.2.5 "What Would it Take?" Scenario Planning – [MWCOG]

"What Would it Take?" is the scenario analysis conducted by the National Capital Region Transportation Planning Board (TPB), the Metropolitan Planning Organization for the Metropolitan Washington area. The analytical process used by TPB involved the following steps:

1. Creating a baseline inventory of mobile source CO_2 emissions;
2. Developing sources of reduction potential;
3. Identifying potential reduction strategies;
4. Analyzing individual strategies for effectiveness, timeframe for implementation, and cost-effectiveness; and
5. Combining additive strategies to determine different pathways toward approaching or meeting goals.

The scenario examined what it would take in the National Capital Region to meet the aggressive regional climate change mitigation goals adopted by the Metropolitan Washington Council of Governments (MWCOG) in the transportation sector and whether any combination of the approximately 40 strategies considered would meet the targets. These targets are to reduce annual regional CO_2 emissions to 2005 levels by 2012, 20% below 2005 levels by 2020, and 80% below 2005 levels by 2050.

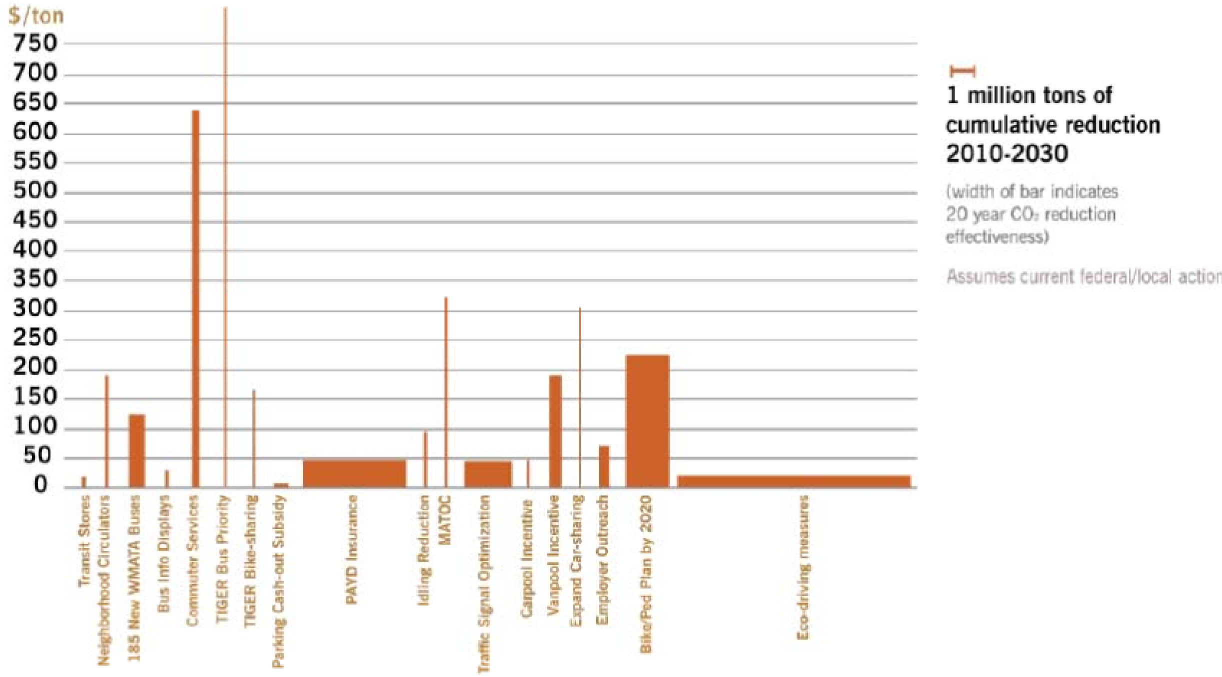
This study included the first mobile CO_2 emissions baseline inventory and forecast for the region. The baseline included an analysis of the current long-range plan, recently adopted national CAFE standards (35.5 mpg by 2016), and transportation emission reduction measures implemented throughout the region for the purposes of reducing other types of air pollutants. The study found that the final baseline, particularly the new CAFE standards, fills part of the gap between business as usual and regional climate change goals.

In addition, the study examined specific emissions sources in the region, enabling a more comprehensive determination of reduction opportunities. Three broad sources of emissions were examined: fleet composition, fuel used, and use of the fleet. The study found that heavy duty vehicles are forecast to account for a growing share of emissions over time as light duty vehicles become more fuel efficient. Lastly, the study found that current travel behavior could benefit from efficiency improvements to reduce CO_2 emissions. For instance, it was forecast that many short trips (under three miles) would be taken by automobile, a portion of which could be shifted to non-polluting modes. Traffic congestion or frequent stop-and-go driving was also a major source of emissions, since CO_2 is quite sensitive to vehicle speeds. Therefore, operational strategies to improve traffic flow were also considered a means to reduce emissions.

What differentiated this process from others was the cost-effectiveness analysis of the CO_2 mitigation measures and whether some strategies should be implemented to meet broader planning goals despite limited CO_2 benefits. Cost effectiveness strategies utilized the latest "central value" for the social cost of carbon, assumed at \$21/ton CO_2 in 2010 rising to \$45/ton CO_2 in 2050 as per research by the United States Government. Cost estimates were represented in 2007 dollars. To analyze strategies that improved traffic flow, a CO_2 emissions speed curve was used. In the future, however, MWCOG plans to use MOVES for these CO_2 evaluations. Figure 5-2 illustrates the results of the cost-effectiveness analysis for a subset of individual mitigation strategies over a 20-year period under current federal and local action.

The results of this analysis showed that eco-driving was one of the most cost-effective strategies to reduce CO_2 emissions in the National Capital Region. In addition to the cost-effectiveness analysis, other strategies like a bike-sharing program were worthwhile strategies to address broader planning goals despite limited benefits in GHG reduction. One of the lessons learned was that looking at strategies in a cost-benefit framework with CO_2 reduction as just one of the potential benefits would be more appropriate than a cost effectiveness calculation.

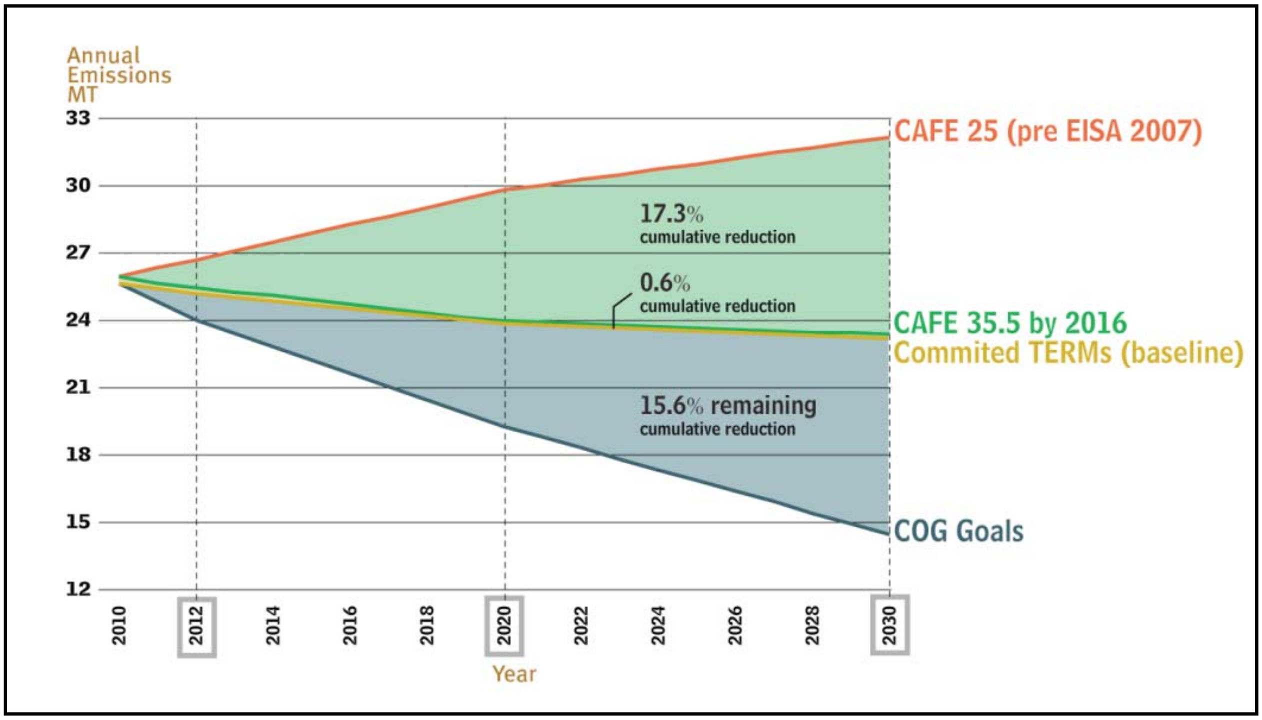
Figure 5-2 Cost-Effectiveness Analysis for Subset of Individual Strategies (Cost per ton of CO_2 Abated)



Source: Metropolitan Washington Council of Governments, 2010.

As shown in Figure 5-3, similar to ODOT, MWCOG found that vehicle technology, in particular, new CAFE standards, were essential to closing the gap between future business-as-usual trends and regional climate change goals.

Figure 5-3 CO_2 Emission Effects of CAFE Standards and Committed TERMs



Source: National Capital Region Transportation Planning Board, 2010

The study also evaluated short and long term actions that could be taken at the regional level, and as shown in Figure 5-4, this still leaves a significant gap to achieve the emission reduction targets. Figure 5-5 illustrates the possible effects of a "High Federal Role" over the course of 2010-2030 to reduce CO_2 emissions. This would include aggressive policy actions like further increasing CAFE standards of both light-duty and heavy-duty vehicles and increasing fuel prices to $7/gallon to reduce VMT.

Figure 5-4 CO_2 Emission Effects of Long Term Regional Actions

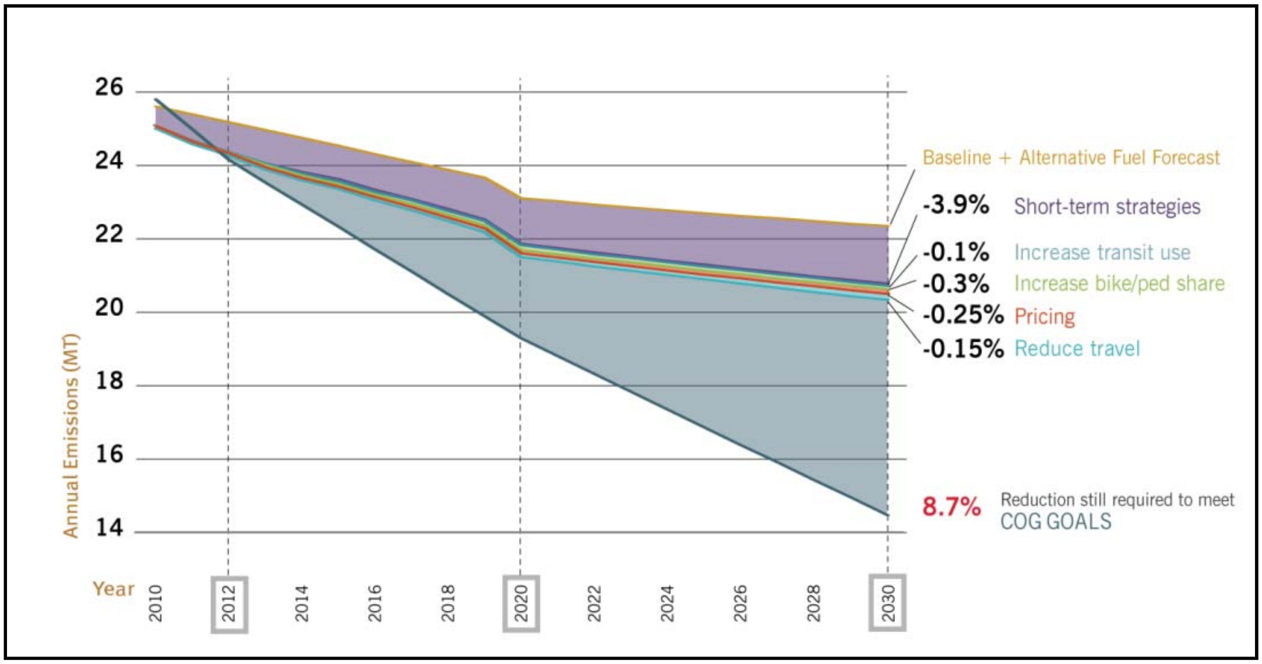
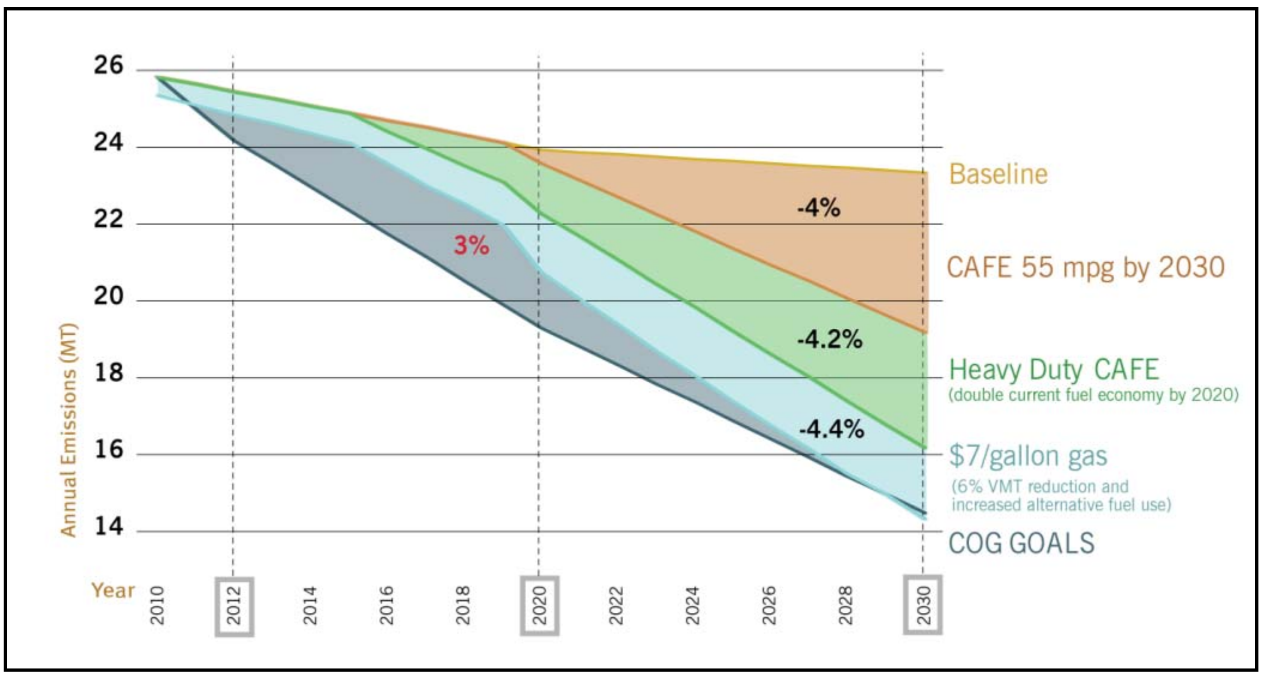


Figure 5-5 MWCOG Scenario Analysis –High Federal Role (2010-2030)



Source: "What Would it Take?" National Capital Region Transportation Planning Board, 2010

5.2.6 Boston Region MPO

In December 2010, the "*Massachusetts Clean Energy and Climate Plan for 2020*" set a target to reduce statewide GHG emissions to 25% below the 1990 levels by 2020. Transportation is second only to buildings as a source of GHG emissions in Massachusetts. The Clean Energy and Climate Plan for 2020 in its projections took into account state and federal measures to improve vehicle efficiency, reduce vehicle miles traveled (VMT), and increase use of lower-carbon fuels. It also proposed additional measures related to building efficiency, electricity, and cross-cutting policies that will contribute toward meeting the 2020 limit.

