Non-Criteria Pollutant Requirements and Impacts: Mobile Source Air Toxics and Greenhouse Gas Emissions in a State and Local Transportation Context

Task 4

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DISCLAIMER

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

1. INTRODUCTION

"One of the first laws against air pollution came in 1300 when King Edward I decreed the death penalty for burning of coal. At least one execution for that offense is recorded. But economics triumphed over health considerations, and air pollution became an appalling problem in England." ~Glenn T. Seaborg, Atomic Energy Commission chairman, speech, Argonne National Laboratory, 1969

"Remember when atmospheric contaminants were romantically called stardust? " ~Lane Olinghouse

Non-criteria pollutants, such as mobile source air toxics and greenhouse gases, by practice fall outside the traditional air pollutant approach. To date, there are no State Implementation Plans for greenhouse gases or motor vehicle budgets for acrolein. While these pollutants may one day be encompassed into some or all of the more established air pollution protocols that compromise the national ambient air quality standards, today they stand addressed and yet still apart from their heavily regulated counterparts. Yet this difference does not imply that greenhouse gases and air toxics are less important or that they will not play a bigger role in the air quality regulations of tomorrow. However, this current position outside of traditional air quality approaches heightens the inconsistency and perhaps ambiguity with which transportation and air quality professionals address these emissions.

This technical memorandum evaluates the implications, policies and actions surrounding mobile source air toxics and greenhouse gases. Emissions mitigation measures are identified along with federal, state and local efforts to reduce or address emissions. In the last chapter, options and considerations are provided for reducing air toxics and greenhouse gases.

The introductory quotes above provide a context for non-criteria pollutants for two reasons. First, draconion laws, extreme regulations or dictatorial approaches do not effectively address air quality issues. Greenhouse gases and air toxics are new to the regulatory environment and some have feared that mandatory approaches to these pollutants will damage our economy or threaten our quality of life. This technical memo focuses on viable methods to reduce emissions of the pollutants based on science and studied policy options. As the second quote depicts, our perspective and approach to air pollution changes through time. As new research and experience provides fresh knowledge regarding pollutants, our outlook and approach evolves. Since MSAT and GHG emissions are comparatively new to air quality management, society's viewpoint and stance on controlling these emissions is still evolving. This technical memo reflects the current state of assessment.

2. MOBILE SOURCE AIR TOXICS

Mobile Source Air Toxics (MSATs) are a subset of air toxic pollutants that are associated with motor vehicles and nonroad sources, including aviation, marine and locomotive. MSATs can be released through the evaporation of fuel, as is the case with benzene, or through exhaust emissions. Like criteria pollutants, MSATs are linked with adverse public health consequences. Unlike ozone, particulate matter, carbon monoxide, lead and other criteria pollutants, the scientific foundation for establishing quantitative limits on atmospheric concentrations contains gaps and uncertainty that have prevented the establishment of ambient MSAT standards. However, MSAT quantification issues have not dampened the linkage between these toxics and public health consequences. Nor has it prevented EPA from issuing regulations to limit MSAT emissions based on protecting public health. The scientific uncertainty has also not shielded MSATs from the transportation process. As chronicled in this report, MSATs provide an alterative method of pollutant management that differs from traditionally regulated pollutants.

EMISSIONS AND PUBLIC HEALTH

EPA defines toxic air pollutants, or hazardous air pollutants (HAPs), as "pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects". The Clean Air Act has identified 187 toxic air pollutants in addition to diesel particulate matter (DPM). EPA's National-Scale Air Toxics Assessments (NATA) program released its most recent completed estimations on emissions, concentrations and risks for 1999 and determined that mobile sources account for approximately 44% of outdoor toxic air emissions and almost half the cancer risk.[1]

EPA has undergone two significant rulemakings to address HAPs from mobile sources. In 2001, the agency identified 21 mobile source air toxics (MSATs) in a rulemaking that set new performance standards for gasoline fuel to reduce toxic emissions. The 2001 effort also included

[1] Federal Register. "Control of Hazardous Air Pollutants From Mobile Sources: Final Rule," U.S. EPA, 72: 8428-8476.

a plan for continued research and analysis on MSATs.[2] The result of that research culminated in a list of six priority MSATs (see Table 1) and a second rulemaking in 2007. This latest rulemaking sets benzene standards for gasoline, reduces non-methane hydrocarbon emissions (which includes many MSATs) from new gasoline-fueled passenger vehicles, and limits hydrocarbon emissions from portable fuel containers.[3]

Table 1. High Priority Mobile-Source Air Toxics (MSATs)

Mobile Source Air Toxic	Mobile Source	Health Effects
Acetaldehyde	Acetaldehyde is a product of incomplete combustion and can be formed secondarily when gasoline and diesel exhaust react with the atmosphere.	Classified by EPA as a probable human carcinogen. The primary acute effects include irritation of the eyes, skin, and respiratory tract.
Acrolein	Acrolein is a product of incomplete combustion and can be formed secondarily when gasoline and diesel exhaust react with the atmosphere.	Classified by EPA as a possible human carcinogen. Acute exposure results in upper respiratory tract irritation and congestion.
Benzene	A component of gasoline, benzene is emitted from vehicles as unburned fuel or as vapor when gasoline evaporates.	Classified by EPA as a known human carcinogen. Noncancer effects to chronic exposure include blood disorders and depression depressed lymphocyte counts.
1,3- Butadiene	1, 3-Butadiene is a product of incomplete combustion.	Classified as a human carcinogen by inhalation and may have reproductive and developmental effects.

2 U.S. EPA, “Control of Emissions of Hazardous Air Pollutants from Mobile Sources. Office of Transportation and Air Quality,” December 2000, EPA420-F-00-055.

[3] U.S. EPA. "Control of Hazardous Air Pollutants from Mobile Sources: Final Rule to Reduce Mobile Source Air Toxics." http://www.epa.gov/otaq/regs/toxics/420f07017.htm, accessed October, 2008.

Mobile Source Air Toxic	Mobile Source	Health Effects
Formaldehyde	A product of incomplete combustion and can be formed secondarily when mobile source exhaust reacts with the atmosphere.	A probable human carcinogen. Acute exposure can result in upper respiratory effects.
Diesel Particulate Matter and Diesel Exhaust Organic Gases (DPM + DEOG)	Composed of many hazardous air pollutants, DPM + DEOG is a mixture of particles and gases and is a byproduct of incomplete combustion.	A cancer risk has not been assigned, but EPA's health assessment[4] of diesel exhaust from engines built prior to mid- 1990's concluded that long-term (i.e., chronic) inhalation exposure is likely to pose a lung cancer hazard.

Source: U.S. EPA (December 2000). Technical Support Document: Control of Emissions of Hazardous Air Pollutants from Motor Vehicles and Motor Vehicle Fuels. Office of Transportation and Air Quality. EPA420-R-00-023.

Both the 1999 NATA results and EPA's most recent MSAT rulemaking place particular importance on benzene. The 1999 NATA results found that benzene contributed 25% of the average individual cancer risk among the 177 HAPs evaluated and that mobile sources accounted for 68% (49% onroad and 19% nonroad) of benzene's emissions inventory. Due to EPA's regulatory and voluntary programs, the agency estimates that mobile source related benzene emissions will decrease by about 60% between 1999 and 2020.[5]

Diesel particulate matter and diesel exhaust organic gases (DPM + DEOG) are also singled out but treated differently in NATA evaluations and MSAT rulemakings. EPA has not assigned a cancer risk estimate for diesel exhaust due to insufficient data. Nonetheless, the agency's health assessment concludes that diesel exhaust does pose a cancer risk, depending on exposure.[6] In addition, the 1999 NATA assessment found that "diesel exhaust is among the substances…that pose the greatest relative risk" because of sufficient ambient air exposure and studies suggesting a link between exhaust and increased lung cancer. In contrast to EPA, California has assigned a cancer risk to diesel exhaust and the California Air Resources Board

[4] U.S. EPA, "Health Assessment Document for Diesel Exhaust," Office of Research and Development, 2002. EPA/600/8-90/057F.

[5] U.S. EPA. "Technical Factsheet: National-Scale Air Toxics Assessment for 1999, Estimated Emissions, Concentrations and Risk." http://www.epa.gov/ttn/atw/nata1999/natafinalfact.html, accessed October, 2008.

[6] U.S. EPA, "Health Assessment Document for Diesel Exhaust," Office of Research and Development, 2002, EPA/600/8-90/057F.