In developing *Paths to a Sustainable Region*, the MPO conceptualized the region's transportation needs over the next 23 years. Land use patterns, growth in employment and population, and trends in travel patterns differ in how they affect demands on the region's transportation system. In order to estimate future demands on the system for this Long-Range Transportation Plan (LRTP), the MPO utilized the regional travel demand model, which included all communities within the commuting area for eastern Massachusetts, encompassing 63 communities that are outside the 101-municipality MPO region.

The model represented all Massachusetts Bay Transportation Authority (MBTA) rail and bus lines, all private express-bus carriers, all commuter boat services, all limited-access highways and principal arterials, and many minor arterials and local roadways. The region is subdivided into over 2,700 transportation analysis zones (TAZs). The model is made up of several models, each of which simulates a step in the travel decision-making process. The model set simulates transportation supply characteristics and transportation demand for travel from every TAZ to every other TAZ. This simulation is the result of several inputs (different categories of data); the most important include population, employment, auto ownership, transit fares, automobile operating costs, and highway and transit levels. Several important travel statistics are reported for these forecasts, including:

- Total vehicle-miles of travel (VMT) and vehicle-hours of travel (VHT) on a typical weekday;
- Average speed of highway traffic;

- Amount of air pollution and GHG produced by automobiles and transit vehicles;
- Total number of daily trips made by auto and transit;
- Average daily fixed-route transit ridership by mode (rapid transit, bus, commuter rail, commuter boat, and express bus); and
- Percentage of people traveling by each of the travel modes.

This traditional travel demand model–emission factor modeling approach used for the past decades for SIP and conformity processes is being used to estimate the region's GHG (CO_2) emissions. At the present time the baseline scenarios have been performed using MOBILE6.2 emission factors, and the MPO is in the process of preparing the transition to MOVES to better quantify the effects of the new CAFE and renewable fuel standards, as well as other state and federal mandates.

5.3 Comparison of Scenario Planning Tools and Approaches

Scenario planning tools continue to evolve and offer a wide range of analytical sophistication from Excel-based spreadsheets to spatial GIS-based analyses to interactive models that require linkages to other MPO models (i.e., travel demand models, economic models, land use and/or integrated land use and transportation models). The tools used by the case study agencies are representative of this range from the spreadsheet-based tools like Rapid Fire and TRIA to spatial analysis as in I-PLACE3S to GreenSTEP.

A number of factors should be considered when deciding which tool is best suited for a particular purpose. The tools have different levels of access (e.g., only some are open source), data requirements, GHG outputs, and policy features. Table 5-4 outlines the access and data requirements and outputs of each tool. Although many of these scenario planning tools are best suited for regional or sub-regional levels, GreenSTEP and Rapid Fire, for example, can also be applied at the state level. GreenSTEP, when compared to Rapid Fire and the other spread-sheet based tools, is able to assess pricing policies and interactions between policies and its effects on VMT and GHG emissions. If more detailed parcel level analysis is required at the regional level, however, a tool like I-PLACE3S may be more useful, especially when analyzing policies that are more land-use based. Table 5-5 outlines the types of policies each tool is able to analyze and the benefits and limitations of each. Considerations in determining the appropriate scenario planning tool may include:

- **Scale:** Statewide, regional or other level analysis?
- **Purpose:** What is the objective? Stakeholder engagement? Internal agency analysis?
- **Range of Policies:** Is the tool designed to analyze a full range of GHG strategies well? Or is it more narrowly designed to analyze a limited set of policies? Is it designed just for individual strategies or can it also analyze bundled policy packages? Is there greater emphasis one type of GHG reduction strategy than another?
- **GHG Output:** Do all the greenhouse gases need to be analyzed, or just CO_2? Per capita or absolute values?
- **Accessibility:** Does the entity using the scenario planning tool already have or is willing to purchase accompanying licenses, such as ArcGIS? Is open-source software required for collaborative planning efforts with other MPOs or state agencies?
- **Transparency:** Is it easy for the public and decision-makers to understand how the tool operates and see what assumptions are driving the results?

Table 5-4: Data Requirements and Outputs of Selected Scenario Planning Tools and Approaches

Scenario Planning Tool or Approach	Availability	Data Input Requirements	GHG Data Output
GreenSTEP[14]	• Open source license	• Urban characteristics (density, mixed use, public transportation, non-motorized transportation, parking management) • Road characteristics, such as the supply of freeways and other arterials and the management of incident delay • Marketing characteristics, such as the deployment of employer-side and household-side travel demand management programs, eco-driving, low-rolling resistance tires, pay-as-you-drive insurance • Vehicle and fuels technology characteristics, such as fuel economy, proportions of plug-in hybrids and electric vehicles, and fuel carbon intensity • Vehicle fleet characteristics, such as the proportions of autos and light trucks and the age distribution of vehicles • Prices, including fuel price, fuel taxes, mileage taxes, and carbon taxes	• CO_2e
I-PLACE3S	• Web-based • Small access fee • May also need licenses for Oracle, ArcIMS, ArcGIS	• Climate (temperatures, wind, heating and cooling degree days) • Housing (dwelling locations, types, and sizes; typical energy equipment & fuels) • Employment (business locations, types, & sizes; typical energy equipment & fuels) • Infrastructure (street locations, types, and conditions; water/sewer locations and capacities; street light and	• CO_2 (any quantity over any time)

[14] Greenhouse Gas Strategic Transportation Energy Planning Model: http://www.oregon.gov/ODOT/TD/OSTI/docs/Media/Model.pdf?ga=t <accessed 28 June 2012>

		traffic signal locations) • Renewable energy resources (solar, groundwater/surface water characteristics, geothermal characteristics, wind speeds, biomass/solid waste quantities) • Conventional Energy Supplies (Electricity grid locations, capacities, and rates; natural gas grid locations and rates; transportation fuel types and prices)	
Rapid Fire	• Microsoft Excel (2007)	• Demographics (baseline and projected population, households, jobs) • Transportation (average per-capita VMT, average LDV fuel economy, baseline GHG emissions per gallon of fuel, baseline auto ownership and maintenance costs per mile) • Building energy (baseline average energy use per existing residential unit/building type and commercial square foot, GHG emissions per kWh of electricity, GHG emissions per therm of natural gas, baseline energy costs per kWh and therm) • Water (baseline residential water use per existing unit, baseline per-capita water use)	• CO_2e (MMT from transportation and buildings)
Trip Reduction Impact Analysis	• Microsoft Excel (2007)	• Demographics (baseline and projected population, households, jobs) • Transportation (number trips and trip length by mode split – including bike/ped, parking spaces,) • Land use (residential unit allocations, commercial square footage, tourist accommodation units)	• CO_2

Table 5-5 Summary of Benefits and Limitations of Selected Scenario Planning Tools and Approaches

Tool or Model	Scale	Policy Analysis	Benefits	Limitations
GreenSTEP[15]	• State • Metropolitan • Household	• Urban (urban growth, mixed-use, transit, parking, bicycles) • Pricing (fuel and carbon taxes, VMT tax, PAYD insurance) • Marketing (travel demand, management, eco driving) • Roads (capacity, incident management) • Fleet (vehicle age, vehicle type, car sharing) • Technology (MPG standards, electric vehicles, etc.)	• Quick results • Comprehensive policy analysis	• Requires training to run and analyze results • Built from national, not local, data • Must be linked to other models to evaluate roadway or transit projects
I-PLACE3S	• Regional • Scalable to site level	• More than 100 evaluation indicators including land use strategies (density, mixed use), demand management, etc.	• Parcel level of detail • Effective tool for community engagement	• Not open source, small access fee • data requirements are extensive • License costs for Oracle, ArcIMS, ArcGIS can be substantial •

[15] Greenhouse Gas Strategic Transportation Energy Planning Model: http://www.oregon.gov/ODOT/TD/OSTI/docs/Media/Model.pdf?ga=t <accessed 28 June 2012>

Rapid Fire	• Nationwide • Statewide • Regional • County or Subregion	• Policy packages for “urban, compact and standard” land use and transportation characteristics	• Excel-based so no major software licenses required • Pre-defined policy packages	• Does not model interactions • Requires training for use
Trip Reduction Impact Analysis	• Regional • County or Subregion	• Parking management • Transportation Demand Management (ridesharing, employer-based alternative work schedule, parking cash-out) • Transit service and facilities • Bike and pedestrian facilities • Capital projects • Road user fees	• Excel-based so no major software licenses required	• Does not model interactions • Requires training for use

5.4 Other Scenario Planning Tools and Approaches

A variety of other scenario models, tools, and approaches exist that, although not currently used by the MPOs or DOTs interviewed as part of this study, they may have been used in the past, or are used by other local cities and/or counties.

- *Clean Air and Climate Protection (CACP)* - This software tool develops local community-wide or internal government GHG emission inventories, quantifies emission reductions from various emission reduction measures, projects future emission levels, and sets reduction targets and tracks progress in meeting these targets. Inputs include fuel use or vehicle-miles traveled by a government vehicle fleet or the community as a whole. Therefore, the tool is best suited to translating VMT and/or fuel consumption (or changes in these) into GHG emissions (or changes), rather than directly estimating the VMT or fuel consumption impacts of strategies.
- *Center for Clean Air Policy (CCAP) Transportation Emissions Guidebook* – This guidebook is designed to engage state and local officials in understanding the extent to which policy decisions impact air pollution, energy use, and GHG emissions. The guidebook provides guidance, rough estimates, and a spreadsheet calculation tool to assess the impact of various strategies and technologies.
- *Climate and Air Pollution Planning Assistant (CAPPA)* – This spreadsheet tool estimates the GHG benefits of a wide variety of policies and strategies, including travel reduction and vehicle and fuel technology strategies as well as non-transportation strategies. It includes over 100 municipal actions such as vehicle fleet purchases and LED traffic signal replacement, in addition to community actions such as transit-oriented development and bicycle programs. A limitation of the tool is that it generally requires user inputs of traveler response factors (such as increased transit ridership or non-motorized travel) rather than predicting a response.
- *CommunityViz* – Developed by the Orton Family Foundation, CommunityViz is a 3D analysis and planning extension for ArcGIS that provides scenario planning, build-out and suitability analysis, impact assessment, growth modeling and 3D

visualization. A key focus of this tool is public participation and facilitation to help groups understand and make better planning decisions.

- *COMMUTER Model* – Developed by EPA, the COMMUTER Model analyzes the impacts of transportation control measures (TCMs), such as employer- or worksite-based transportation demand management programs and transit improvements on VMT, criteria pollutant emissions, and CO_2. The model can also be adapted for sketch-level analysis of general response to pricing policies or to measures that affect travel time. The CO_2 calculations are simple, and based on default emission factors from MOBILE6. It is a spreadsheet based model which only estimates the effects of specific scenarios within the range of TCMs coded into the data set. It will not compile baseline emissions for the area analyzed, since it was not designed as an emission inventory tool.
- *Energy and Emissions Reduction Policy Analysis Tool (EERPAT)* – This model developed by the FHWA is based on GreenSTEP and is intended to be a screening tool to analyze GHG reduction policy scenarios at a statewide level (Federal Highway Administration 2012). It estimates VMT and the resulting GHG emissions, including fuel use by autos, light trucks, transit vehicles, and heavy trucks. As noted in the user's guide, EERPAT should not be used to assess individual project impacts on GHG reductions. The tool operates primarily at the household level where vehicle ownership and use is predicted. Because of this, the types of strategies that this tool can analyze include: metropolitan, other urban, and rural area densities; urban form in metropolitan areas (proportion of population living in mixed-use areas with a well interconnected street and walkway system); metropolitan area transit service; freeway and arterial supplies; average vehicle fuel economy by vehicle type and year; electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs); non-motorized vehicles or two-wheeled electric vehicles, such as bicycles, electric bicycles, electric scooters, etc.; pricing – fuel, vehicle miles traveled (VMT), parking; demand management – employer-based and individual marketing programs; car-sharing; and vehicle operation and maintenance – eco-driving, low rolling resistance tires, speed limits.

- *Envision Tomorrow* – Envision Tomorrow began as a proprietary toolkit developed by Fregonese Associates, Inc. and with increased demand an open source version is now available. The toolkit is based on Microsoft Excel and ArcGIS to assess up to five land use-based growth and development scenarios concurrently. The scenarios can range from neighborhood to regional scale. Eighteen additional modules are being developed covering transportation, housing, economics, environment, and other planning elements. The release of these modules will occur over the 2012-2013 timeframe.
- *Index* – First developed by Criterion Planners in 1994, Index is an integrated suite of desktop and web-based scenario planning tools for land use, transportation and environmental planners. The application begins with a baseline assessment of current conditions to produce a SWOT (strengths, weaknesses, opportunities, and threats) analysis and frame of reference for evaluating future alternatives. Like I-PLACE3S and CommunityViz, Index can work up through parcel level data, census block groups, traffic analysis zones, local government jurisdictions, and regions. Index has a library of over 150 indicators including measurements of demographics, land use, housing, employment, transportation, environment, energy, and climate protection. It also has 7D functionality to estimate changes in walk, bike, transit, and auto use as a result of land use and urban design changes.
- *Intelligent Transportation Systems Deployment Analysis System (IDAS)* – The Federal Highway Administration (FHWA) developed IDAS as a sketch planning tool to estimate the impacts, benefits, and costs resulting from the deployment of ITS components. It estimates CO_2 and criteria pollutant emissions.
- *Low-Carb Land* – Developed by the Washington State Department of Transportation, the Washington State Department of Commerce, the Thurston Regional Planning Council, and Sonoma Technology, Inc., this tool gives users the ability to sensitivity test how land use shifts affect on-road travel and resulting CO_2 emissions. Low-Carb Land is especially useful for small- to medium-sized agencies that lack the financial resources or technical expertise to: evaluate travel impacts from compact, mixed use development; assess how travel changes affect CO_2 emissions; compare the relative

merits of various land use proposals; improve communication of land use outcomes to the general public; and understand the GHG implications of employment and housing development options.

- *TRIMMS* – The TRIMMS Model (Trip Reduction Impacts of Mobility Management Strategies) predicts trips, VMT, fuel, and emissions impacts for worksite-based TDM programs. It has many similarities to the COMMUTER model but uses somewhat different methodologies. The model is also intended for cost-benefit assessment and incorporates damage costs for various pollutants.
- *UrbanFootprint* – The open source geo-spatial UrbanFootprint model is being developed as part of the Vision California process, and is designed to deploy in regions and jurisdictions across California and the United States. Built by Calthorpe Associates on a base of open source software (i.e. Linux, PostGIS, and PostGreSQL), it is a powerful and dynamic scenario creation and modeling tool with full co-benefits analysis capacity. UrbanFootprint is more than just a land use sketch model – it is a complete data, scenario, and analysis system, serving as a practical platform for large and varied data sets, future plan and scenario data, modeling engines, and results reporting. Its web-based interface requires no proprietary software to run and is designed to run on virtually all operating systems, desktop, and mobile environments. The model currently includes:
    - A full set of 30+ detailed and researched place types built up from a set of 50+ building types, each one mixed from three to over a dozen actual real-world built or planned buildings
    - A complete 5.5-acre loaded grid for the entire California study area, with the ability to scale down to the parcel level for both scenario creation and analysis
    - A scenario translation engine that converts regional and local land use plans into UrbanFootprint place types
    - A web-based scenario ‘painter’ that allows for custom built scenarios and scenario editing

- An 8-D travel sketch travel model to accurately assess the impact of changes to urban form on travel behavior
- A public health analysis engine that estimates a complete range of active transportation metrics
- Climate-sensitive building energy and water modeling
- Fiscal impacts analysis
- Greenhouse gas and other emissions modeling

UrbanFootprint results are calculated for both the base (existing) year as well as for future scenarios, so as to capture the effect of changes in future urban form on existing areas. The power and speed with which UrbanFootprint operates allows it to undertake much more sophisticated geographical analyses than previous generations of GIS-based sketch models. The model can be used to create and test scenarios at the statewide, regional, county, jurisdictional, neighborhood or single-development scales.

- *URBEMIS (Urban Emissions Model)* – URBEMIS is software originally developed by the California Air Resources Board as a modeling tool to assist local public agencies with estimating air quality impacts from land use projects when preparing an environmental analysis. The model estimates construction, area source, and operational air pollution emissions from a wide variety of land use development projects. The model also identifies mitigation measures and emission reductions associated with specific mitigation measures. The "Mobile Source Mitigation Component" allows the user to estimate the potential vehicle travel and emission reduction benefits from a number of land use and transportation-related strategies within the project site and in the surrounding area.

5.5 Summary

The types of transportation modes considered as part of the DOT and MPO GHG emissions analysis varied across the agencies. Light-duty vehicles (or passenger cars) and transit buses were a common transportation mode included in GHG scenario analysis, while heavy duty vehicles (primarily truck freight), rail, marine, and aviation were less common.

Scenario planning tools are being utilized to assess the GHG effects of the emission reduction strategies under consideration, particularly at the MPO level. These tools often generate estimates of GHG emissions from buildings, energy consumption, water usage, land use changes, transit, bicycle lanes expansion, and other sources not accounted for in the traditional TDM and emission factor models which produce VMT, fleet characteristics, and CO_2 by VMT and vehicle type. Many scenario planning tools have been developed in response to growth challenges and the need for more comprehensive vision planning. They are often used in the development of Regional Transportation Plans, integrated transportation - land use processes, regional visioning, and forecasting efforts to reach GHG emission reduction targets. These tools (which are mostly designed to look at the localized effect of specific scenarios) are often linked with other MPO models, like travel demand models and emission factor models (MOBILE 6.2, MOVES or EMFAC) to provide an emission inventory for the region analyzed.

These tools continue to evolve and offer a wide range of analytical sophistication. The tools used by the case study agencies are representative of this range from the spreadsheet-based tools like Rapid Fire and TRIA to spatial analysis as in I-PLACE3S to GreenSTEP. This chapter also reviewed tools beyond the ones used by the case study agencies, those which may have been used in the past, or are used by other local cities and/or counties, and provided a summary of the benefits and limitations of each one analyzed.

The next chapter provides a discussion of findings, limitations, challenges, and recommendations for future research.

CHAPTER 6: FINDINGS AND FUTURE DIRECTIONS

6.1 Introduction

This chapter summarizes the drivers and challenges in GHG analysis for transportation agencies. Major findings and barriers to better, more accurate analysis and planning trends are explored across DOTs and MPOs through the combination of survey work, review of recently published literature, and agency case studies. The limitations of current GHG models and tools are outlined along with noted opportunities for future improvement and areas of future research to advance the state of practice.

6.2 Drivers and Challenges for GHG Analysis in Transportation Planning

A variety of motivations were found in this research for considering GHG emissions in planning and policy decisions. The primary motivation for considering GHG emissions in decision-making seems to be state or local legislation and/or agency policy that requires such analysis. Three state DOTs and six MPOs in the survey reported GHG consideration as a result of state or local legislation. Three state DOTs and eight MPOs were motivated to consider GHGs in planning and/or project development as a result of agency policy. In addition, two DOTs and six MPOs reported considering GHG emissions as part of climate action planning efforts. Seven MPOs reported the consideration of GHG emissions for other reasons including responding to an urgent planning need, setting or following best practice, including considerations in regional long-range transportation planning efforts (20), transportation improvement programs (3), corridor level planning procedures (2), in response to Board direction and/or interest from MPO member jurisdictions. Although five MPOs reported conducting project level analysis under state environmental procedures, no survey participants reported conducting GHG emissions analysis under the National Environmental Policy Act (NEPA). [Note: While not reported in the survey, some state DOTs are known to have done GHG analysis in NEPA documents, a leading example of which is Washington DOT/Oregon DOT's analysis for the Columbia River Crossing in response to public interest.]

For those state DOTs and MPOs reporting GHG emissions considered under a state or local mandate or climate action planning effort, 22 agencies reported having some level of GHG reduction goal or target. Most emission targets were generally compared against a base year of 2005 or 1990, consistent with either state goals or the Kyoto Protocol. Medium term goals generally fell in the range of 7-25% by 2020, with longer term goals of 30-80% reductions by 2035 or 2050 in order to meet climate stabilization. Five agencies reported having specific per-capita reduction targets, while another five agencies reported absolute overall reduction targets in place.

It is worth noting that GHG targets are usually set in terms of achieving reductions below some historic year (such as 1990 or 2005), whereas some analyses of GHG reduction strategies report results in terms of reductions below a future year baseline. It is important for decision makers to clarify this aspect to the public, as it could create an impression of greater contribution to achieving GHG targets than is supported by the strategy analysis.

6.2.1 Challenges and Barriers to GHG Analysis and Reductions

Why are so few state DOTs and MPOs conducting GHG emissions analysis? Survey participants reported a variety of explanations as outlined in Table 6-1. For agencies reporting "other" reasons, explanations included, but were not limited to:

- Local political resistance to climate change and GHG analysis exists especially in air quality attainment areas; many surveys of the public reveal that this resistance is based in part on skepticism about climate science, but more powerfully by higher public concern with other issues, such as jobs and the economy;
- Awaiting guidance or regulatory requirements from state or federal level; and
- Unclear expectations from the governor or state legislature – or clear opposition on the part of the governor or state legislature to any action on climate change.

Table 6-1 DOT and MPO Barriers to Conducting GHG Analysis

Barriers to Conducting GHG Analysis	DOTs	MPOs	Total
Public skepticism to climate change	2	4	6
Other agency priorities take precedence	5	5	10
Insufficient staff time for such analysis	6	13	19
Budgetary constraints	4	10	14
Data limitations	4	8	12
Other	3	8	11

As evidenced in Chapter 2, GHG reduction targets are often extremely ambitious and can be daunting for agencies to find appropriate resources to not only conduct the GHG analysis (especially in locations where not required), but also to implement the GHG emission reduction strategies. This is especially true in the current economic climate where agencies are pressured to do more with less, have competing priorities, and must comply with new requirements with reduced funding or little or no additional funding to do so.

For those agencies that have analyzed GHG emission reduction strategies against specific reduction targets, most have found the targets to be unachievable without additional federal actions like further increasing CAFE standards of both light-duty and heavy-duty vehicles and implementing pricing strategies and programs more broadly, as was the case in the analysis done by MWCOG and ODOT. Some have found that even very aggressive local actions are insufficient to reduce transportation GHG below historic levels, much less meet reduction targets.

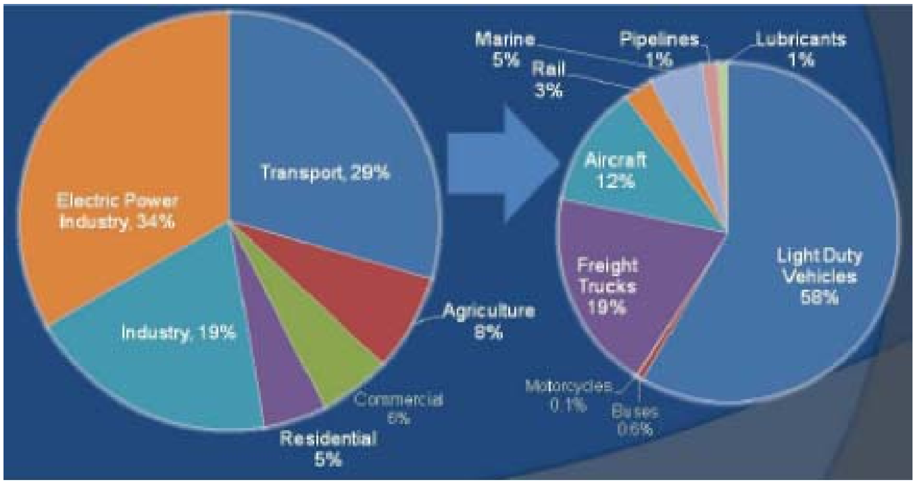
6.3 GHG Analysis Tools and Methods

When developing a GHG emissions inventory and forecast, appropriate QA/QC principles should be followed consistent with those established by the IPCC and EPA. Most established procedures by organizations like ICLEI, The Climate Registry, and World Resources Institute are consistent with these protocols. Survey findings showed that only 5 agencies reported use of these established GHG analysis protocols. A majority of other survey respondents borrowed from or developed approaches with other agencies, used approaches defined in the technical literature or developed an approach based on staff or agency ideas on how to conduct such an analysis.

Major findings relevant to the scope of GHG analysis conducted by state DOTs and MPOs included:

- *GHG analysis focused primarily on direct emissions from transportation operations.* Emissions from nonoperational activities, such as construction and petroleum extraction and delivery, were not included. Lifecycle analysis was not reported, although well-to-wheel analysis has recently been included in Oregon DOT's GreenSTEP tool for analyzing statewide transportation GHG emissions. The national inventories developed annually by EPA consider the lifecycle transportation emissions (from the upstream and downstream processes) as part of (and accounted in) the industrial or commercial sectors rather than the transportation sector. Consequently, these emissions are not usually considered within traditional transportation analyses. However, lifecycle analysis could be important when analyzing the full range of long range transportation strategies, in order to evaluate the GHG emissions from capital intensive infrastructure roadway and transit projects. Section 6.5 discusses the benefits and opportunities of lifecycle analysis.
- *The primary mode of transportation analyzed in GHG estimation efforts was light-duty vehicles.* Light-duty vehicles account for the largest share of transportation emissions in the United States – approximately 58% of the transportation share (see Figure 6-1). Recent research, however, is showing that GHG emissions from freight transportation are expected to grow three times as fast as light-duty vehicles from 2009 to 2035. (Transportation Research Board, 2012) Moreover, various experts point out that GHG reduction targets of 60-80% cannot be achieved if non-highway modes as well as highway freight modes are ignored.

Figure 6-1 Transportation Shares of GHG Emissions in the United States



Source: Transportation Research Board, 2012

- *GHG estimation methods were most commonly based on VMT data.* Because transportation agencies do not typically collect data to track vehicle fuel consumption by fuel type (such as from fuel purchase data), VMT (or person miles traveled for transit and non-road modes) was the primary metric for transportation activity used along with assumptions about vehicle fuel economy. Significant knowledge has been accumulated from traditional travel demand model–emission factor modeling approaches used in the past for SIP and conformity processes. Since these processes are well established with QA/QC procedures to reconcile VMT-VHT estimates versus data collected as part of the HPMS system, these procedures are being used by many agencies to estimate the region's GHG (primarily CO_2) emissions from motor vehicles.

  The relationships between these factors and fuel economy are not simple. For instance, the implications of vehicle operating speeds on fuel consumption are not linear and depend on vehicle type, size, and age. Consequently, an approach that assumes an average fuel economy by vehicle category will not accurately account for the effects of transportation projects that address vehicle speeds and traffic flow, accelerate fleet turnover, or shorten trip lengths.

- Fleet and fuel efficiency will improve over time, and better data on this subject is anticipated to be included in future upgrades of agency models and GHG analyses. Data and assumptions on the new fleets are dictated at a minimum by federal Corporate Average Fuel Economy (CAFE) standards and state regulations such as the Pavley (GHG tailpipe emissions) standards adopted by approximately 15 states. With increased locally and regionally coordinated efforts to implement supporting infrastructure for electric vehicles, the deployment and market penetration of these newer vehicle types and technologies will also be considered in near-term analyses. As mentioned in previous chapters, it is a great challenge to predict future vehicle technology, vehicle fuel efficiency, and variations in types of fuel that will be used 20-40 years into the future, since there is substantial potential for technology breakthroughs and shifts in the carbon-intensity of future vehicles and fuels over coming decades.
- Scenario planning and accompanying tools are playing an increasingly integral role in state DOT and MPO GHG planning efforts. With the lack of federal regulatory requirements, state DOTs, MPOs, and other transportation agencies have developed their own ways of analyzing the GHG emissions impacts of transportation plans and projects based on best practice, technical literature, and available tools. In the last few years alone, a proliferation of tools – including GreenSTEP, Rapid Fire, EERPAT, and Urban Footprint to name a few – were developed and released to meet this immediate planning need. Scenario planning allowed agencies to understand impacts of alternative courses of action in the preparation of climate change action plans or regional planning analyses. The scenario tools, particularly the 2D or 3D spatial tools like I-PLACE3S or CommunityViz, have been an effective means of engaging stakeholders in discussions about the future vision of the region or state.