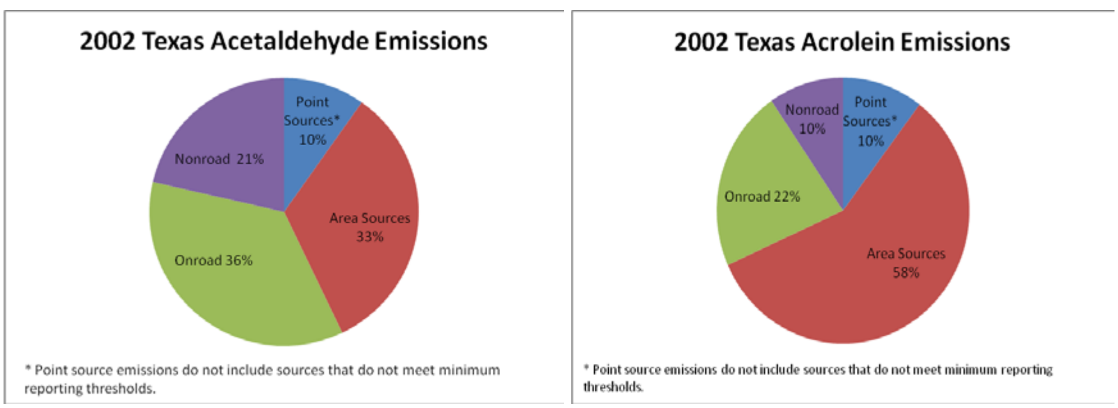
estimates that “about 70 percent of the cancer risk that the average Californian faces from breathing toxic air pollutants stems from diesel exhaust particles.”[7]

MSATs pose a greater health risk to certain populations. Populations that spend a lot of time in their vehicle or live or work near major roadways will have more exposure to MSATs and thus higher risk. People that live in homes with attached garages could experience approximately twice the exposure to benzene emissions. As with particulate matter, MSATs may pose a greater risk to some susceptible and sensitive populations, such as pregnant women, children, the elderly or the sick.

Texas MSAT Inventory

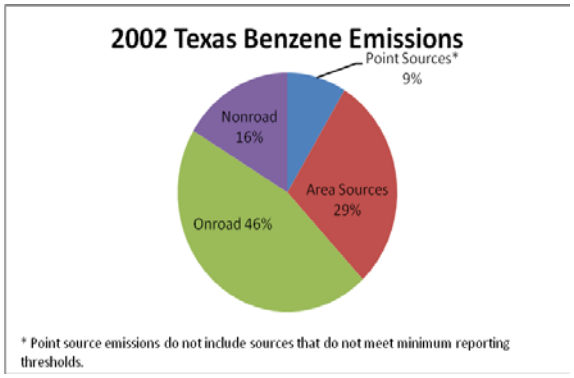
The priority MSATs identified by EPA come from many different sources. The charts in Figure 1 reflect statewide inventory data for 2002 and were obtained from the Texas Commission on Environmental Quality. [8]

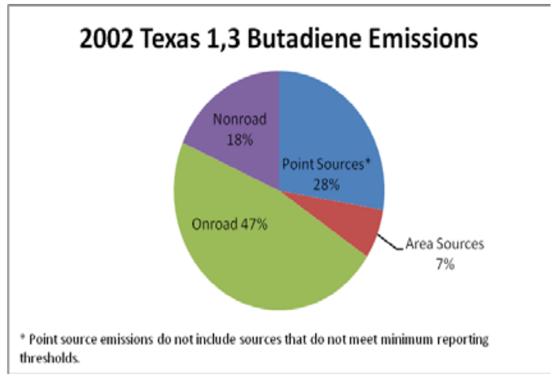
Figure 1. Priority MSAT Emissions Inventory

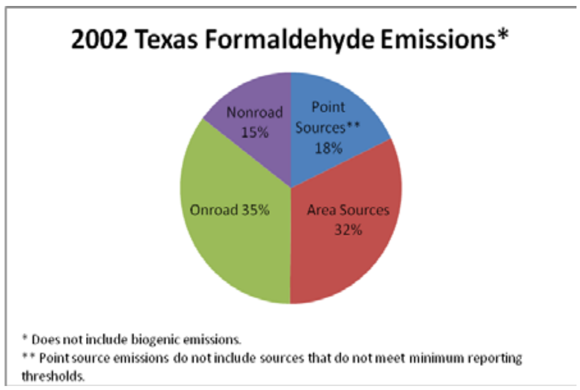


[7] California Office of Environmental Health Hazard Assessment. "Health Effects of Diesel Exhaust," http://www.oehha.ca.gov/public_info/facts/dieselfacts.html, accessed November, 2008.

8 An alternative data source is EPA’s National Emissions Inventory (NEI) which provides HAP estimates for point, nonpoint and mobile sources. Updated every three years, NEI’s 2005 data is available in limited form, and only the 2002 data is available and easily searchable through EPA’s AirData website (http://www.epa.gov/oar/data/index.html).







The 2002 Texas inventories depict mobile source contributions as accounting for at least one-third of priority MSAT emissions. Of the mobile source contributions, the onroad sector accounts for roughly two-thirds of the emissions. Biogenic emissions, such as those from vegetation, are not included in these charts. Of the priority MSATs, formaldehyde is the only toxic with significant biogenic sources and data was omitted for reasons of uncertainty.

Houston may have a significantly different emissions inventory profile than the statewide data. EPA showcased Houston as a case study in its 2002 report, *Example Application of Modeling Toxic Air Pollutants in Urban Areas*.[9] Utilizing monitor data with the Industrial Source Complex (ISCST3) and the Emissions Modeling System for Hazardous Pollutants (EMS-HAP) models, the findings differ from the 2002 statewide emissions inventories depicted above. While the EPA report looked at several HAPs, the only priority mobile source toxics examined were formaldehyde and benzene. Mobile sources contributed 81% of the city's formaldehyde

9 U.S. EPA, "Example Application of Modeling Toxic Air Pollutants in Urban Areas," Office of Air Quality Planning and Standards, 2002, EPA-454/R-02-003.

emissions, compared to 50% of statewide emissions. Unlike statewide emissions, Houston's nonroad sector contributed the largest share at 46% of all emissions. The City's port and marine activity, which often use higher emitting fuel and engines, could be one contributing factor to account for the difference. For benzene, Houston's contributions did not differ significantly from the statewide picture. Mobile sources' estimated benzene contributions totaled 65% for Houston and 62% statewide, with the onroad sector accounting for the largest contribution (41% and 46% respectively).

Monitoring Data

Several types of ambient air monitors can collect MSAT data which is typically used to support the development of models. However, monitoring data can also be used to examine air toxics in transport, dispersion and deposition. EPA's AirData website provides monitoring data for all of the priority MSATs except DPM + DEOG. There are 139 monitors in 54 sites in Texas collecting data on at least one of the five priority MSATs (see Table 2 below). Monitoring sites for each MSAT are typically dispersed in a variety of settings throughout the state (i.e. urban, rural, and suburban), but Houston has some of the best monitoring data of any area in the country. The City is home to two of 23 National Air Toxic Trends Stations (NATTS) and TCEQ has housed its four Automatic Gas Chromatograph (AutoGC) monitoring stations in Houston and Corpus Christi. These AutoGC stations collect concentration data for several HAPs, including benzene and 1, 3 butadiene.[10]

Table 2. Monitoring Stations in Texas Collecting MSAT Data (2007-2008)

MSAT	Number of Monitors*	Number of Sites
Acetaldehyde	7	7
Acrolein	10	7
Benzene	48	47
1,3- Butadiene	48	47
Formaldehyde	7	7

Source: U.S. EPA. "AirData," http://www.epa.gov/air/data/repsst.html, accessed October 2008.
* Includes official and unofficial monitors.

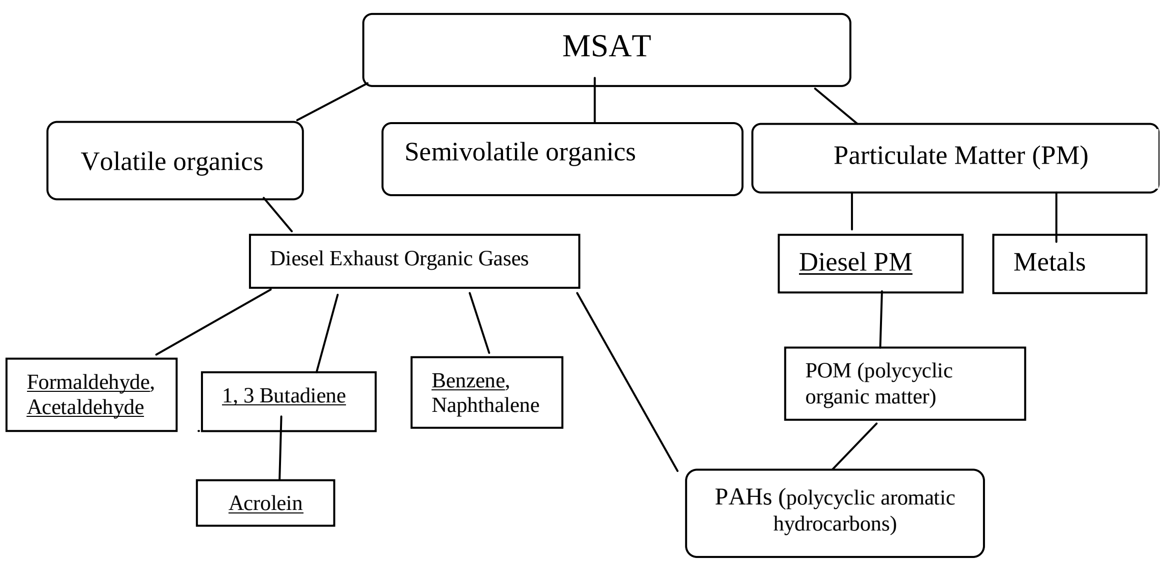
10 Texas Commission on Environmental Quality, "Air Pollution Data Collected by Automated Gas Chromatographs (AutoGCs)," http://www.tceq.state.tx.us/compliance/monitoring/air/monops/agc/autogc.html, accessed May, 2009.