6.4 Limitations of Current GHG Analysis Tools and Methods

The variety of scenario planning tools in use, described in detail in Chapter 5 and summarized above, provide important capabilities to evaluate and test the possible GHG effects of local and state level policy actions. These actions include such things as land use planning, future housing and transit developments, non-motorized transportation, and the many scenarios that affect VMT and travel patterns with its associated fuel consumption.

The analyses from scenario planning tools generally result in changes to projected VMT, vehicle speeds, and level of congestion. Where these tools fall short is in forecasting the changes to the motor vehicle fleet characteristics, and the future effect of fuel economy standards on the local fleet. These require the evaluation of large state and national data sets regarding fleet composition, vehicle registration and mileage accumulation rates, and how new vehicle technologies will capture market share of the U.S. vehicle fleet. In these cases, the best available modeling option seems to be the use of the MOVES emissions model (MOVES2010b – latest version at the time of this writing) and EMFAC2011 in California.

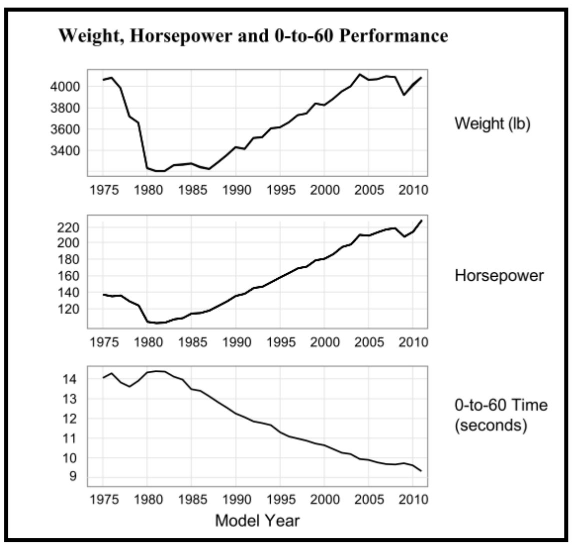
As described in this document and several other research efforts, it is very clear that the ambitious emission reduction targets set by many states cannot be met with just changes to land use, roadway efficiencies, and expansion of transit. Changes to vehicle technology, with the corresponding federal role in setting fuel economy standards, is paramount to achieve these targets.

6.4.1 Vehicle Technology's Role in GHG Reductions at the National Level

As described in Chapter 2, transportation activities accounted for 32 percent of CO_2 emissions from fossil fuel combustion. Virtually all of the energy consumed by the transportation sector came from petroleum products, with almost 65 percent of the CO_2 emissions resulting from gasoline consumption for personal vehicle use (defined by EPA as light duty vehicles - LDVs). Passenger cars account for over 50 percent of highway vehicles and over one-third of all the energy consumed in the transportation sector. Light duty or personal vehicles include sport utility vehicles, minivans, vans, and pickup trucks with gross vehicle weight ratings up to 8500 pounds, or beginning in model year (MY) 2011, medium-duty passenger vehicles (sport utility vehicles or passenger vans with gross vehicle weight ratings between 8500 and 10,000 pounds).

Improvements in CO_2 emissions and fuel economy from MY 1975 to 1986 were reversed by 1987 with increasing CO_2 emissions and decreasing fuel economy until MY 2004 where the trend started to improve fuel economy. Vehicle weight and performance are two of the most important engineering parameters that help determine a vehicle's CO_2 emissions and fuel economy. All other factors being equal, higher vehicle weight (which supports new options and features) and faster acceleration performance (e.g., lower 0-to-60 mile-per-hour acceleration time) increase a vehicle's CO_2 emissions and decrease fuel economy. Automotive engineers are constantly developing more efficient vehicle technologies. As shown in Figure 6-2 vehicle weight, horsepower, and acceleration performance increased significantly between 1980 and 2005, with the consequent increases in CO_2 emissions.

Figure 6-2 Average LDV Weight, Horsepower, and Acceleration (MY 1975-2010)

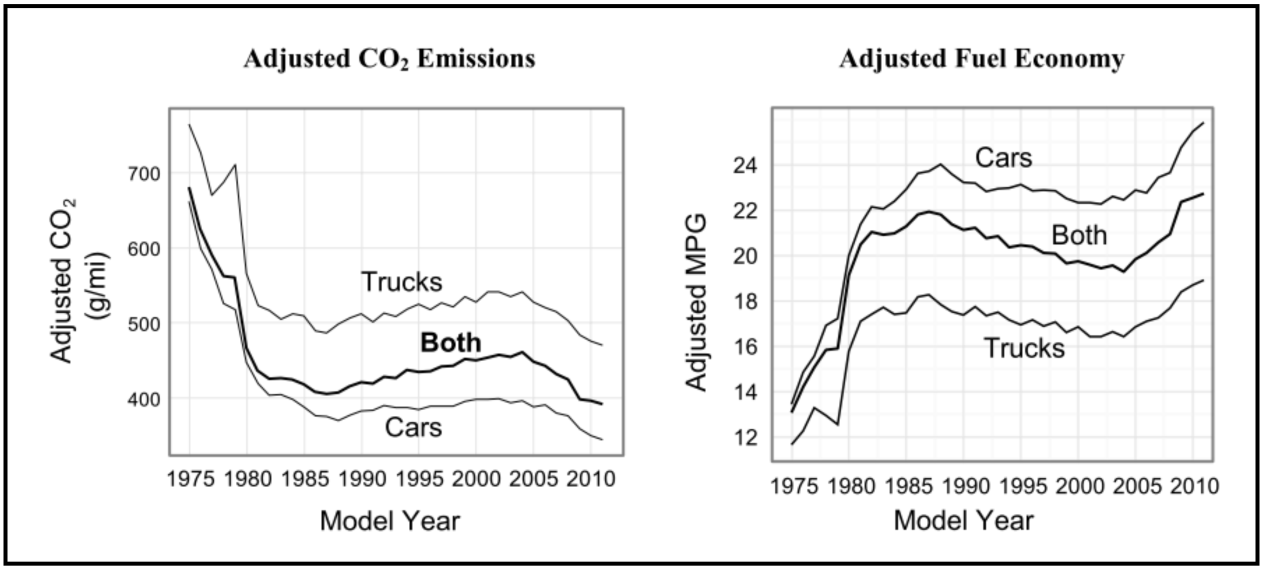


Source: Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2011; EPA-420-S-12-001a, March 2012

Beginning in MY 2005, technological improvements have been used to increase both fuel economy (which has reduced CO_2 emissions) and performance, while keeping vehicle weight relatively constant. MY 2010 national adjusted composite CO_2 emissions were 394 g/mi, a record low for the post-1975 database, and adjusted composite fuel economy was

22.6 mpg, an all-time high since the database began in 1975. Figure 6-3 provides both parameters from MY 1975 to 2010.

Figure 6-3 Average LDV CO_2 Emissions and Fuel Economy (MY 1975–2010)



Source: Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2011; EPA-420-S-12-001a, March 2012

In 2010, EPA and NHTSA finalized the first harmonized standards for MY 2012-2016 (75 *Federal Register* 25324, May 7, 2010). The standards for MY 2012 are now in effect. By MY 2016, the average industry-wide compliance levels for these footprint-based standards are projected to be 250 g/mi CO_2 and 34.1 mpg CAFE. The 250 g/mi CO_2 compliance level would be equivalent to 35.5 mpg if all CO_2 emissions reductions are achieved through fuel economy improvements.

In 2011, the agencies proposed additional harmonized standards for MY 2017-2025 (76 FR 74854, December 1, 2011). Under the currently-proposed footprint-based standards, by MY 2025 the average industry-wide compliance levels are projected to be 163 g/mi CO_2 and 49.6 mpg CAFE. The 163 g/mi CO_2 compliance level would be equivalent to 54.5 mpg if all CO_2 emissions reductions are achieved solely through improvements in fuel economy. These projected levels for MY 2025 represent an approximate halving of CO_2 emissions and doubling of fuel economy levels since the national program was announced in May 2009.

EPA and NHTSA, on behalf of USDOT, developed a joint rulemaking to propose GHG and CAFE standards for model years 2017-2025 light-duty vehicles, which was finalized on August, 28, 2012.

Plug-in hybrid and battery electric vehicles are expected to play a major role in achieving a 163 g/mi CO_2 (54.5 mpg) average fleet in 2025. However, this will require much cleaner power generation than is currently common. Today, the national average power grid produces the equivalent to 620 gmCO_{2e}/kwh, with large variations across the country (from 300 to 1,000 gmCO_{2e}/kwh depending if the power is produced by renewable, hydropower, nuclear, or coal sources), which means that an electric vehicle will have the equivalent global warming emissions of a 30 to 100 mpg gasoline vehicle depending on the region where it is recharged.

6.4.2 Current Effect of Fuel Economy Standards on Emission Factor Models

MOBILE6.2 (released in 2002) estimates CO_2 emission factors for gasoline-fueled and diesel highway motor vehicles by vehicle class (28 individual vehicle types) for model years 1951 to 2050. Its greatest limitation as a tool for GHG analysis is that CO_2 emission estimates are not adjusted for speed, temperature, fuel content, or the effects of vehicle inspection maintenance programs. The most significant shortcoming for modeling CO_2 emissions is that MOBILE6.2 does not include any data for the post 2007 CAFE fuel economy standards or any alternative fuels program. One of the findings of this research is that over half of MPOs estimating GHG emissions are still using MOBILE6.2 for their future projections.

MOVES2010 replaces EPA's previous MOBILE6 and NMIM models, and is built with a far greater and wider data set. It includes the effects of the post 2007 CAFE fuel economy standards affecting model years 2008-2011, and contains internal datasets that can be used to project the market penetration of alternative fuels, and newer vehicle technologies. A comparison of both models for a national fleet at a national inventory level recently performed by FHWA (using the internal data set of MOVES2010b – latest version CO_2e inventory) is provided in Table 6-2.

Table 6-2 Projected National Level Increases Based on EPA MOVES2010b Database

Year From 2005	National VMT % increase	CO_{2e} Emissions MOVES % increase	CO_{2e} Emissions MOBILE 6.2 % increase
2005 – 2020	17%	4%	22%
2005 – 2030	39%	14%	45%
2005 – 2050	100%	60%	109%

The relevance of this comparison is that both models predicted similar national CO_2e results (total millions of tons within 2%) for year 2005, while MOVES emissions were 16% lower than MOBILE6.2 for 2020, 26% lower for 2030, and 30% lower for 2050. This is very close to the predicted effects that the new CAFÉ standard will have in the national vehicle fleet. Table 6-2 results also provide some perspective on the projected national VMT increases for a "business as usual" scenario as built into the MOVES national dataset. Even though these increases could be seen as large; they represent an annual average growth rate in the range of 1.3 to 1.5%, which is below the historic 1990-2006 annual rate of 2%, and the 1990-2010 annual rate of 1.5%.

Once the majority of DOTs and MPOs acquire the familiarity and expertise to use the full capabilities of these emission factor models, future scenario forecasting methods will be able to better evaluate the GHG effects of the full spectrum of transportation emissions.

The state of practice in California is less complex since (as described in Chapter 4) CARB has set up a unified methodology to project GHG emissions using the latest EMFAC2011. It will take some time until all California MPOs revise their projections with the latest EMFAC model.

6.4.3 VMT and Travel Data Limitations

Just as the quality of model inputs and assumptions are crucial to the accuracy of future traffic and travel projections in travel models, the quality of model inputs and assumptions to estimate GHG emissions and impacts of reduction measures are equally important. Access to quality data depends on availability, collection method, and scale. In some cases, MPO datasets were downscaled from state aggregated information and where data was missing national or statewide assumptions were used. The quality of inputs like VMT also depended on variables like the level of sophistication in the travel model being used. Depending on the type of GHG reduction strategy, parcel level data can be preferred over data at the traffic analysis zone level, although such data are not always easily accessible or easy to work with.

6.5 Opportunities for Advancement and Recommended Areas of Further Research

Update assumptions in GHG inventories and models to more accurately reflect future fleet mixes and fuel economies. Key assumptions in estimating GHG emission forecasts should include fleet turnover including conversion to hybrid electric and fully electric vehicles in the forecast year(s). Also, as discussed in Section 6.4.2, post 2007 CAFE fuel economy standards and future market penetration of alternative fuels should be included in GHG emissions forecasts. Since many of the MPOs conducting GHG analysis will continue to use MOBILE6.2 through 2013, training opportunities and/or peer exchanges on incorporating MOVES2010 into inventorying, forecasting, and scenario planning efforts could facilitate the transition over to the recently improved models.

Several research efforts are underway including NCHRP 25-25 Tasks 71 and 77 to assist DOTs and MPOs in the future use of MOVES and other analytical tools, as well as FHWA-TOPR Number 6801-12009: "Assessment of MPO and State DOT Resources and Technical Capabilities Relative to Adopting New Air Quality Modeling Applications".

Utilize lifecycle analysis to evaluate complete impacts of fuel and technology-based strategies. A lifecycle assessment is important in evaluating transportation the full range of transportation strategies. For alternative fuel vehicle strategies (e.g., purchases of alternative fuel buses, incentives for consumer use of alternative fuel vehicles), the benefits of strategies on a lifecycle GHG basis may be very different than when only examining direct vehicle emissions (from tailpipe). For instance, for certain types of fuels, vehicle GHG emissions are lower than conventional fuels but are offset by higher upstream emissions. As a result, lifecycle analysis should be conducted when examining vehicle fuels/technology combination. Also, capital intensive strategies (such as construction of new rail transit or highways) generate high GHG during construction and this needs to be accounted for, especially to allow valid comparison to pricing and operational strategies which entail little or no "up front" GHG.

Improve understanding of the effects of hybrid, plug-in and battery powered electrical vehicles. It is also important to include non-fuel based energy and associated GHG emissions, such as electricity used by transit service and electric vehicles. Since the GHG content of electricity varies significantly, from the low-carbon hydro power of the west to the high-carbon coal based power in the east, electrification of travel may have varying GHG impact leading to different infrastructure investment decisions if fully accounted for. The general understanding and available tools to analyze such effects need further development and integration into the transportation GHG analytical process.

How and where freight emissions should be considered. Freight also poses additional challenges, as they often utilize a mix of modes in their supply chain and incur idling and other GHG emissions (e.g., refrigeration) during loading and overnight operations. The estimation of GHG emissions related to freight depends on a series of variables and assumptions related to the type of cargo to be moved, and the carrier moving the cargo. If one considers the extreme example of a truck transporting potato chips or iron, it is easy to understand that the enormous difference in the weight of the cargo can contribute to a wide variation in emissions per ton. This is an area where improvements to analytical tools and a better understanding of the limitations of existing tools by state DOTs and MPOs will be useful on the preparation of emission inventories and future scenario forecasts.

Identify practical, implementable strategies to close the target achievement gap. In order to meet climate stabilization, agencies are looking at significantly reducing current GHG emissions by about 30%-80% over the next 20-40 years. Meeting these extremely ambitious targets would require a variety of strategies implemented at all planning levels, including a possible federal role to further increase CAFE standards for not only light-duty vehicles but also heavy-duty vehicles to address the anticipated growth of freight-related GHG emissions. In Chapter 5, agency-led scenario analyses illustrated the difficult challenge in meeting the GHG reduction target without a stronger federal role, or significant changes in pricing or vehicle technology. Improving the understanding of what practical and effective strategies could be implemented under the authority of a DOT and MPO and how these transportation strategies work with reductions from other sectors is part of the equation in moving forward to addressing the gap.

Provide tools and opportunities enabling more coordinated planning efforts between State DOTs and MPOs, between MPOs, and between MPOs and member jurisdictions. In some areas across the country, states have taken a stronger leadership role in addressing climate change and GHG emissions, where in other areas, the MPO(s) or local jurisdictions have taken a more proactive leadership role. Where varying methodologies, tools, targets, and guidelines have been set at these different planning levels, increased coordination and collaborative planning is necessary to achieve local, regional, and statewide goals. Consistent tools that provide these types of collaborative planning opportunities and coordination, like ODOT's GreenSTEP DOT and MPO model versions or SACOG's move towards an open source scenario planning tool like Urban Footprint, can open the policy discussions needed to implement the strategies down to the master planning or general planning level.

6.6 Summary

The results of this research indicated that the primary motivation for considering GHG emissions in decision-making seems to be state or local legislation and/or agency policy that requires such analysis. For state DOTs and MPOs reporting GHG emissions considered under a state or local mandate or climate action planning effort, 22 agencies reported having some level of GHG reduction goal or target. Most emission targets were generally compared against a base year of 2005 or 1990 – consistent with either state goals or the Kyoto Protocol, with medium term goals in the range of 7-25% reductions by 2020, and longer term goals of 30-80% reductions by 2035 or 2050.

These GHG reduction targets are ambitious and represent challenges to agencies in finding appropriate resources to not only conduct the GHG analysis, but also to implement the GHG emission reduction strategies. In addition, most agencies with established targets have found the targets to be unachievable without additional federal actions, like further increasing CAFÉ standards of both light-duty and heavy-duty vehicles and implementing pricing strategies and programs at a national scale.

For the majority of agencies not performing GHG analysis the reasons varied from public skepticism of climate change, awaiting guidance or regulatory requirements from the state or federal level; and unclear expectations from the governor or state legislature.

On the use of analysis methods, the survey findings showed that only five agencies reported use of these established GHG analysis protocols (like ICLEI, The Climate Registry, and World Resources Institute). Due to lack of federal regulatory requirements, state and local agencies developed their own ways of analyzing the GHG emissions based on best practice, technical literature, and available tools.

In terms of the scope of GHG analysis, this research found:

- GHG analyses focused primarily on direct transportation emissions from vehicle operations (not life cycle emissions).
- The primary mode of transportation analyzed in GHG estimation efforts was light-duty vehicles.
- GHG estimation methods were most commonly based on VMT data.
- Fleet and fuel efficiency benefits such as CAFÉ standards and state regulations (such as the Pavley GHG tailpipe emissions standards adopted by approximately 15 states) were seldom included in the analysis.
- Scenario planning and accompanying tools are playing an increasingly integral role in State DOT and MPO GHG planning efforts.

The variety of scenario planning tools in use provide a fair degree of accuracy to evaluate and test possible GHG effects of local and state level policy actions, but they fall short in forecasting the changes to the motor vehicle fleet characteristics, and the future effect of fuel economy standards on the local fleet. In these cases the best available options seem to be the use of the MOVES emission model (MOVES2010b – latest version at the time of this writing) and EMFAC2011 in California.

Possible research opportunities include:

- Development and continuous updating assumptions in GHG inventories and models to more accurately reflect future vehicle technologies and fuel economies and how various scenarios affect the effectiveness of VMT reduction strategies and other strategies;
- Better tools for lifecycle analysis to evaluate and compare GHG strategies based on their full GHG effects;
- Better understanding of the GHG effects of hybrid, plug-in and battery powered electrical vehicles;
- More comprehensive tools for assessing freight GHG emissions from supply chains, and when they should be considered;
- Better understanding of sensitivities in GHG analysis, to support greater focus on the variables of greatest consequence;
- Additional research to monitor and evaluate the real-world results of GHG policies, programs, and projects to facilitate validation and calibration of GHG models and assumptions; and
- More coordinated planning efforts between state DOTs, MPOs, and federal agencies (e.g., EPA and USDOT) in normalization and/or standardization of analytical procedures.

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APPENDIX I

Survey Questions

NCHRP Survey on GHG Planning and Analysis Methods

Thank you for participating in this study with the National Cooperative Highway Research Program (NCHRP) to develop a synthesis of State DOT and MPO planning and analysis methods to reduce greenhouse gas (GHG) emissions. The objective of this survey is to identify actions that are being taken to implement GHG emission reduction strategies as part of the transportation planning process, and which methods and estimation techniques are most prevalent in the field. *Individual agency responses will not be cited, unless the agency is contacted and gives approval.*

Please complete your survey by 8:00pm Eastern Friday, January 13, 2012.

Survey Participant Name: ___________________________________

Survey Participant Agency: _________________________________

Survey Questions	Comments / Instructions	Answer
I. GHG Considerations in the Planning Process		
1. Is your agency conducting or considering GHG emission analysis?		☐ Yes, we have completed a GHG analysis in some form ☐ Yes, we are doing or will be doing a GHG analysis in the next year ☐ We may be conducting a GHG analysis in the foreseeable future ☐ We do not expect to conduct a GHG analysis in the foreseeable future
If you selected "Yes, we have completed a GHG analysis in some form" or "Yes, we are doing or will be doing a GHG analysis in the next year," please proceed to question 3. If you selected "We may be doing a GHG analysis" or "We do not expect to do a GHG analysis in the foreseeable future," please proceed to question 2.		

2. If your agency is not sure if it will conduct a GHG analysis or does not expect to conduct a GHG analysis in the foreseeable future, what are the primary reasons?	*Please check all that apply.*	☐ Public or policy opposition to climate change ☐ Other priorities take precedence ☐ Insufficient staff time for such analysis ☐ Budgetary constraints ☐ Data limitations ☐ Other? Please Explain:____________________
The remaining questions in this survey pertain to GHG analysis tools and methods. If your agency does not expect to conduct a GHG analysis in the foreseeable future, please feel free to submit this survey with responses 1 and 2 above completed. Your time and participation is greatly appreciated.		
3a. Is your agency considering GHG emission reduction strategies as part of its planning process or in project development?	*If answer is "no," please skip to question #4.*	☐ Yes, in the planning process ☐ Yes, in project development ☐ Yes, in both project development and the planning process ☐ No

3b. If yes, is such consideration part of a State or local mandate or agency policy?	*Please select all that apply.*	☐ State or local legislation ☐ State or local regulation ☐ State or local climate action plan ☐ Governor's action ☐ Agency policy ☐ Federal NEPA law ☐ Other? Please Explain:______________________________
4. Is GHG analysis performed for the:	*Please select all that apply.*	☐ Long Range Transportation Plan (LRTP)? ☐ Transportation Improvement Program (TIP)? ☐ Corridor Level Planning Process? ☐ Project Level Analysis (NEPA or State Environmental Project Review)? ☐ Other? Please Explain:______________________________

5. What types of GHG emission reduction strategies have been considered as part of your agency's planning process?	*Please select all that apply.*	☐ Transportation system planning and design ☐ Construction and maintenance practices ☐ Transportation system management and operations (e.g., speed limit reductions, signalization) ☐ Vehicle and fuel policies ☐ Land use codes, regulations, and other land use policies ☐ Taxation and road pricing ☐ Travel demand management (passenger) ☐ Travel demand management (freight) ☐ Transit strategies ☐ Public education ☐ Bicycle and pedestrian ☐ Other? Please Explain:______________________________
II. GHG Emissions Analysis Framework		

6. Do you have a defined protocol or approach for estimating GHG emissions reduction	*If answer is "yes," please continue with questions 7-18.*	☐ Yes ☐ No
7. Is the protocol or approach based on:		☐ Established GHG analysis protocols (ICLEI, WRI, TCR, etc.) ☐ Approaches borrowed from/developed with other agencies ☐ Approaches defined in the technical literature ☐ Your own ideas on how to conduct such an analysis ☐ Other? Please Explain:____________________
8. For any GHG analysis you conduct in your agency, do your study boundaries extend to:	*Please select all that apply.*	☐ Parts or all of more than one state? ☐ An entire state? ☐ An MPO planning area?

		☐ A municipality level? ☐ A corridor study boundary? ☐ Project level ☐ Other? Please Explain:______________________
9a. What is the base year for your GHG emissions analysis?		
9b. How was the base year determined?		☐ Base year aligned with LRTP, TIP, SIP or other transportation plan or program ☐ Base year established in state or local GHG mandates ☐ Base year determined on case-by-case basis ☐ Other? Please Explain:______________________
10a. What is the horizon year for your GHG emissions analysis?		

10b. How was the horizon year determined?		☐ Base year aligned with LRTP, TIP, SIP or other transportation plan or program ☐ Base year established in state or local GHG mandates ☐ Base year determined on case-by-case basis ☐ Other? Please Explain:________________________________
11. Which of the following modes of transportation are considered in GHG analysis in your agency?		☐ Light duty passenger vehicles ☐ Transit buses ☐ Heavy duty trucks ☐ Transit Rail ☐ Intercity bus and passenger rail ☐ Off-road freight (rail, intermodal, marine and air) ☐ Airports and passenger aviation ☐ Bicycling

		☐ Walking
12. Do you have established GHG emission reduction targets?	*Please select all that apply.*	☐ ____% GHG reduction by short-range target year_____ ☐ ____% GHG reduction by mid-range target year_____ ☐ ____% GHG reduction by long-range target year_____ ☐ ____% GHG yearly reduction ☐ Above target(s) are per capita ☐ Above target(s) are overall reductions ☐ Above target(s) are the same for all sectors, including transportation as well as electric power, industry, etc. ☐ No specific targets
III. GHG Emission Estimation Techniques and Methodologies		
13. Which metrics do you use in estimating GHG emissions?	*Please select all that apply.*	☐ Carbon dioxide (CO_2) ☐ GHG (including CO_2, methane (CH_4), and nitrous oxide

		(N_2O) ☐ CO_2 equivalent ☐ Energy consumption (BTU) ☐ Others? Please Explain:_______________________
14. Which type of emissions do you consider in the analysis?		☐ Direct emissions from vehicle travel that begins or ends within boundary region only ☐ Direct emissions from vehicles that pass through the region ☐ Construction and maintenance emissions of transportation agencies ☐ Full fuel-cycle emissions (electricity transmission for electric vehicles; up-stream GHG associated with production and distribution of petroleum; etc.)

15. Which methods or tools do you use as part of the GHG analysis?	*Please select all that apply.*	☐ Sketch planning tools – GHG calculators based on fuel consumption ☐ VMT data – applying GHG emission factors ☐ HPMS data – applying GHG emission factors ☐ Travel demand models based on activity data ☐ Various depending on transportation mode (vehicles, rail, air, marine)
16. Which motor vehicle emission models do you use?		☐ Mobile 6.2 ☐ MOVES ☐ EMFAC ☐ GREET (life cycle) ☐ Other? Please Explain:________________________________

17. On a scale of 1 to 7, where 1 is very dissatisfied and 7 is very satisfied, how satisfied are you with the analysis tools you are using to estimate GHG emissions?	1 2 3 4 5 6 7
18. If you could make one improvement in the models, methods, tools, or data that are part of your GHG emissions analysis, what would that improvement be?	

APPENDIX II

Interview Questions

Legislative/ Regulatory Mandate

- Is there a legislative or regulatory mandate for conducting GHG emissions analysis and for considering GHG emission reduction strategies in the agency's programs? If so, what are the specifics? Deadlines? Target reductions? Strategies?
- Have the state/region decision makers adopted specific policy statements that direct the agency to consider GHG emissions in planning?

Scope of GHG Consideration

- Are these analyses performed at the regional, corridor or project level?
- What transportation modes are being included – light-duty vehicles, heavy-duty vehicles, freight, transit buses, rail, water transportation, all modes?
- What is the scope of GHG emissions being considered:
    - Direct emissions of agency activities and vehicle fleet operations?
    - GHG associated with agency electricity consumption?
    - Direct emissions plus indirect emissions associated with use of the system (e.g., VMT on agency-owned infrastructure or geographic boundaries)?
    - Construction and/or maintenance emissions?
    - Full life cycle of vehicles?
    - Others?

Approaches and Methods

- What transportation and emission models/tools were used? Pros and cons of the models/tools used?
- What types of data and assumptions were necessary in conducting such analyses?
- What were the major challenges or limitations of the analytical approach?
- Did you conduct an assessment of different methods that could be used before you adopted your current approach? If so, why was the current approach chosen?

- If you used scenario analysis, what were the major assumptions employed?

  In particular, what assumptions were made about future auto fuel economy or GHG rates?

- Could you determine the confidence level of the results of your obtained?

Interagency Coordination

- Was there coordination with other agencies – transportation agencies, state/local, Departments of Environmental Protection (DEP/DEC/other), EPA, other governmental agencies, community groups, NGOs, etc.?

Policies and Strategies

- Did you consider all reduction strategies in five “legs” of the GHG stool

  1. Vehicle efficiency
  2. Low-carbon fuels
  3. VMT Reductions (including land use)
  4. Vehicle/System Operations
  5. Construction, Maintenance, and Agency Operations

- What types of policies received or are receiving greater emphasis in your analysis and planning?