MSATs and Criteria Pollutants

Air toxics are interrelated with criteria pollutants or their precursors (see figure 2). Volatile Organic Compounds (VOCs) are a precursor to ozone and include many MSATs. The criteria pollutants PM_{10} and $PM_{2.5}$ are subclasses of particulate matter found in DPM + DEOG. Therefore, reductions in either PM or VOCs will generally have air toxic benefits and vice versa.

The particulate matter found in diesel exhaust has been a target for emissions reductions in several efforts to comply with National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ and PM_{10}. El Paso County is the only area in Texas that does not meet current PM standards and is in nonattainment for PM_{10}. Several federal rules will take effect to reduce DPM from mobile sources over the coming decades. By 2020, DPM from onroad sources is expected to be reduced 94% from 1990 levels. EPA's regulations for the nonroad mobile sector are expected to reduce more than 85% of nonroad DPM from year 2000 levels.

Figure 2. Relationship between MSAT and Diesel-Related Compounds.



Source: Zietsman, J., M. Farzaneh, et al, "Emissions of Mexican-Domiciled Heavy-Duty Diesel Trucks Using Alternative Fuels", Texas Transportation Institute, College Station, (2007).

Public Health Impact and Uncertainty

There is little consensus on the risk levels that MSATs pose on public health. California, the EPA and many community or environmental groups have highlighted the probable health impacts of MSATs, while other scientists and the transportation community has remained uncertain as to the level of risk that MSATs pose on public health. Unlike criteria pollutants, there are no ambient air quality standards for MSATs that would clarify the level of ambient concentrations that pose an unacceptable risk to human health.

The transportation community's concern about the level of uncertainty regarding MSATs health effects was largely confirmed in a recent report by the Health Effects Institute (HEI). HEI is an independent non-profit research organization funded by EPA and the motor vehicle industry. The report reviewed the exposure and health effects literature of the priority MSATs with the exception of diesel exhaust. The report included naphthalene and polycyclic organic matter (POM). Naphthalene is a polycyclic aromatic hydrocarbon (PAH) emitted through fuel combustion and evaporation. POM is a mixture of chemicals, including PAHs. The report concluded that there were many gaps in the research leading to uncertainties in the link between human health, exposure from ambient air and mobile source contributions to ambient concentrations. In short, the scientific research is not yet available to quantify the mobile source emissions levels that pose a public health risk.[11]

Rather than focus on ambient air exposure, many community and environmental groups have focused on near roadway exposure and concentrated levels of pollutants. For example, opposition to the Katy Freeway in Houston from groups like "Mothers for Clean Air" often cited near roadway air pollution impacts on vulnerable populaitons.[12] Transportation projects have garnered considerable attention as possible "hot spots" and notable projects have been challenged through the NEPA process by community and environmental groups concerned about a transportation project's potential to create elevated near-roadway exposure to air toxics. Several studies have shown elevated levels of pollutants near roadways, including a study commissioned by TCEQ whose draft results showed elevated concentrations of pollutants near roadways fall to background levels exponentially with distance.[13]

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[11] HEI Air Toxics Review Panel, "Mobile-Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects," Health Effects Institute Special Report 16, Boston, MA, 2007.

[12] Mothers for Clean Air, "Clearing the Air Newsletter," Summer 2004, vol. 7, issue 1, http://www.mothersforcleanair.org/newsletters/NewsletterSummer04.pdf, accessed April 2009.

[13] David Allen, A. DenBleyker, et al, "Draft Report: Air Pollutant Concentrations Near Roadways," Submitted to Texas Commission on Environmental Quality, 2007.

The challenge with quantifying the health impacts of MSAT emissions is that formal health risk assessments are the only way to scientifically link the toxic emissions from transportation projects with estimated public health impacts. Such assessments are complex, require sophisticated tools, have large data requirements, necessitate a high degree of technical effort and inherently cannot establish causality. Many in the transportation community, including FHWA and AASHTO, have asserted that the necessary tools to make such assessments are unreliable, imprecise, too uncertain or are not available. The quantification challenges will be discussed in detail below. However, some community groups have asserted that the health, environmental and social impacts of transportation should be analyzed and mitigated despite any difficulties in analysis.[14]

MSAT ANALYSIS

Air toxics are not subject to a National Ambient Air Quality Standards (NAAQS) and therefore state governments are limited in regulatory approaches to air toxics. While there has been significant research on the health effects of MSATs, considerable uncertainty remains regarding the quanitity and exposure rates from mobile sources that pose an unacceptable public health risk.[15] This lack of federal and scientific consensus prevents the establishments of NAAQS standard for mobile source air toxics. Nonetheless, community concerns over HAP emissions have affected major transportation projects and the transportation community is often asked to address air toxic issues in the NEPA process. FHWA has provided Interim Guidance on the level of MSAT analysis that is appropriate for NEPA processes.

However, there has been much debate regarding the impact of MSATs, the appropriate levels of analysis needed for different types of transportation projects, analysis methodologies and the availability of tools needed for analysis. The widening and improvements of US 95 in Clark County, Nevada, is an example where an environmental group legally challenged the project. The controversy resulted in construction delays and a lawsuit settlement between FHWA and the Sierra Club to conduct an on-going study on the near roadway effects of

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[14] Palaniappan, M., S. Prakash, et al, "Paying With Our Health: the Real Cost of Freight Transport in California," I. Hart, Pacific Institute, 2006.

[15] HEI Air Toxics Review Panel, "Mobile-Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects," Health Effects Institute Special Report 16, Boston, MA, 2007.

MSATs.[16] Other examples where there have been legal challenges citing MSAT concerns include the Katy Freeway, Vermont's Chittendon County Circumferential Highway and New Hampshire's I-93.[17] To date, the courts have upheld challenges to FHWA's guidance regarding MSAT analysis.

Without an ambient air quality standard, formal health risk assessments are the only quantitative method for *directly* linking a transportation project's impact on MSAT emissions to expected human health effects. Formal risk assessments involve a complex array of models and analysis that follow four quantification steps:

1. emissions (usually EPA's MOBILE or NMIM models);
2. ambient concentrations (dispersion models);
3. human exposure modeling;
4. health impacts.[18]

Formal health risk assessments often require expertise found outside transportation agencies and can be expensive and time consuming.

FHWA has asserted that the vast majorityof transportation projects do not require a formal risk assessment and would not benefit from such analysis.[19] The agency maintains that the technical tools needed for rigorous analysis are not available or complete and that the uncertainties inherent in current analytical methods and tools are too great at the project level to be reliable. Moreover, the transportation community has argued that EPA regulations resulting in the declining MSAT emission rates make such emissions more immune to VMT increases and project related emissions. FHWA analysis in Figure 3 demonstrates decreases in MSAT emissions despite a 64% increase in VMT.