Analysis Results

- What do you consider the top 3 conclusions or results of your GHG analysis?
- Did any of the results surprise you?
- How confident are you in the analytical results?
- What recommendations would you make to other state DOTs/MPOs or the Federal government based on your analysis and results?

Implementation

- What legislative/policy/finance/regulatory actions are necessary to implement the GHG emission reduction strategy?

APPENDIX III

Interview Case Studies

ATLANTA REGIONAL COMMISSION

BACKGROUND

LEVEL OF ANALYSIS:
Regional
METHODS/MODELS USED:
• 4-Step Travel Demand Model • Mobile6.2
RELEVANT POLICIES, REGULATIONS, LEGISLATION:
• N/A
TARGETS:
• No specific targets set
EMISSIONS ANALYZED:
CO_2 and CO_2e

The Atlanta Regional Commission (ARC) is the MPO overseeing transportation planning in 18 Georgia counties. With fast growth, low density and limited mass-transit systems, Atlanta ranks among the highest one-third of average carbon footprints out of 100 major metropolitan regions across the country, according to a 2008 study by the Brookings Institute. The Atlanta region has experienced significant growth in VMT from 1990 to the present. In 1990, the 20-county regional VMT was 94 million vehicle miles per day, with a total population of 3.06 million. By 2000, the regional VMT was 137 million with a total population of 4.23 million. In 2010, the regional VMT is estimated at 167 million with a total population estimated at 5.1 million.

Power generation and transportation are the two biggest sources of CO_2 in Georgia. Transportation CO_2 emissions increased 42% between 1990 and 2005 (as compared to national average of 26%). Although ARC is not mandated to consider GHG emissions in its planning process, the efforts have primarily been undertaken through staff initiative to link regionally adopted goals to greenhouse gas emissions, climate change, and energy.

DEVELOPING AND IMPLEMENTING APPROACH

ARC's regional GHG analysis was used as one factor of many in prioritizing projects in the transportation plan. Direct CO_2 emissions were the primary GHG analyzed.

ARC used a VMT-based approach, utilizing CUBE, its 4-step travel demand model for estimating VMT and then MOBILE6.2 to develop emission factors for each scenario. Data for the travel demand model was derived from household surveys. Modes considered were the same as found in the travel demand model: light-duty vehicles, heavy-duty vehicles and buses.

ARC based its analysis on scenarios. The scenarios reflected: 1) changed land density, 2) different transportation networks (for example, in one scenario a build out of the proposed regional transit network was assumed), 3) a combination of 1 and 2, and 4) a continuation of development trends. Out of the "five-legged transportation GHG reduction stool," the GHG reduction strategies focused on transportation/land use strategies (that is, those related to reducing VMT) and vehicle technology (primarily fuel economy). ARC adjusted vehicle fuel efficiency for each scenario depending on the assumptions of future CAFE standards.

LESSONS LEARNED: CHALLENGES AND BENEFITS

The major challenge for this analysis was the assumption that travel behavior in the future would not change as represented in the underlying relationships in the travel demand model. For example, there is a tendency in the model not to reflect any significant changes in transit ridership…2 to 3 % regional transit ridership today, 2 to 3% regional transit ridership tomorrow. Another analytical limitation, inherent in the Mobile6.2 model, was the inability to model emissions at varying speeds. This limitation, however, may be addressed with the future use of EPA's MOVES model.

The increase in CO_2 in the Atlanta region can be attributed to four primary factors: increase in VMT, fleet inefficiency, increase in freight volume (especially container shipments), and system/vehicle operating characteristics (e.g., congestion, speed, idling, acceleration, etc.). ARC drew the following major conclusions from its scenario analysis:

1. Vehicle technology is the primary driver for reducing GHG emissions,

2. There is a need for better tools for more accurate estimating, and

3. Increasing land use density helps, but it is not a panacea (and has no influence on travel behavior according to the travel demand model).

Better tools are needed for estimating GHG emissions, on both the travel demand and emissions modeling side. ARC believes MOVES might be more helpful in the emissions side but there is a need for a more flexible travel demand model that allows them to do "what if…" scenario analyses.

NEXT STEPS

At this time, ARC has limited plans to extend the GHG analysis. ARC officials have applied for an EPA grant to use the TRIMMS model to evaluate GHG and criteria pollutants for travel efficiency programs. There seems to be little interest from public officials in the Atlanta region for having such information, especially with recent focus on a major transportation funding referendum. With the defeat of the referendum, most transportation officials do not believe there will be enough funding in the next few years to implement many projects, and thus there is likely little interest in developing an improved GHG analysis methodology. However, the motivation for the GHG scenario analysis came from MPO staff, and the same will likely continue in the future as new tools become available. The current use of MOVES considers $C0_2$ emissions as part of project and program analyses, and the staff will continue to report on regional $C0_2$ emissions in the future.

BOSTON REGION METROPOLITAN PLANNING ORGANIZATION

BACKGROUND

Massachusetts adopted The Global Warming Solutions Act in 2008, requiring the Secretary of Energy and Environmental Affairs to establish a statewide limit on greenhouse gas emissions, which was set at 25% below 1990 levels by 2020, and 80% below 1990 levels by 2050. The Massachusetts Clean Energy and Climate Plan for 2020 outlined the measures required to meet that limit.

The 2020 Plan in its projections took into account state and federal measures to improve vehicle efficiency, reduce vehicle miles traveled (VMT), and increase use of lower-carbon fuels. In Massachusetts, transportation accounts for about a third of GHGs, up slightly from 31% in 1990, and estimated to rise to 38% by 2020.

LEVEL OF ANALYSIS:

Regional

METHODS/MODELS USED:

- Regional Travel Demand Model
- Mobile6.2 – in process of changing to MOVES

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- Global Warming Solutions Act of 2008
- Massachusetts Clean Energy and Climate Plan for 2020
- Paths to a Sustainable Region 2035

TARGETS:

- 25% below 1990 levels by 2020
- 80% below 1990 levels by 2050
- No specific MPO targets

EMISSIONS ANALYZED:

CO_2

DEVELOPING AND IMPLEMENTING APPROACH

The Long-Range Transportation Plan (LRTP), "Paths to a Sustainable Region", is a guide to the future of transportation in the Boston region published in September 2011. In it, the Boston Region Metropolitan Planning Organization (MPO) describes how the transportation network is currently serving users and explores how it might be improved to better serve the region, considering the changes that are expected between 2011 and 2035.

Paths to a Sustainable Region was guided by a vision for the future, a respect for previous plans, and a realistic assessment of the maintenance needs of the existing system and the financial constraints to be faced during the next two decades.

The MPO policies evaluate a priority of programs, services, and projects that contribute to meet the targets for reducing GHG emissions including:

- Implement action to meet defined targets for reducing vehicle-miles traveled (VMT) by tying transportation funding to VMT reduction;
- Support stronger land use and smart growth strategies;
- Increase transit, bicycle, and pedestrian options;
- Invest in adaptations that protect critical infrastructure from effects resulting from climate change;
- Encourage strategies that utilize transportation demand management;
- Promote fleet management and modernization, idling reduction, and alternative-fuel use; and
- Contribute to reduced energy use in the region; energy use will be part of the environmental impact analysis of all projects.

The MPO estimated GHG emissions using the regional travel demand forecast model (TDM) to estimate VMT, and Mobile6.2 for emissions factors. The TDM included all communities within the commuting area for eastern Massachusetts, encompassing 63 communities that are outside the 101-municipality MPO region.

The TDM model included all Massachusetts Bay Transportation Authority (MBTA) rail and bus lines, all private express-bus carriers, all commuter boat services, all limited-access highways and principal arterials, and many minor arterials and local roadways. The model is made up of several models, each a step in the travel decision-making process. The model estimates network performance characteristics and transportation demand for travel from every TAZ to every other TAZ. The model relies on several inputs (different categories of data), the most important including population, employment, auto ownership, transit fares, automobile operating costs, and highway and transit levels. Several important travel statistics are reported for these forecasts, including:

- Total vehicle-miles of travel (VMT) and vehicle-hours of travel (VHT) on a typical weekday;
- Average highway speed;
- Amount of air pollutants and GHG emissions produced by automobiles and transit vehicles;
- Total number of daily trips made by auto and transit;
- Average daily fixed-route transit ridership by mode (rapid transit, bus, commuter rail, commuter boat, and express bus); and
- Percentage of people traveling by each of the travel modes

LESSONS LEARNED: CHALLENGES AND BENEFITS

The MPO is expecting to use the same modeling approach (use of TDM and emission factor models) which has been used for the SIP and conformity processes, to estimate the GHG emission effects of TIPs and Transportation Plans in the near future.

The benefit of this approach is the built-in knowledge of forecasting the region's VMT, VHT and other regional factors.

Currently for projects in the TIP and not included in the regional model, the GHG estimate is done through an off-model manual spreadsheet approach.

The current limitation is the use of MOBILE6.2 emission factors for all the baseline and future scenarios. This will be corrected in the next year or two once the MOVES local data sets and integration is finalized.

Another long term limitation of this modeling process is that only direct (fuel use) transportation emissions are considered; and the capital intensive infrastructure projects will not be evaluated from the life cycle emission analysis perspective.

NEXT STEPS

Massachusetts Department of Environmental Protection is preparing the localized emission data sets, vehicle registration, and future projections regarding fuels and market share of new vehicle technologies (hybrids, electric) for inclusion in MOVES.

The MPO is in the process of preparing the TDM files for integration with MOVES for the analysis of future years 2020 and 2035. It is expected that in another year all air pollutant inventories for the region's transportation sector (including CO2) will be estimated using MOVES. This will allow a better quantification the effects of the new CAFÉ and renewable fuel standards, as well as other state and federal mandates

DENVER REGIONAL COUNCIL OF GOVERNMENTS

BACKGROUND

Metro Vision 2035 is the overarching plan for the Denver region with multiple planning goals for more compact transit oriented development. Within its goals it aims to reduce the 2005 daily VMT of 26.3 miles per capita by 10% by 2035, and reduce commuter single occupancy vehicle (SOV) from 74% currently to 65% by 2035. It also includes established GHG emissions reduction goals of 60% on a per-capita basis to reduce the 4.5 metric tons (MT) of annual per capita CO2 in 2005 to 1.8 MT per capita CO_2 by 2035.

LEVEL OF ANALYSIS:

Regional

METHODS/MODELS USED:

- Activity based Regional Travel Demand Model (TDM)

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- Previous governor established targets as policy discussion

TARGETS:

- Per capita CO2 reductions of 60% below 2005 levels by 2035
- Per capita VMT reductions of 10% below 2005 levels by 2035

EMISSIONS ANALYZED:

No scenario analysis performed to date.

DRCOG adopted by Resolution No. 5, 2011 (Feb. 16, 2011), the Metro Vision 2035 Plan as part of DRCOG's regional master plan for the Denver region. Within the METROVISION umbrella it is a 2035 Regional Transportation Plan (RTP). This fiscally constrained RTP guides the priorities of the 6 year Transportation Improvement programs (TIPs).

DEVELOPING AND IMPLEMENTING APPROACH

Although the state of Colorado completed a statewide Climate Action Plan that estimated GHG emissions and identified potential policy options to achieve GHG reductions in the mid- and long-term; DRCOG is just beginning the discussion of how to estimate GHG emissions and model various scenarios at the regional level.

The new activity based Travel Demand Model (TDM) includes all modes of surface transportation (9 modes) auto, trucks, transit, bicycles, pedestrians, etc. No scenario specific GHG emissions (current and future) have been analyzed to date.

There is ongoing work on preparing a Metro Vision 2040, and there is discussion that GHG will be part of it.

LESSONS LEARNED: CHALLENGES AND BENEFITS

DRCOG is just starting to talk about the procedures for estimating GHG emissions at a regional level.

No specific scenarios have been analyzed to date. There is no quantification regarding the future effect of the new CAFÉ fuel economy standards, or future vehicle technologies.

It does not appear to be any direct connection between GHG reduction goals with any specific means to achieve them.

NEXT STEPS

The SIP, TIP process is a well developed interagency process. The assumption is that once the GHG process becomes mandatory it will follow the same framework as the SIP existing system.

There are a series of policy discussions and draft alternatives for the expansion of transit systems, bicycle lanes and pedestrian oriented facilities.

It seems that the current effort is into improving the capabilities of the TDM to be able to encompass all modes of transportation.

The Air Pollution Control Division (part of State Department of Health and Environment) is in charge of preparing the mobile source emission factors in MOVES. To date DRCOG has only used MOVES on test runs for the SIP and conformity determinations.

MARYLAND DEPARTMENT OF TRANSPORTATION

BACKGROUND

The State of Maryland established a goal of reducing greenhouse gas (GHG) emissions by 25 percent in 2020, compared to 2006 levels. In 2008 the state developed a Climate Action Plan that included eight transportation and land use policy options. The Maryland Department of Transportation (MDOT) was given the lead responsibility to design and implement most of these policies. In 2016, the Legislature will determine whether to continue, adjust, or eliminate the requirement to achieve a 25 percent reduction by 2020.

LEVEL OF ANALYSIS:

Statewide

METHODS/MODELS USED:

- Regional travel demand models
- EPA SIT, MOBILE 6.2
- Draft MOVES 2009,
- Sketch-models

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- Greenhouse Gas Emissions Reduction Act of 2009 (GGRA)

TARGETS:

- Greenhouse gas (GHG) emissions reduced by 25 percent in 2020, compared to 2006 levels

EMISSIONS ANALYZED:

CO_2e

DEVELOPING AND IMPLEMENTING APPROACH

To develop the policies in more detail, the Department conducted a baseline inventory of statewide transportation GHG emissions for 2006 and 2020, then analyzed the GHG benefits and costs of a variety of existing, planned, and proposed transportation strategies. The analysis examined vehicle and fuel technology strategies such as federal and state adopted fuel economy standards; regional transportation plans with committed projects; committed emission reduction measures implemented for air quality purposes; and a set of additional unfunded GHG reduction strategies identified in the 2008 Climate Action Plan and by a Coordinating Committee led by MDOT consisting of state, regional and local transportation officials.

Of all state 42 GHG reduction policies, eight were transportation and land use strategies. These strategies related to: land use & location efficiency; transit; intercity travel; pay-as-you-drive insurance; bike & pedestrian infrastructure; incentive, pricing & resource measures; transportation technology; and evaluation procedures for GHG emissions from major projects.

An updated GHG transportation sector inventory was estimated for a 2006 baseline and a 2020 forecast analysis year. The inventory was determined by estimating emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) then converting these emissions to carbon dioxide equivalents, measured in million metric tons (MMT CO_2e).

MOBILE6.2 model and post processing software (PPSUITE) for the regional travel demand models were used to estimate VMT and GHG emissions at the link-level for the regional roadway networks. For rural counties not included in travel demand models, VMT data from the Highway Performance Monitoring System (HPMS) were used. The DRAFT MOVES 2009 model was used to develop speed adjustments to the CO_2 emission factors to support the analyses. Fuel economy values were adjusted to reflect actual on-road performance (typically 15 percent lower) using degradation factors provided by the United States Department of Energy's (DOE) Energy Information Administration (EIA).

EPA's State Inventory Tool (SIT) was used to estimate on-road CH_4 and N_2O emissions based on the inputs of vehicle miles of travel (VMT) and SIT defaults for fleet characteristics and vehicle technology. VMT was based on available 2005-2006 Maryland State Highway traffic data and reported 2006 HPMS VMT.

The off-road GHG emission analysis relied on the emission factors and methodologies provided in EPA's State Inventory Tool (SIT). The SIT estimates off-road CO_2, CH_4 and N_2O emissions based on historical fuel consumption data. Inputs to the SIT tool for the 2006 baseline inventory were based on the EIA's State Energy Data (SED). MDOT reviewed and confirmed all baseline and BAU emissions analysis assumptions and methodologies with MDE.

The key methods and assumptions for each type of strategy analyzed are shown in Table 1.

Table 1. TLU Strategy Analysis Methods

	Strategy	Analysis Methods
TLU-2	Land Use & Location Efficiency	Data on per-capita VMT by census tract density combined with assumptions about population growth in different density ranges.
TLU-3	Transit	Ridership and service growth needed to reach previously-established state goal of doubling 2000 ridership by 2020 compared with extrapolation of existing ridership and service trends (incorporating Baltimore and Washington regional trends and committed projects).
TLU-5	Intercity Travel	Assumed increased transit mode share to BWI Marshall Airport; assumed increased MARC and Amtrak ridership compared to existing levels, as a result of service improvements.
TLU-6	Pay-As-You-Drive Insurance	Applied VMT percentage reductions from other PAYD pilot studies to different assumptions regarding percentage of policies covered in Maryland by 2020.
TLU-8	Bike & Pedestrian Infrastructure	For trails, compared existing walk and bike mode shares in areas near trails with other areas; assumed greater trail coverage consistent with Maryland Strategic Trail Plan and resulting mode impacts for residents near new trails. For pedestrian infrastructure, applied an elasticity of VMT with respect to a Pedestrian Environment Factor (PEF) to assumed changes in PEF as a result of neighborhood pedestrian improvements in business districts and near schools and transit stations; baseline mode shares varied by population density.
TLU-9	Incentive, Pricing & Resource Measures	Applied VMT elasticities (change in VMT with respect to change in travel cost) to VMT fees and congestion pricing. EPA COMMUTER Model used to assess impact of expanded workplace-based travel demand management programs.
TLU-10	Transportation Technology	Traffic management benefits projected from existing evaluations of the Maryland Coordinated Highways Action Response Team (CHART) program. Benefits for idle reduction programs, truck fuel economy improvements, and off-road vehicle retrofits projected from various assumptions regarding technology benefits and fleet penetration.

TLU-11	Evaluate GHG Emissions from Major Projects	Not applied.

LESSONS LEARNED: CHALLENGES AND BENEFITS

Assuming federal and state fuel economy and renewable fuel standards as forecasted, such standards would reduce the 2020 GHG forecast by 4.76 MMT to slightly below 2006 levels. Existing transportation plans and programs, combined with existing emission reduction measures, reduced projected 2020 emissions by an additional 2.11 MMT to 9 percent below 2006 levels. Implementation of the eight unfunded TLU policy options at different levels of deployment created a range from a 1.62 to 3.16 MMT reduction in 2020, thus accounting for an additional 30 to 60 percent of the target shortfall. At the highest level of potential TLU strategy deployment through 2020, plus the benefits of existing statewide transportation sector strategies, the transportation sector was estimated to achieve a reduction of 82 percent of the 2020 shortfall. In other words, compared to the Climate Action Plan and Maryland GHG Emission Reduction Act goal of a 25 percent reduction of 2006 emissions in 2020, the transportation sector could reduce GHG emissions by 20.4 percent in 2020.

The level of investment in transportation strategies and projects represented by the highest level of TLU deployment was estimated to require roughly a 40 to 50 percent increase in funded transportation system capital investment in the 2009-2014 capital investment program.

NEXT STEPS

Maryland DOT and its state and regional partner agencies will continue to consider implementation of the strategies evaluated in the plan. This will include outreach and coordination activities with the modal agencies, MPOs, other state agencies, and local jurisdictions to build consensus, gain buy-in and assist in the planning and implementation of the transportation sector climate change-related strategies. The Greenhouse Gas Emissions Reduction Act of 2009 requires annual updates to the Maryland Commission on

Climate Change from each state agency regarding progress in implementing greenhouse gas emission mitigation measures. This includes tracking of the implementation of specific GHG beneficial projects and programs. Maryland DOT is working with other state agencies to develop a publicly-reviewed state implementation plan for meeting the 2020 GHG reduction targets.

MINNESOTA DEPARTMENT OF TRANSPORTATION

BACKGROUND

Numerous laws in Minnesota have driven the Minnesota Department of Transportation (MnDOT) to explore GHG reduction strategies. The Next Generation Act of 2007 set landmark legislation in the state with the following multi-sector, statewide GHG reduction targets:

- At least 15% below 2005 levels by 2015;
- At least 30% below 2005 levels by 2025; and
- At least 80% below 2005 levels by 2050.

In addition, the Act stated two primary energy policy goals to reduce per capita use of fossil fuel by 15% by 2015 and 25% of the total energy used in the state be derived from renewable energy sources by 2025.

LEVEL OF ANALYSIS:

Statewide

METHODS/MODELS USED:

- For Minneapolis/St.Paul, regional demand model; MOVES2010a; national estimates of VMT reduction by strategy

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- The Next Generation Energy Act of 2007
- Adopted transportation goal of reducing GHG emissions
- Annual statewide performance report (including gallons consumed)

TARGETS:

- 15% below 2005 levels by 2015
- 30% below 2005 levels by 2025
- 80% below 2005 levels by 2050
- Targets are across all sectors; per capita

EMISSIONS ANALYZED:

CO_2

DEVELOPING AND IMPLEMENTING APPROACH

As a requirement under the Next Generation Energy Act of 2007, a climate change action plan is to be developed which will:

1. Estimate 1990 and 2005 GHG emissions in the state and make GHG projections for 2015, 2025, and 2050;
2. Identify, evaluate, and integrate a broad range of statewide greenhouse gas reduction options for all emission sectors in the state;
3. Assess costs, benefits, and feasibility of implementing the options;

4. Recommend an integrated set of reduction options and strategies for implementing the options;

5. Estimate the statewide GHG reductions anticipated from implementation of existing state policies;

6. Recommend a system to require the reporting of statewide GHG emissions, identifying which facilities must report, and how emission estimates should be made; and

7. Evaluate the option of exempting a project from the prohibitions contained in section 2w16H.03, subdivision 3, if the project contributes a specified fee per ton of carbon dioxide emissions emitted annually by the project, the proceeds of which would be used to fun permanent, quantifiable, verifiable, and enforceable reductions in GHG emissions that would not otherwise have occurred.

MnDOT itself has not used models or tools to estimate GHG emissions reductions given different scenarios or actions, but Met Council, the MPO for the Twin Cities metropolitan area, has. In its Land Use Planning and Resources Report, the Met Council reported on the development and application of an air quality assessment tool. The spreadsheet-based tool relied on inputs from the regional travel demand model to estimate VMT by community, international and national estimates of how land use changes would affect VMT, and applied MOVES2010a to estimate changes in emissions, including CO2e. The tool included emission estimates from personal vehicles, transit and commercial trucking. The tool was used primarily to examine air quality emissions impacts on different land use scenarios.

Two hypothetical examples were used that assumed different land use concentrations in different communities in the region. Although the tool estimated that travel-related air pollutant levels were lowered for the region (and CO_2e was reduced the most), additional development concentrations generated higher rates of VMT leading to slightly higher emissions in the local area.

LESSONS LEARNED: CHALLENGES AND BENEFITS

One of the lessons MnDOT learned is that fleet change and VMT reductions are not enough to meet the GHG reduction targets. Land use has to be considered a long term solution and user-based strategies such as VMT fees or pay-as-you-go insurance are promising strategies to help close the gap. However, the analysis conducted by Met Council showed that the land use-related impacts on CO_2e emissions would likely be very modest.

NEXT STEPS

MnDOT is investing heavily in strategies to reduce VMT especially in the larger metropolitan areas. A major transitway system has been developed in the Twin Cities with more investment being planned by 2030. Twin Cites is considered the #2 bike friendly city in the country, and a Complete Streets policy has been adopted for appropriate projects. With respect to GHG analysis, there does not seem to be any effort underway to require such analyses for plans or projects, and the GHG emissions reduction strategy focuses on fleet conversion to less GHG emitting vehicles and the implementation of transportation strategies that are expected to reduce VMT (linked to the state performance goals, which measure gallons of gasoline consumed).

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS

BACKGROUND

In November 2008, the Metropolitan Washington Council of Governments (MWCOG) Climate Change Steering Committee completed a comprehensive, multi-sector report with recommended goals to reduce GHG emissions to meet 2005 levels by 2012, 20% below 2005 by 2020, and 80% below 2005 by 2050. The GHG goals focused on absolute CO_2 reductions across all sectors. Work is on-going with sector-specific studies, including transportation, which accounts for about 30% of GHG.

LEVEL OF ANALYSIS:

Regional

METHODS/MODELS USED:

- Mobile6.2

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- N/A

TARGETS:

- Absolute targets, multi-sector
- 2005 levels by 2012
- 20% below 2005 levels by 2020
- 80% below 2005 levels by 2050

EMISSIONS ANALYZED:

CO_2

DEVELOPING AND IMPLEMENTING APPROACH

The National Capital Transportation Planning Board (TPB), the MPO for the Metropolitan Washington region, was responsible for providing on-road mobile source inputs into the National Capital Region's first GHG inventory. The "What Would it Take?" Scenario analysis examined what it would take in the National Capital Region to meet the aggressive regional climate change mitigation goals in the transportation sector and whether any combination of the approximately 40 strategies considered would meet the targets. The initial approach TPB used to estimate GHG emissions was based on its methodology for developing criteria pollutant inventories for air quality conformity. Strategy analysis was based on existing methodologies for analyzing Transportation Emission Reduction Measures (TERMs) for criteria pollutants. The analytical process used by TPB involved the following steps:

1. Creating a baseline inventory of mobile source CO_2 emissions;
2. Developing sources of reduction potential;
3. Identifying potential reduction strategies;

4. Analyzing individual strategies for effectiveness, timeframe for implementation, and cost-effectiveness; and

5. Combining additive strategies to determine different pathways toward approaching or meeting goals.

TPB considered approximately 40 strategies including transportation system management and operations, vehicle and fuel policies, taxation and road pricing, transportation demand management, transit, public education, and bicycle/pedestrian strategies to reduce CO_2 emissions. Each strategy was evaluated for its potential to reduce CO_2 emissions along with the cost effectiveness. Cost effectiveness estimates utilized the latest data on the social cost of carbon, assumed at $21/ton CO_2 in 2010 rising to $45/ton CO_2 in 2050 as per research by the United States Government. Cost estimates were represented in 2007 dollars.

TPB relied on its travel forecasting model, Mobile6.2, and a spreadsheet tool to help estimate the CO_2 impact from increased CAFE standards. A speed curve developed by the University of California, Riverside was also used to analyze strategies intended to improve traffic flow.

LESSONS LEARNED: CHALLENGES AND BENEFITS

Three broad sources of emissions were examined: fleet composition, fuel used, and use of the fleet. The study found that heavy duty vehicles are forecast to account for a growing share of emissions over time as light duty vehicles become more fuel efficient. Lastly, the study found that current travel behavior could benefit from efficiency improvements to reduce CO_2 emissions. For instance, it was forecast that many short trips (under three miles) would be taken by automobile, a portion of which could be shifted to non-polluting modes. Traffic congestion or frequent stop-and-go driving was also a major source of emissions, since CO_2 is quite sensitive to vehicle speeds. Therefore, operational strategies to improve traffic flow were also considered a means to reduce emissions.

For future GHG analysis work, TPB plans to use the MOVES model which is a better tool for GHG forecasting. One limitation of MOVES, however, is the ability to test different vehicle fleet mix and CAFE scenarios.

The results of this analysis showed that eco-driving was one of the most cost-effective strategies for reducing CO_2 emissions in the National Capital Region. In addition to the cost-effectiveness analysis, other strategies like a bike-sharing program were considered worthwhile strategies to address broader planning goals despite limited benefits in CO_2 reduction. Vehicle technology, in particular, further increasing CAFE standards, (for both light duty and heavy duty vehicles) were essential, in addition to pricing strategies, to closing the gap between future business-as-usual trends and regional climate change goals.

NEXT STEPS

Next steps for TPB include refining sector-specific goals and transition to use of MOVES for emissions analysis. TPB's focus on climate adaptation is also growing. TPB is looking into its role in planning for climate change adaptation including strengthening capabilities for managing severe weather events and incorporating adaptation into long range planning.

OREGON DEPARTMENT OF TRANSPORTATION

BACKGROUND

LEVEL OF ANALYSIS:
Statewide, regional
METHODS/MODELS USED:
• GreenSTEP
RELEVANT POLICIES, REGULATIONS, LEGISLATION:
• SB 1059 (2010)
• HB 2001 (2009)
GOALS:
• 10% below 1990 levels by 2020
• 75% below 1990 levels by 2050
EMISSIONS ANALYZED:
CO_2e

Oregon enacted two major state laws in the last few years influencing greenhouse gas reduction planning in Oregon: Senate Bill 1059 (2010) and House Bill 2001 (2009). Under SB 1059, the Oregon Department of Transportation (ODOT) and the Department of Land Conservation and Development (DLCD), in consultation with local governments and other state agencies, is charged with developing tools and guidelines for planning efforts to reduce GHG emissions, and ODOT is charged with the development of a state-level scenario plan, the Statewide Transportation Strategy. Collaboratively, these efforts are known as the Oregon Sustainable Transportation Initiative (OSTI), which is intended to produce a number of work products to help meet state GHG reduction goals. The statewide goals cover the three main GHGs (CO_2, CH_4, and N_2O). Adopted multi-sector goals call for a 10% reduction below 1990 levels by year 2020 and a 75% reduction below 1990 levels by year 2050.