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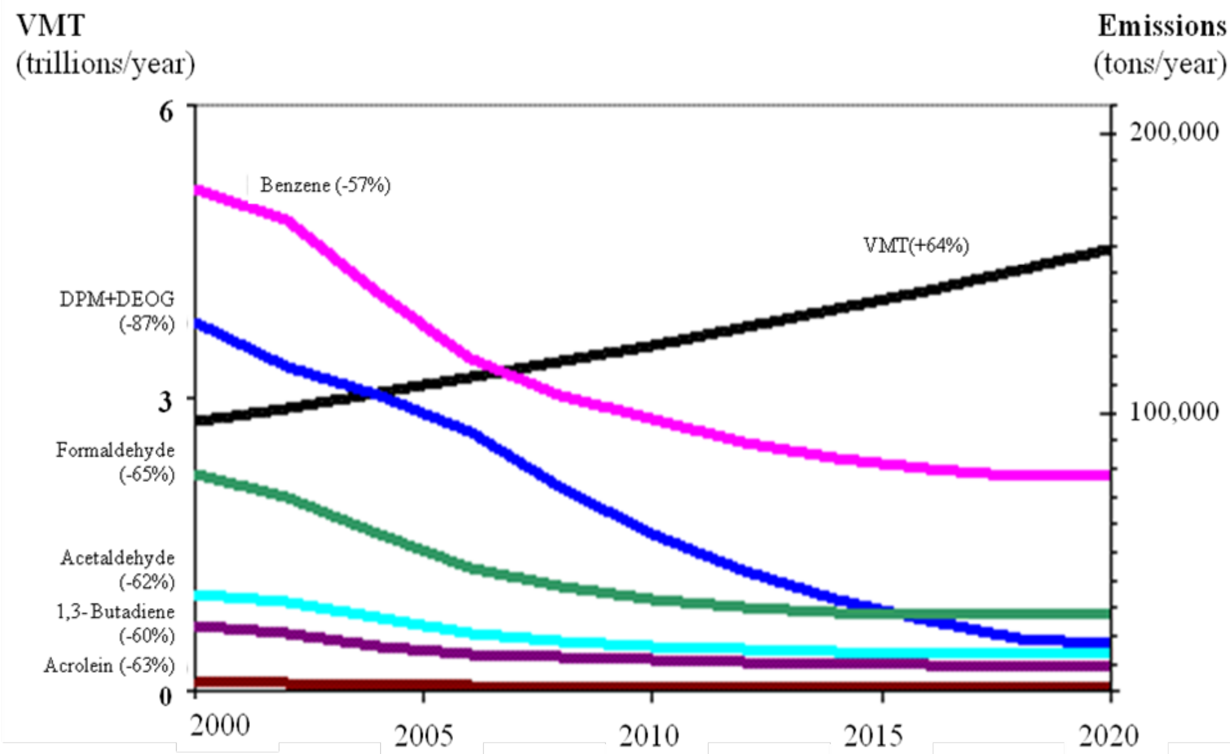
[16] FHWA, "The National Near Roadway MSAT Study," http://www.fhwa.dot.gov/environment/airtoxicmsat/index.htm, accessed October, 2008.

[17] FHWA, "Air Quality Issues on Highway Projects," Presentation by April Marchese, June 2006.

[18] U.S. EPA, "Technology Transfer Network: FERA (Fate, Exposure, and Risk Analysis)," http://www.epa.gov/ttnmain1/fera/, October, 2008.

[19] American Association of State Highway and Transportation Officials (AASHTO), Meeting Minutes for the Air Quality Subcommittee. AASHTO Annual Conference, La Jolla, CA, 2006.

Figure 3. U.S. Annual Vehicle Miles Traveled (VMT) vs. MSAT, 2000-2020



Notes: For on-road mobile sources. Emissions factors were generated using MOBILE6.2. MTBE proportion of market for oxygenates is held constant, at 50%. Gasoline RVP and oxygenate content are held constant. VMT: Highway Statistics 2000, Table VM-2 for 2000, analysis assumes annual growth rate of 2.5%. "DPM + DEOG" is based on MOBILE6.2-generated factors for elemental carbon, organic carbon and SO4 from diesel-powered vehicles, with the particle size cutoff set at 10.0 microns.
Source: Federal Highway Administration, "Memorandum: Interim Guidance on Air Toxic Analysis in NEPA Documents," February 3, 2006.

On-going research and upcoming tools may help mitigate some of the debate regarding MSAT analysis in future years. In the meantime, the transportation community has provided guidance on what level of analysis is needed currently for NEPA processes.

NEPA and MSAT Analysis

FHWA released Interim Guidance in 2006 on when and how to incorporate MSATs into the NEPA process for highways. [20] The agency offers three options for analysis based on the potential for MSAT emissions.

[20] Federal Highway Administration, "Memorandum: Interim Guidance on Air Toxic Analysis in NEPA Documents," February 3, 2006.

1. Projects with no meaningful potential for MSAT effects were exempt for addressing MSATs. Examples include projects that are exempt from conformity (under 40 CFR 93.126), excluded from NEPA under 23 CFR 771.117, or are expected to have no meaningful impacts on traffic volumes or fleet make up.
2. The second option is reserved for projects with a low potential for MSAT effects that do not substantially add capacity or emissions. These projects can take a qualitative approach.
3. Lastly, projects that have a high potential for MSAT effects are defined as being near populated areas or vulnerable populations (such as children, the elderly and infirmed) and either concentrating diesel emissions in a single location or significantly adding capacity (Annual Average Daily Traffic (AADT) levels of 140,000 or more by the design year). These projects should be "rigorously assessed" for MSAT impacts.

In a March 2007, a NCHRP report conducted on behalf of American Association of State Highway and Transportation Officials (AASHTO) expanded the levels of analysis to five.[21] Summarized in Table 3, increased levels of assessment levels call for more rigorous and complex analysis. Each assessment level builds on the analysis recommended for the previous level.

At the base level of analysis suggested for level 2 and higher, FHWA guidance states that a *qualitative* approach "would compare, in narrative form, the expected effect of the project on traffic volumes, vehicle mix, or routing of traffic, and the associated changes in MSATs for the project alternatives, based on VMT [vehicle miles traveled], vehicle mix, and speed".[22] FHWA expects that most transportation projects requiring MSAT analysis would fall into this level 2 category. A report with examples and methodology provides further guidance for evaluating MSATs among transportation using traffic data and MOBILE6.2. In the methodology, priority

[21] Carr, Edward L., David A. Ernst, et. al. "Analyzing, Documenting, and Communicating the Impacts of Mobile Source Air Toxic Emissions in the NEPA Process," Prepared for the American Association of State Highway Transportation Officials (AASHTO), Fairfax, VA, March 2007.

[22] FHWA, "Memorandum: Interim Guidance on Air Toxic Analysis in NEPA Documents," February 3, 2006.

MSAT emissions are calculated three transportation scenarios taking into account changes in traffic volume and characteristics, among other factors. [23]

Table 3. MSAT Analysis Recommendations for NEPA
(Compiled from NCHRP 25-25 Task 18, ICF International)

Assess-ment Level	Level of Analysis	Determinations and/or Thresholds	Examples of Projects
1	None	Projects that qualify as categorical exclusion under 23 CFR 771.117(c)	Activities which do not involve or lead directly to construction, such as planning and technical studies; grants for training and research programs. Bike and pedestrian paths or facilities and many other projects.
2	Qualitative	Projects with activity thresholds that are: >40,000 AADT for an intersection, >100,000 AADT for an arterial, >125,000 AADT for a freeway or >750 idling vehicle-hours per day for heavy-duty vehicles.	Typically operations or safety improvements with no new substantial increases in capacity.
3	Quantitative Emissions Assessment	Projects that exceed the activity thresholds listed in level 2	Major intermodal freight facilities and highway projects which add or create new capacity above the thresholds listed for Level 2. Not recommended for small projects.
4	Quantitative Air Toxic Risk Assessment	Projects that exceed the activity thresholds listed in level 2, have the potential to affect sensitive populations (schools, daycare, healthcare, etc.) or where MSATs were identified as a concern in the scoping process.	Major transportation projects likely to concentrate MSAT emissions in populated areas.
5	Quantitative Exposure Assessment	In addition to the determination and thresholds of level 4, these projects have local information available on nearby population and human activity levels.	Major transportation projects likely to concentrate MSAT emissions in populated areas, with close proximity to schools, hospitals, nursing homes or other facilities catering to sensitive populations.

EPA and FHWA recommend MOBILE6 models for onroad air toxics emissions information. For nonroad emissions, EPA recommends the National Mobile Inventory Model (NMIM), which provides pollutant inventories for the six primary MSATs along with 27

[23] Claggett, M. and T. L. Miller, "A Methodology for Evaluating Mobile Source Air Toxic Emissions Among Transportation Project Alternatives," Federal Highway Administration, www.fhwa.dot.gov/environment/airtoxic/, accessed November 2008.

additional HAPs. NMIM runs EPA's MOBILE6 and NONROAD models and provides inventories down to the county level. NMIM will not estimate HAPs for CNG fueled vehicles.

Level three analyses quantitatively examines the relative impact of various proposed actions on priority MSAT emissions, taking into account background concentrations, national emission trends and the limitations in the tools currently available.

The use of air dispersion models is recommended for level four analyses to examine the cumulative MSAT concentrations from various project alternatives. The report recommends the following models based on project type and examines their strengths and weaknesses: CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, and ISC3.

Level five analyses builds exposure assessment techniques onto air dispersion models. Models such as EPA's HAPEM6 (Hazardous Air Pollutant Exposure Model) or TRIM (Total Risk Integrated Methodology) help translate air pollutant concentrations into human exposure and resulting risk estimates (in the case of TRIM). Transportation agencies may want to request assistance from health or environmental organizations with these more involved levels of complex analysis.

The NCHRP report also provides suggestions on how to communicate MSAT emissions and findings. Human health risk assessments require careful interpretation and communication with the public due to the inherent uncertainties in the analysis. Uncertainty in the data include emissions quantification, outdated background concentration data, inconsistency in cancer unit risk values and reference concentration levels (between EPA and California) and linking exposure levels to health effects. These uncertainties are often documented in NEPA analyses in order to comply with CEQ regulations (40 CFR 1502.22) regarding incomplete or unavailable information, but must also be carefully communicated with the public.

Hot-Spot Analysis and Conformity

Areas that are in nonattainment status for PM may have to perform a qualitative hot-spot analysis for transportation conformity. Hot-spot analysis examines emissions on a smaller scale than normal conformity determinations and is defined as "an estimation of likely future localized $PM_{2.5}$ or PM_{10} pollutant concentrations and a comparison of those concentrations to the relevant air quality standards." [24] Certain highway and transit projects that involve significant levels of diesel vehicle traffic or other projects of air quality concern could qualify for the analysis. Currently, the County of El Paso is the only Texas area in PM nonattainment.

MSAT EMISSIONS MITIGATION

Many of the strategies employed to reduce criteria pollutants will have air toxics benefits. The one exception may be some alternative fuels, although definitive studies are still needed to clarify the impacts of most alternative fuels on toxic emissions. Generally, strategies for reducing air toxic emissions and impacts can be categorized into cleaner engines, VMT reduction and traffic management. Road design options are being studied as a potential method of reducing public exposure to transportation emissions.

MSATs and Alternative Fuels

While alternative fuels are a popular mitigation strategy for some pollutants, their overall impacts on MSATs is largely unstudied, inconclusive or conflicting. In many cases, use of an alternative fuel will results in a decrease in some air toxics and an increase in others. For example, EPA's Regulatory Impact Analysis for the Renewable Fuel Standard Program estimates that 10% ethanol decreases benzene (25%) and 1, 3-butadine (13%) but increases formaldehyde (7%) and acetaldehyde (157%).[25]

Biodiesel use is expected to generally reduce overall toxics when blended with diesel fuel, but the data is scant and inconclusive when examining individual toxics. EPA's analysis of biodiesel expects the fuel to reduce acetaldehyde and formaldehyde emissions. However, in a TTI study that tested heavy-duty diesel trucks, no consistent decrease in acetaldehyde emissions was detected with the use of B20 (20% biodiesel, 80% USLD).[26] EPA expects that biodiesel use

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[24] U.S. EPA and FHWA, "Transportation Conformity Guidance for Qualitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas," March 2006, EPA420-B-06-902.

[25] U.S. EPA, "Regulatory Impact Analysis: Renewable Fuel Standard Program," Office of Transportation and Air Quality**,** Chapter 3, Page 153, April 2007.

[26] Zietsman, J., M. Farzaneh, et al. "Emissions of Mexican-Domiciled Heavy-Duty Diesel Trucks Using Alternative Fuels," Texas Transportation Institute, College Station, Texas, 2007.

would either result in no change of acrolein emissions or a small reduction. Biodiesel's effects on benzene and 1, 3- butadiene is undetermined according to EPA.[27]

Similarly, there is considerable conflicting information available regarding overall air toxic impacts from natural gas. While natural gas use is associated with reduced benzene levels, it is also linked with increased levels of formaldehyde and acetaldehyde. CNG has been associated with increased levels of ambient formaldehyde levels in Brazil[28] and studies have found higher levels of acetaldehyde, acrolein and benzene emissions among natural gas vehicles when compared with diesels outfitted with particulate filters.[29] However, the use of catalysts with natural gas vehicles can reduce air toxic emissions impacts.

Cleaner Vehicles

Due to emissions standards, older, less regulated vehicles are assumed to produce more toxics than newer, cleaner vehicles. Particulate matter reductions are directly linked with reductions in air toxics. Therefore, cleaner PM standards for newer engines mean that repair, retrofit and replacement programs will positively reduce MSAT emissions. While there are plenty of programs focused on light-duty and gasoline vehicles (inspection and maintenance, low-income repair and replacement programs), air toxic considerations have largely focused on heavy-duty diesel sources. Compared to gasoline, diesel exhaust is particularly high in particulate emissions which contain many toxics.

There are a suite of programs and approaches for reducing diesel emissions that include:

- Idle reduction;
- Vehicle replacement;
- Engine replacement;
- Low sulfur fuels; and
- Retrofit technologies.

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[27] U.S. EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report," Office of Transportation and Air Quality, October 2002, EPA420-P-02-001.

[28]HEI Air Toxics Review Panel, "Mobile-Source Air Toxics: A Critical Review of the Literature on Exposure and Health Effects," Health Effects Institute, Special Report 16, 2007, Boston, MA.

[29] California Air Resources Board, "CARB's Study of Emissions from In-Use CNG and Diesel Transit Buses," October 2005, http://www.arb.ca.gov/research/cng-diesel/cng-diesel.htm, accessed October, 2008.

EPA and CARB have retrofit technology verification programs that confirm the emissions performance of technologies for use in the existing fleet. Their list of approved technologies include diesel particulate filters which reduce PM by 85% or more and come as a standard feature of 2007 and later model year heavy duty diesel trucks. Diesel oxidation catalysts generally reduce particulate matter by 20-30% depending on the technology and fuel used.[30,31]

Assuming that fuel economy benefits translate to reduced MSAT emissions, another strategy for both diesel and gasoline emissions reductions are hybrid and/or electric vehicles. Traditional hybrids can see fuel economy improvements of 30-60% when compared to conventional gasoline models and are available for light-duty and heavy duty diesel trucks and buses.[32] Plug-in hybrids are expected to improve emissions performance by offsetting conventional fuel use with electricity. Studies have demonstrated that plug-in hybrids have an emissions benefit even after accounting for emissions from electric generation.[33] While plug-in hybrids are not currently commercially available, they are on the horizon. General Motors expects to release the first mass produced plug-in hybrids with the Saturn Vue and the Chevy Volt in 2011 and Toyota plans to release a plug-in Prius in 2010. EPA has developed hydraulic hybrid prototypes for SUVs and an urban delivery truck that it hopes will be a viable commercial option for vehicles with drive cycles that include a lot of stop and go driving. The Department of Energy's National Renewable Energy Laboratory (NREL) is working on battery technology to improve the range, cost and utility of plug-ins.

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[30] California Air Resources Board, "ARB's Diesel Emission Control Strategies Verification," December, 2008, http://www.arb.ca.gov/diesel/verdev/verdev.htm, November, 2008.

[31] U.S. EPA, "Diesel Retrofit Technology Verification," http://www.epa.gov/otaq/retrofit/index.htm, accessed October, 2008.

[32] U.S. EPA, "Technical Highlights of Plug-in Hybrid Electric Vehicles," Office of Transportation and Air Quality, October 2007, EPA420-F-07-048.

[33] Electric Power Research Institute, "Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options," 2001, Palo Alto, CA, 1000349.

Reductions in Vehicle Miles Traveled

Programs that reduce VMT will correspondingly reduce MSAT emissions. Examples of such programs include efforts that increase public transit use, commuter reduction programs, land use and smart growth policies, taxation and pricing policies for single occupancy vehicle use. For example, the Best Workplaces for Commuters program reduces VMT by recognizing employers that incentivizing the use of commuting alternatives. Employers under the program can subsidize transit trips and vanpools, provide carpool matching and allow employees to telecommute.[34] Some communities have sought to reduce trips through fee-based mechanisms such as parking pricing, registration fees based on mileage, and pay-as-you-drive insurance. In Texas, some cities have offered free or reduced transit on ozone action days and implemented the use of HOV lanes and provided free parking at park-and-ride facilities and facilities for bike and pedestrian trips.[35]

Travel Demand Management

Modeling indicates that air toxic emissions are generally higher, per VMT, at lower speeds.[36] This indicates that congestion and non-highway traffic will contribute increased levels of MSAT emissions per VMT. Therefore travel demand management strategies that reduce congestion, such as intelligent transportation systems and market based pricing, could result in lower MSAT emissions if there is not an offsetting rise in VMT.[37,38] For example, a previous TTI policy studies found that financial incentives and disincentives were effective in reducing

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[34] Center for Urban Transportation Research, "Best Workplaces for Commuters," http://www.bestworkplaces.org/index.htm, accessed December 2008.

[35] Texas Transportation Institute, "Emissions Reduction Measures to Help Meet 8-Hour Ozone and $PM_{2.5}$ Standard," July 2004.

[36] Tang, T., M. Claggett, et al., "MOBILE6.2 Air Toxic Emission Factor Modeling: A Trend and Sensitivity Analysis," http://www.fhwa.dot.gov/resourcecenter/teams/airquality/aq_tang1.pdf, accessed November, 2008.

[37] Texas Transportation Institute, "Emissions Reduction Measures that Help Meet the Eight-hour Ozone and $PM_{2.5}$ Standard," unpublished report prepared for TxDOT, August 2004.

[38] Texas Transportation Institute, "Texas Local Agency Clean Air Programs," unpublished report prepared for TxDOT, August 2007.

employer-based trips.[39] Telecommuting and education campaigns for pollution action day programs are commonly used in Texas to reduce transportation emissions.[40,41] Zoning policies that separate sensitive populations from emissions could also limit the impacts of air toxic emissions.