DEVELOPING AND IMPLEMENTING APPROACH

A greenhouse gas reduction Toolkit was developed by ODOT as a component of the OSTI. The Toolkit includes a searchable database of actions and programs with case studies and research-backed estimates of CO_2 emissions reduction potential and cost effectiveness estimates, a summary of GHG models and tools, and a communications guide for talking about climate change.

To evaluate GHG emissions and potential impacts of policies and other factors on travel and transportation sector GHG emissions, ODOT developed a tool called GreenSTEP, or Greenhouse Gas Strategic Transportation Energy Planning Model. GreenSTEP includes household data, travel demand forecasts, fuel consumption, vehicle types (with a current focus on light duty vehicles), and a well-to-wheel component to estimate GHG emissions at a statewide or regional level for the development of scenario plans or other long-range transportation plans.

In May 2012, ODOT released a draft Statewide Transportation Strategy (STS) outlining a path to reducing transportation-related greenhouse gas emissions by 2050. The plan was the result of statewide research and collaboration among state agencies, local governments, industry representatives, MPOs, and others. The STS includes strategies for land use, such as mixed use development and urban consolidation centers, and transportation systems, such as increased transportation options like transit and movement of freight by rail. Technology is a large part of the STS, as is the concept that future transportation users pay the full price of travel decisions (e.g., parking, transit, congestion, etc.). The outcome of the STS vision was measured in terms of GHG emissions, as well as health impacts and changes in household costs. The estimated GHG emissions reduction from the STS was about 60% below 1990 levels by 2050.

LESSONS LEARNED: CHALLENGES AND BENEFITS

Through this process, a number of lessons were learned, including:

- The visioning process and seeking discussions with other agencies and stakeholders were a critical means of establishing the foundation for the STS process.
- Although Oregon is known for its legal and regulatory approach to land use and transportation planning, ODOT officials stressed the importance of not introducing a regulatory framework too early.
- Improvements in vehicle technology and the use of pricing strategies were critical to meeting the greenhouse gas reduction goal for 2050. It was determined that meeting a 75% reduction in GHGs could not be possible without substantial changes in vehicle technology and pricing travel. In fact, even with extensive urban development, technology, pricing, and system optimization

strategies, the plan still fell short of the goal because of challenges in reducing greenhouse gas emissions from the freight market segment.

NEXT STEPS

GreenSTEP is currently being used for state and metropolitan level analysis. A simpler interface is being developed to make the model easier to use by MPO staff. Additional components are also being developed to model GHG emissions from other modes, long distance travel and freight. Following public comment of the Draft Statewide Transportation Strategy, ODOT anticipates finalizing the strategy in Fall 2012.

SACRAMENTO AREA COUNCIL OF GOVERNMENTS

LEVEL OF ANALYSIS:
Regional, Jurisdictional, County Level (Parcel and TAZ-based analysis)
METHODS/MODELS USED:
• Network Simulation Travel Model • GRIP, ICLEI • I-PLACE3S • EMFAC
RELEVANT POLICIES, REGULATIONS, LEGISLATION:
• CA Senate Bill 375
TARGETS:
• Per capita, passenger vehicles • 7% below 2008 levels by 2020 • 16% below 2008 levels by 2035
EMISSIONS ANALYZED:
CO_2 equivalents

BACKGROUND

SACOG is one of 18 MPOs in California and one of the largest four MPOs in the state. Through Senate Bill 375, SACOG is responsible for reducing its regional light-duty vehicle GHG emissions by 7% below 2008 levels by 2020 and 16% below 2008 levels by 2035 on a per capita basis. They are also required to demonstrate how they would reach these targets through the development of a "Sustainable Communities Strategy (SCS)" as adopted through its Metropolitan Transportation Plan.

Local leaders recently approved the $35 billion regional plan including a number of strategies covering land use, transportation, finance and policy, system operations and maintenance, and system expansion.

DEVELOPING AND IMPLEMENTING APPROACH

SACOG initiated their GHG analysis efforts by utilizing a protocol developed in the United Kingdom known as the Greenhouse Gas Regional Inventory Protocol (GRIP). The GRIP tools and processes were assessed in addition to ICLEI's local government protocol to provide assistance early on to member jurisdictions.

In the development of the region's long-range metropolitan transportation plan, SACOG utilized a web-based scenario planning tool called I-PLACE3S. Data was analyzed at the parcel scale in order to assess land use impacts on transportation performance, energy usage, cost efficiency, health benefits (i.e., minutes of physical activity) and climate change. SACOG chose this tool for a number of reasons including its ability to work with parcel level data with flexibility to translate data at the TAZ level, assess a wide variety of planning indicators, create visualizations, and provide 4D functionality. I-PLACE3S was used in combination with the MPO's travel model and utilized EMFAC – consistent with the California Air Resources Board assumptions – to calculate regional GHG emissions.

LESSONS LEARNED: CHALLENGES AND BENEFITS

The spatial analytical capabilities of I-PLACE3S proved to be extremely beneficial in engaging stakeholders and consensus building processes. The process SACOG laid out for smart growth in the region (also known as the "Blueprint Planning Process") became a leading example for other MPOs in the state to follow.

Some of the limitations in using I-PLACE3S, however, included varying assumptions across MPO users and the open-source format of the tool. The assumptions are created in a single set and can often affect multiple MPO users that may need to have differing assumptions. For example, if one MPO needs to change a specific assumption, it may also affect this same assumption for other MPOs using the tool. The tool has evolved from a desktop only program to a web-based semi-open source tool. There is also a fee for data storage and an ArcGIS license is required. Since SACOG is currently the only MPO in California using the tool, the agency is exploring alternative scenario planning tool options, such as UrbanFootprint and Envision Tomorrow, that may provide more flexibility to develop a community of users for collaborative planning with other MPOs. UrbanFootprint, for example, is completely open source and does not require substantial licensing fees.

Although working with data at the parcel level was challenging, the detailed nature of the data was also beneficial because it provided a comprehensive analysis and assessment of broader planning issues, such as environmental justice impacts of strategies. Some of the lessons learned that SACOG addressed or will address in future GHG analysis efforts include changes in modeling time periods and sufficient time allocation for regional level data collection. Previously, SACOG conducted these analyses every five years to line up with the air quality conformity years. However, since enough change was occurring within a shorter timeframe, the modeling years were updated to every three years. Aside from analytical improvements made in the future, in order to effectively implement the strategies laid out in the Metropolitan Transportation Plan, additional incentives and/or guidance may be needed to implement at the general plan level.

NEXT STEPS

SACOG was recently awarded the Smart Growth Council grant to develop regional climate action plan guidance for the region and corresponding member jurisdictions. This guidance will be the first of its kind and will set a path towards more coordinated planning at the MPO and sub-regional levels.

With respect to advancing GHG calculations and implementing strategies within the region, next steps for SACOG will involve the following:

- SACOG currently has five transit priority projects undergoing Environmental Impact Report (EIR) analysis. The EIR findings are anticipated to be available in the next six months;
- In the next SCS process, SACOG will include electric vehicles in forecasts; and

In future planning efforts, SACOG will evaluate waste and water issues.

SAN JOAQUIN COUNCIL OF GOVERNMENTS

BACKGROUND

The San Joaquin Council of Governments (SJCOG) is one of eight California MPOs in the Central Valley. SJCOG is responsible for reducing its regional light-duty vehicle per capita GHG emissions 5% below 2005 levels by 2020 and 10% below 2005 levels by 2035 as adopted by the California Air Resources Board under Senate Bill 375. Like other California MPOs, SJCOG is required to demonstrate how they would reach these targets through the development of a "Sustainable Communities Strategy (SCS)" as adopted through its Regional Transportation Plan (RTP). It is still to be determined, however, whether the adopted targets will apply for the entire Central Valley region collectively or individually for each MPO.

LEVEL OF ANALYSIS:

Regional analysis,
some jurisdictional level analysis

METHODS/MODELS USED:

- CalSEEC
- Blueprint Process
- Smart Growth Cards
- EMFAC2007

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- CA Senate Bill 375

TARGETS:

- Per capita, passenger vehicles
- 5% below 2005 levels by 2020
- 10% below 2005 levels by 2035

EMISSIONS ANALYZED:

CO_2

DEVELOPING AND IMPLEMENTING APPROACH

SJCOG is part of a "Blueprint Integration Project" to integrate smart growth principles into the 46 smaller Valley cities' General Plans and planning policies. As part of SJCOG's Smart Growth Plan, a greenhouse gas inventory was developed to assess baseline conditions for 2005. The multi-sector inventory was developed using the California Statewide Energy Efficiency Collaborative (CalSEEC) community inventory method. CalSEEC is a collaborative effort among the International Council for Local Environmental Initiatives (ICLEI), Local Government Commission, Institute for Local Government, and energy companies like Pacific Gas and Electric, Southern California Edison, and Sempra Energy providing support to cities and counties to help them save energy and reduce greenhouse gas emissions. SJCOG used this tool to develop a multi-sector GHG emissions inventory at the community scale for consistency with existing community action plans also developed with this tool. Other tools and models used to evaluate transportation improvement projects and GHG reduction strategies included a VMT/GHG reduction evaluation model for local agencies and general plans, and Smart Growth Score Cards to evaluate Proposition K transportation improvement projects. To assess reductions in VMT, ITE (Institute of Transportation Engineers) trip generation rates were used, but lowered to account for internal trips, pedestrian trips, and transit trips associated with infill projects. SJCOG will soon use off-model integration analysis tools like RAPIDFIRE to evaluate GHG reduction strategies as part of its Sustainable Communities Strategy.

Transportation accounts for about 44.7% of SJCOG's total emissions. SJCOG's transportation emissions were calculated for both on-road and off-road vehicles and equipment within the county. On-road emissions, accounting for about 95% of total transportation emissions, were calculated using EMFAC2007 and VMT was obtained from the SJCOG RTP. Off-road emissions were calculated using CARB's OFFROAD 2007 model for San Joaquin County. All off-road vehicles were included with the exception of agricultural equipment (which was accounted for in the agricultural sector inventory).

LESSONS LEARNED: CHALLENGES AND BENEFITS

SJCOG is at the beginning stages of evaluating its GHG reduction strategies, but anticipates realizing major benefits from ridesharing programs due to the county's land use and commute patterns.

One of the analytical challenges SJCOG faced in estimating GHG emissions was obtaining localized data. In many cases, the data was collected at the statewide level and allocated based on population. To supplement data gaps, traffic counts were also used. Additional local household surveys are desirable, but collecting such data would impose extra costs.

NEXT STEPS

SJCOG is refining its GHG inventory and forecasts and will embark upon evaluating measures to reduce GHG emissions as part of its next RTP/SCS update. SJCOG also plans to move from using EMFAC2007 to EMFAC2011 in its update process.

TAHOE METROPOLITAN PLANNING ORGANIZATION

BACKGROUND

The Tahoe Metropolitan Planning Organization (TMPO) spans two states (Nevada and California) and five counties. TMPO is responsible for reducing its regional per capita light-duty vehicle GHG emissions 7% below 2005 levels by 2020 and 5% below 2005 levels by 2035 as adopted by the California Air Resources Board under Senate Bill 375. Like other California MPOs, TMPO is required to demonstrate how they would reach these targets through the development of a "Sustainable Communities Strategy (SCS)" as adopted through its Regional Transportation Plan (RTP).

LEVEL OF ANALYSIS:

Regional analysis,
some corridor level analysis

METHODS/MODELS USED:

- Tour-based travel demand model
- Trip Reduction Impact Analysis (TRIA), Carbon Footprint Impact evaluation Toolkit (CarbonFIT)
- EMFAC2007

RELEVANT POLICIES, REGULATIONS, LEGISLATION:

- CA Senate Bill 375

TARGETS:

- Per capita, passenger vehicles
- 7% below 2005 levels by 2020
- 5% below 2005 levels by 2035

EMISSIONS ANALYZED:

CO_2

TMPO's 2035 Draft RTP/SCS was publicly released in April 2012 with a Final RTP/SCS anticipated for adoption in October 2012. Unlike most other MPOs, TMPO has land use planning authority in addition to transportation planning authority. Thus, in addition to transportation demand management strategies and efforts to expand alternative transportation (e.g., regional bicycle/pedestrian network) initiatives, TMPO was also able to include innovative land use strategies, such as development transfers, to further reduce transportation-related GHG emissions in its SCS. To better manage growth and water quality, TMPO is exploring incentives to shift residences in environmentally sensitive zones closer to town.

DEVELOPING AND IMPLEMENTING APPROACH

TMPO analyzed the impact of its SCS measures using a spreadsheet-based tool called the Trip Reduction Impact Analysis (TRIA). VMT inputs were provided through the MPO's tour-based travel model and emission factors were derived using EMFAC2007. Additional models like URBEMIS were used earlier, but only once for the Homewood Ski Resort development project. VMT validation and calibration was made possible through the following data means: vehicle license monitoring, surveys for residents, visitors, and licenses, and annual winter/summer travel mode surveys.

LESSONS LEARNED: CHALLENGES AND BENEFITS

TMPO recognized that although California adopted state-level targets before setting MPO level targets, this is not the case in every state considering GHG emissions. The benefits of having state level targets set first, however, enabled active participation and coordination among the California Air Resources Board, MPOs and smart growth advocates. It also marked the beginning for improved resource/knowledge sharing and consistency in modeling parameters and indicators across the state. Examples included assessment of GHG analysis tools, varying travel model capabilities and sensitivities, and a CARB effort to collect modeling parameters and indicators from MPOs for years 2005, 2008, 2020 and 2035.

Although big steps have already been taken to consider GHG emissions at both the MPO and state levels through the RTP process, it has not been an entirely easy road. One of the biggest challenges for TMPO is the geographic coverage and differing regulatory requirements. The TMPO region includes portions of the states of California and Nevada, and while California requires consideration of GHG emissions in the RTP process, Nevada does not and therefore the availability of and access to certain data has been a challenge.

As far as improving analytical methods, for TMPO and for other MPOs advancing the sophistication of their travel models, moving from a 4-step activity based model to a tour-based model required a steep learning curve. In addition, the spreadsheet analysis tool, although convenient, grew more complex over time. For future analyses, TMPO would consider a non-spreadsheet based tool and would also utilize EMFAC2011 to reflect updated forecast assumptions.

GHG analysis aside, one of TMPO's biggest concerns is how the region will implement the strategies within the SCS/RTP with little or no funding. The MPO would like to explore a local funding source as a more sustainable solution to support implementation of transportation improvements.

NEXT STEPS

At the time of writing, TMPO is currently finalizing its Draft RTP/SCS and anticipates adoption in October 2012. In the near-term, TMPO plans to further explore the appropriate incentive ratio for location transfers and will explore innovative funding sources to ensure successful implementation of its plan.