Roadway Design

Recent near-roadway fieldwork conducted by EPA suggests that roadway design could limit public exposure to mobile source emissions. Using a mobile monitoring van, wind tunnel assessments and modeling, EPA examined the impacts of vegetation and barriers to reduce exposure and found evidence that these abatements have a positive effect. EPA and FHWA will continue to study near roadway impacts and potential mitigation opportunities through noise barriers, vegetation, roadway configuration and traffic operations.

ACTIONS FROM STATE AND LOCAL GOVERNMENTS

While all state and local governments traditionally address project level MSAT issues through the NEPA process, some state and local governments have taken voluntary approaches to reduce MSAT emissions and their effects. This section discusses the transportation community's experience with the NEPA process as well as cover major studies conducted that aid both voluntary and mandatory approaches. Lastly, diesel emissions reduction activities provides one of the more common mechanisms for state and local governments looking to mitigate air toxics and other pollutants.

Quantitative Risk Assessment and Exposure Studies

Several states and localities have undertaken efforts to examine the scope and extent that air toxics affect their communities through inventories, monitoring, risk assessments and other quantitative studies. EPA's database for Community-Based Air Toxics project lists activities in

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[39] Texas Transportation Institute, "Incentive Programs that Work," unpublished report prepared for TxDOT, August 2004.

[40] Texas Transportation Institute, "Texas State Agency Clean Air Actions," unpublished report prepared for TxDOT, November 2003.

[41] Texas Transportation Institute, "Effectiveness of Pollution Action Day Programs," unpublished report prepared for TxDOT, June 2004.

37 states and Puerto Rico, and most of these projects are some form of study or assessment. One of the most notable efforts is a study conducted by California's South Coast Air Quality Management District that is entitled "Multiple Air Toxics Exposure Study (MATES II)". The MATES II study included air monitoring, a detailed emissions inventory, and modeling to effectively characterize the air toxic risk in the South Coast Basin. Monitoring suggested that mobile sources are the largest contributor to air toxics and that diesel particulate emissions accounted for roughly 70% of all cancer risk.

A comprehensive air toxic study is currently underway to examine air toxic exposure in Houston. Termed the Houston Exposure to Air Toxics Study (HEATS), the study will look at the relationship between indoor and ambient toxic concentrations and personal exposures. This examination will augment a previous study, entitled *Relationships of Indoor, Outdoor, and Personal Air (RIOPA)* that examined air pollution exposures in Houston, Los Angeles CA, and Elizabeth NJ. The HEATS study is collecting data from personal, home and ambient air monitors in two Houston neighborhoods. One neighborhood is near the Houston Ship Channel and the other neighborhood is demographically similar, but situated away from the Channel. The study expects to connect the emissions contributions from various sources to actual human exposure and could provide information on the links between mobile source contributions and exposure. Preliminary results are expected to be available in spring 2009.

NEPA Actions

As was previously discussed, FHWA provides interim guidance to States regarding the level of MSAT analysis recommended for a transportation project's NEPA process. The agency also provides guidance and example methodologies for conducting analyses. Included within these resources is prototype language that States can incorporate into NEPA documents. Since the guidance was released more than two years ago, States have successfully used the interim guidance and taken advantage of the suggested language.

Much of the analysis conducted for NEPA has shown that MSAT emissions will be reduced significantly due to EPA regulations regardless of whether a transportation project is implemented. For example, the I-93 rebuilding from Salem MA to Manchester NH found an 80% reduction in MSAT emissions projected from 1997 to 2020. The no-action alternative predicted an 82% reduction and the build alternative had an 81% reduction in MSATs. Similar findings were found Intercounty Connector in Maryland.

The North Central Council of Governments (NCTCOG) has developed a tool called EmiLink to automate the process for quantitatively analyzing the MSAT implications of transportation options in NEPA processes. EmiLink will estimate MSAT emissions for every roadway link on an hourly basis using inputs from EPA's MOBILE6 model and information from regional travel demand modeling. NCTCOG believes that other regions could utilize EmiLink with some modifications.

EmiLink was used to quantitatively analyze MSAT emissions for the Loop 12 project in the Dallas-Fort Worth area in accordance with FHWA guidance for projects that exceed an AADT of more than 140,000. The tool's results were consistent with other traditional methods of emissions analysis and were found to decrease costs, time and labor while increasing the consistency in analysis between projects. For the Loop 12 project, EmiLink identified transportation links that had a 5% increase or decrease in volume or VMT for the design year (2015) and calculated the emissions difference between build and no-build scenarios for these links and the project in total. The results are consistent with MSAT analysis for other transportation projects in that the overall level of MSAT emissions decrease with time and that the transportation projects' emissions impacts are small when compared to EPA's MSAT controls.[42]

Diesel Emissions Reduction Activities

One of the notable aspects of MSAT mitigation compared to criteria pollutant reductions is that interest and action is not confined to nonattainment areas and NEPA considerations. Much of the interest in air toxics mitigation outside of mandatory processes has been focused on diesel emissions and, in particular, children's exposure to diesel emissions through school buses.

California has taken a lead in reducing air toxics through diesel emissions reductions. Unlike the federal government, California has assigned a cancer risk factor to particulate matter in diesel exhaust. According to the California Diesel Risk Reduction Plan, the State estimates

[42] Christopher Klaus, M. Venugopal, et al, "EmiLink: A Quantitative Mobile Source Air Toxics (MSATs) Analysis Tool for the Dallas Fort Worth Region: Loop 12 Roadway Alternative, A Case Study," Presented in 2008 at the 17th Annual International Emission Inventory Conference: Inventory Evolution - Portal to Improved Air Quality, Portland, OR.

the statewide average potential cancer risk is more than 500 potential cases per one million. In the populated South Coast Air Basin, the estimated cancer risk is double the statewide average.[43] In a comprehensive effort to mitigate these risks, California has enacted a suite of diesel related programs aimed at reducing particulate matter and other pollutants. From regulatory to voluntary and mobile to stationary, California looks to reduce diesel emissions from practically every major source.[44]

Nearly every state in the nation has undergone some form of diesel reduction activities, whether for reasons related to the criteria pollutants (NOx and PM) or for air toxics reductions. Efforts take a variety of forms, such as idle reduction policies, contract provisions, tax incentives and grant programs.[45] At least 19 states have established state grant programs for reducing diesel emissions[46] and every state has elected to use federal funds from EPA to create a clean diesel program or project. The Texas Emissions Reduction Plan administered by TCEQ is one of the largest grant programs aimed at diesel in the nation, with more than $120 million annually in funding.

From an air toxics perspective, reducing diesel emissions from school buses has played a prominent role. Children are especially vulnerable to diesel emissions because they have a faster respiratory rate than adults and their respiratory systems are still developing. EPA estimates that millions of children ride cleaner buses nationwide as a result of clean school bus activities. In Texas, past projects in Dallas, Houston, Austin and San Antonio have worked to reduce diesel emissions from school buses. Currently, TCEQ is administering a statewide clean school bus program open to all public schools.[47]

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[43] California Air Resources Board, "California Diesel Risk Reduction Plan," 2000.

[44] California Air Resources Board, "Diesel Programs and Activities," December 2008, http://www.arb.ca.gov/diesel/diesel.htm, accessed November, 2008.

[45] U.S. EPA, "National Clean Diesel Campaign: State and Local Toolkit," http://www.epa.gov/otaq/diesel/slt/basicinfo.htm, accessed November, 2008.

[46] U.S. EPA. "State and Local Toolkit: Funding," http://www.epa.gov/otaq/diesel/slt/funding.htm, accessed November, 2008.

[47] Texas Commission on Environmental Quality, "Texas Clean School Bus Program," http://www.tceq.state.tx.us/nav/pollution/school_buses.html, accessed November, 2008.

CONCLUSIONS ABOUT AIR TOXICS

With declining ambient levels of MSATs, the health risks from mobile source air toxics may be more relevant for localized environments at smaller geographic scales, such as at the near-roadway or intermodal transfer level. EPA MSAT regulations are expected to dramatically decrease ambient concentrations, but near-roadway exposures may remain a concern in areas where vulnerable populations may be exposed to a significant amount of exhaust from high emitting or heavy-duty engines.

The concern about localized concentrations and diesel emissions is consistent with FHWA interim guidance and the NCHRP 25-25 report, and both efforts focused on the project-level analysis and the NEPA process, although not on comprehensive near-roadway exposures. Since National Ambient Air Quality standards apply to large areas, this policy tool, along with the NEPA process, may not be appropriate for assessing the more comprehensive localized impacts of MSATs. The lack of localized analysis of personal exposure near all major roadways is often one of the reasons why local communities are sometimes not satisfied when NEPA analysis is used to demonstrate that air toxics are not a concern.[48]

While EPA's guidance on hot-spot analysis attempts to shrink the window of analysis to a scale more appropriate for assessing public exposure, it is limited to only PM nonattainment and maintenance areas and lacks analysis tools capable of handling more localized impacts. The FHWA guidance and the associated NCHRP report do not handle near-roadway exposures explicitly, but do provide a logical methodology and framework for identifying projects with a high potential of MSAT effects and for screening projects that might require a more qualitative or quantitative assessment at the near-roadway level.

Regardless of the policy mechanism for addressing MSAT emissions, a central issue is the lack of available tools for effectively and efficiently analyzing air toxic issues at more localized levels. The full implementation of EPA's new MOVES model may help in providing emissions factors at smaller scales of analysis. However, the model does not provide the dispersion and exposure information that would be needed for a complete health risk assessment. A full risk assessment is the most assured way of directly linking MSAT emissions to potential public health effects but will likely only be needed for only a small number of transportation

[48] Mothers for Clean Air, "Clearing the Air Newsletter," Summer 2004, vol. 7, issue 1, http://www.mothersforcleanair.org/newsletters/NewsletterSummer04.pdf, accessed May 2009.

projects, as is suggested in the FHWA Interim Guidance. More research, tools and perhaps training for relevant transportation professionals are needed to address the expense, uncertainty and resource intensity issues associated with the risk assessment process. In the meantime, FHWA's Interim Guidance recommends that impacted transportation communities contact FHWA for assistance.

While transportation professionals continue to monitor progress in analyzing MSAT emissions, state DOTs and MPOs can continue to gain air toxic benefits from other pollutant reduction efforts. Any strategy that reduces vehicular emissions or limits public exposure to exhaust has air toxic benefits. In Texas, there are many mobile source programs focused on NOx reductions and particulate emissions from school buses that similarly help protect public health from air toxic impacts.

3. TRANSPORTATION AND GREENHOUSE GAS EMISSIONS

Greenhouse gase emissions (GHG) are the driving force behind global climate change. While there are great uncertainties in predicting global climate change effects on particular locations, Texas temperature averages are expected to steadily climb, sea levels will rise, and the likelihood of a major storms striking the Texas coast is increased.[49] These effects could severely affect the transportation infrastructure through accelerated deterioration, inundatation of roadways, and loss of service.[50] The scientific community recommends an 80 percent reduction from 1990 GHG emissions levels by 2050 to avoid the worst impacts of climate change.[51] Texas is the state with the most GHG emissions and could become a focus of efforts crafted to curb GHG emissions. If Texas were its own country, it would rank globally as the seventh largest emitter. In 2005, Texas emitted 743 metric tons (Mt) of carbon dioxide (CO_2).

The transportation sector is a large source of GHG emissions, accounting for more than 27 percent of U.S. GHG emissions in 2006. The growth of transportation emissions over the recent decades has outpaced any other sector, which highlights the critical need for understanding GHG emissions from the transportation sector.[52] This report examines transportation-related GHG emissions and key mitigation options for reducing emissions. A discussion of greenhouse gas inventory issues transitions the discussion from emission sources to GHG mitigation efforts, since inventories are often first step in GHG planning efforts. Actions taking place at the federal level are explored and leadership at the state level in a few key states is highlighted.

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49 Schmandt, Jurgen, Judith Clarkson, Gerald R. North, et. al. "The Impact of Global Warming on Texas, " http://www.texasclimate.org/Home/BookImpactofGlobalWarmingonTexas/tabid/481/Default.aspx, accessed April 2009.

50 Transportation Research Board. Special Report 290: Potential Impacts of Climate Change on U.S. Transportation. Transportation Research Board, Washington D.C., 2008.

51 Gupta, S., D. A. Tirpak, N. Burger, J. Gupta, N. Höhne, A. I. Boncheva, G. M. Kanoan, C. Kolstad, J. A. Kruger, A. Michaelowa, S. Murase, J. Pershing, T. Saijo, A. Sari. "Policies, Instruments and Co-operative Arrangements." In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, 2007.

[52] U.S. EPA, "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003" March 2006. Report EPA420-R-06-003

TRANSPORTATION-RELATED GHG EMISSIONS

Greenhouse gases (GHG) include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20) and several other classes of halogenated substances that are associated with industrial activities. The transportation sector emits primarily CO_2, although $CH_{4,}$ N_20 and hydrofluorocarbons (HFC) are also emitted. Transportation-related HFCs are emitted from vehicle air conditioning systems and refrigeration systems used in transit.

Some GHG are more potent than others, having more of a positive radiative forcing effect that results in trapping the earth's heat more effectively. This potency is referred to as a GHG's global warming potential (GWP). In order to effectively equate each GHG according to this GWP, a common standard of carbon dioxide equivalent (C_2O eq) is used. Table 4 shows the GWP for each GHG, the percentage of each GHG that compromises the transportation sector's contributions and the factors affecting the emissions. Although CO_2 is the reference point with a base GWP of one, it compromises the vast majority of GHG from the transprotation sector. Unlike CH_4 and N_2O which are often reduced by vehicle emission control technologies, CO_2 is directly related to the amount of fuel consumed and the carbon content of the fuel.

Table 4. Transportation-Related GHG Emissions

Green House Gas (GHG)	Global Warming Potential (GWP)	Percent of GWP-Weighted emissions from Transportation Sector (2003)	Transportation Factors Affecting Emissions
CO_2	1	96%	The amount of fuel combusted and the fuel's carbon content
CH_4	21	< 1%	CH_4 content of fuel, vehicle emission control technologies, operating characteristics and vehicle miles traveled
N_2O	310	<2%	Vehicle emission control technologies, operating characteristics and vehicle miles traveled
HFC	120-4,300 (depending on the HFC)	2%	Leakage from air conditioners

Source: US EPA. "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003," March 2006. Report EPA420-R-06-003

The transportation sector also emits several indirect (or precursor) GHG which form substances that contribute the greenhouse effect. These include NOx, non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), ammonia (NH_3), sulphur dioxide (SO_2) and aerosols. NOx and NMVOCs contribute to ozone formation that exacerbates global warming. International bodies on GHG request inventory and emissions information on indirect GHGs, but do not provide GWP for these pollutants or require their reporting in international efforts.

There is also some evidence that black carbon (BC) from particulate matter (PM) could also be a significant contributer to climate change. Speculated to be the "second most potent" global warming gas, diesel particualet matter accounts for a significant portion of BC in the U.S.[53,54] However, the science is still new in this area and black carbon is not currently part of inventory and control programs focused on GHGs.

A Modal and Growth Breakdown of GHG Emissions

Transportation accounted for about 27% of US GHG in 2003 and is the highest growth sector for GHG emissions.[55] Much of the growth in emissions is attributable to increased passenger and freight travel, which has exceeded energy efficiency gains. Vehicle miles traveled (VMT) increased 35% for passengers cars and 48% for heavy-duty vehicles from 1990 to 2003. Over all, onroad GHG emissions rose 26% and nonroad emissions grew 3%. Table 5 is derived from EPA's transportation inventory and provides the modal breakdown of GHG emissions from each mode, the percentage change from 1990 to 2003 and factors affecting the percentage change.

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[53] Ramanathan, V. and G. Carmichael. "Global and Regional Climate Change Issues Due to Black Carbon," *Nature Geoscience*, vol. 1, April 2008.

[54] University of California - San Diego, "Black Carbon Pollution Emerges As Major Player In Global Warming". *ScienceDaily*, March 24, 2008, http://www.sciencedaily.com/releases/2008/03/080323210225.htm, accessed February 19, 2009.

[55] U.S. EPA, "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003," March 2006. Report EPA420-R-06-003.

Table 5. GHG Inventory and Growth Percentages by Mode for 2003

Mode	Percentage of Transportation GHG in 2003	Percentage Change: 1990 to 2003	Comments and Factors Affecting Increase/Decrease
Passenger cars	35%	+2%	• A 35% increase in VMT. • Increase in vehicle ownership. • Stagnation in fleet fuel economy. • Increased percentage of light duty trucks, which tend to have lower fuel economy.
Light-duty trucks (vans, SUVs, pickup trucks)	27%	+51%	
Heavy-Duty Trucks	19%	+57%	• A 48% rise in VMT. • Slight decrease in fuel economy. • Increase in trucking's share of total ton-miles from 19% in 1980 to 32% in 2002.
Buses	0.5%	+12%	• VMT increases for transit and schoolbuses. • The VMT for alternatively fueled buses had the largest increase at 273%.
Aircraft	9%	-3%	• Increased efficiencies in number of seats occupied in passenger travel. • Improved fuel economy.
Boats and Ships	3%	+17%	• Marine GHG emissions are very uncertain. • Estimates vary significantly from year to year.
Locomotives	2%	+18%	• Increase in total ton-miles shipped by rail. Freight accounts for 89% of rail GHGs. • Increase in VMT for passenger rail. • Rail uses 90% less energy than trucks and 80% less than ships when measured in BTUs/ton-mile.
Pipelines	2%	-3%	• Pipelines are included in the transportation sector of the U.S. GHG Inventory but are not included in the mobile source section. • Roughly two-thirds of domestic petroleum transport is through pipelines, which use natural gas and electricity.
Lubricants	1%	-14%	• Consists of oil used in engine combustions.

Source: U.S. EPA, "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003," March 2006. Report EPA420-R-06-003.

Construction and agriculture equipment, recreational vehicles and other commercial and industrial equipment are accounted for separately from transportation sources in the U.S. inventory. The sector produced about 144.8 Tg CO_2 Eq. in 2003, which amounts to about 7% of the 1,866 Tg CO_2 Eq. from transportation GHG emissions in Table 5. These emissions increased 44% from 1990 levels, with the highest emissions coming from construction equipment.

GHG EMISSIONS INVENTORIES

Greenhouse emissions inventories are often the first step to taking action on GHG gases. Inventories have often been used in regulatory settings for creating benchmarks and demonstrating progress. In addition to providing a sense of scale to emissions, they are often the foundation needed for action plans in setting quantifyable goals and targets. Inventories identify key emissions sources, uncover emission trends and can be used to quantify the benefits of mitigation measures. GHG inventories are key programmatic tools in international efforts for curbing emissions. The U.S. creates an annual GHG emissions inventory as part of its obligations to the United Nations Framework Convention on Climate Change (UNFCCC) treaty. Countries that are signatories to the Kyoto Protocol utilize their inventories for tracking progress toward emissions goals. At least 40 states have developed GHG emissions inventories.

GHG Inventory Methodology

The Intergovernmental Panel on Climate Change (IPCC) has established the methodology used by EPA and most other entities worldwide for creating GHG inventories. The EPA's latest accounting, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006,* conforms to IPCC reporting guidelines and uses the recommended top down approach for national inventories. Inventories utilize either a top-down strategy, in which data is disaggregated, or a bottom-up approach, which relies on end-use data, or a combination of both approaches. Top down inventories tend to be more accurate but often lack some of the detail provided by bottom up approaches, which may limit analysis of mitigation measures.[56] EPA's inventory estimates are based on fuel consumption, activity data and emission factors to account for CO_2, N_2O, CH_4, PFCs, HFCs, SF_6 emissions. Data sources for the U.S. inventory are

[56] U.S. EPA, Transcript: "Greenhouse Gases Inventory 101: Creating an Inventory" http://www.epa.gov/climatechange/emissions/downloads/ts1_transcript.pdf

outlined in Table 6 by mode and indicate the complexity of analysis and the challenge for inventories at the state and local level. In general, CO_2 emissions are based on fuel sold, although apportioning fuel sales to local levels can be difficult. CH_4 and N_2O emissions are much more of a challenge for inventories, but compromise approximately 2% of emissions. Since CH_4 and N_2O emissions are affected by operating characteristics and emissions control devices, inventories take into account activity levels, such as vehicle miles traveled (VMT) by vehicle types.

Table 6. U.S. Inventory Data Sources by Travel Mode

Mode	Data Sources
On-road	FHWA's *Highway Statistics*, DOE's *Transportation Energy Data Book*, MOBILE, MOVES. Emission factors for N_2O and CH_4 come from the literature.
Nonroad (including as construction and agriculture)	EIA fuel consumption compared with NONROAD and FHWA's *Highway Statistics*
Rail	Association of American Railroads (AAR), American Public Transportation Association and several unpublished sources of data.
Boats and Ships	EIA sources including *Fuel Oil and Kerosene Sales,* Department of Homeland Security, and NONROAD model.
Aircraft	DOT, FAA and unpublished data from the Department of Defense's Defense Energy Support Center

Source: Inventory of U.S. GHG Emissions and Sinks: 1990-2006 (April 2008) USEPA #430-R-08-005 ANNEX 3, 3.2. Methodology for Estimating Emissions from Mobile Combustion and Supplemental Information on Transportation-Related GHG Emissions

The transportation portion of the U.S. inventory does not include the lifecycle analysis of transportation; such an analysis is incorporated in other economic sectors, such as the industrial sector. These emissions would include upstream emissions from production and assembly, downstream emissions from disposal and infrastructure related emissions such as those associated with road constructon, operation, and maintenance. While not estimated in the official U.S. GHG inventory, EPA examined upstream transportation related emissions for vehicles and fuels and found them to be 27-37% higher than direct fuel combustion emissions. For example, passenger cars have lifecycle emissions that are estimated to be 1.35 to 1.43 times that of direct GHG emissions. These estimates do not include emissions from the construction and maintenance of infrastructure or upstream vehicle emissions for non-highway vehicles.[57]

Levels of Uncertainty in Inventories

There are several levels of uncertainty within GHG inventories, which vary by vehicle type and GHG. Primary sources of uncertainty include ambiguity in the primary data, fuel consumption, allocations to the various vehicle types and transportation modes. For example, EPA's Office of Transportation and Air Quality (OTAQ) states that the U.S. GHG inventory's top-down approach to CO_2 emissions may underestimate emissions from gasoline and regular diesel sources and overestimate emission from jet fuel. The U.S. inventory uses fuel data primarily from the Energy Information Administration which has lower estimates for gasoline and diesel than those compiled from bottom-up sources. Smaller degrees of uncertainty for CO_2 include carbon content of fuel and oxidation factors.

Uncertainty is greater for CH_4 and N_2O because estimates include VMT calculations, fleet distributions by emission control technology and limited emissions factor data. Accurate accounts of vehicle emissions control technologies which vary by class of vehicle and type of emissions control system (and may be influenced by regulatory banking and trading systems) are difficult.

Nonroad estimations of CH_4 and N_2O are less certain than on-road estimates due the lack of precise emissions factors and the operational influence on emissions. For example, IPCC CH_4 estimates from aviation and marine may be off by a factor of two. N_2O estimates may be off by several orders of magnitude and not take into account the higher emitting events of take-offs and landings in the aviation sector. Despite these uncertainties, the overall impact on the inventory is expected to be low due to the small amounts of CH_4 and N_2O emitted by the transportation sector. [58,59]

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[57] U.S. EPA, "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003," March 2006. Report EPA420-R-06-003.

[58] U.S. EPA, "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003," March 2006. Report EPA420-R-06-003.

[59] IPCC, "2006 IPCC Guidelines for National Greenhouse Gas Inventories," Volume 1, Chapter 3.

REDUCING GHG EMISSIONS

From policy and planning efforts to new technology implementation, there are a myriad of mitigation measures for reducing GHG emissions from transportation. Often these mitigation measures are categorized according to the three- or four-legged stool shown in Figure 4. The vehicle leg refers to vehicle fuel economy gains and the fuel leg signifies the use of low-carbon fuels. The VMT support represents a reduction in activity level or avoided activity. The vehicle/systems operation leg often refers to congestion mitigation and intelligent transportation systems that make efficient use of the roadway system. However, this leg is sometimes not included because system efficiency gains can also create increases in VMT and activity use.

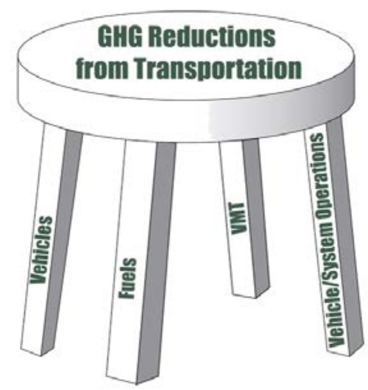

Figure 4. GHG Emissions Mitigation Measures
Source: Cynthia Burbank. "Global Climate Change: Transportation's Role in Reducing GHG Emissions," Presentation at the American Association of State and Highway Transportation Officials (AASHTO) Annual Meeting, October 19, 2008.

Vehicle Strategies

Vehicle strategies are aimed at increasing the fuel efficiency of the vehicle. Examples include vehicle technologies such as the hybrid-electric engine or more fuel efficient vehicles. The Energy Information Administration forcasted that in 2025, hybrids will compose 6% of new car sales. Vehicle strategies can include non-engine characteristics, such as low rolling resistant tires that reduce aerodynamic forces and maintenance practices that improve fuel economy such as keeping tires properly inflated and practicing preventative maintenance.

Fuel Strategies

Alternative fuels such as ethanol, methanol, biodiesel, propane and natural gas are often used to displace carbon based petroleum and diesel fuels. The Energy Information Administration forcasted alcohol flexible fuel (mainly ethanol) vehicles will comprise 8% of new sales in 2025. Despite the positive predictions for ethanol, other boutique fuels must overcome several barriers to widespread implementation. Natural gas, hydrogen and high levels of ethanol (i.e., E85) require their own infrastructure, while low levels of ethanol and biodiesel can be mixed into the current supply. Compressed natural gas (CNG) and hydrogen have handling and storage issues and require dedicated engines that are currently expensive. Biodiesel has had quality control issues in the past that are largely overcome by suppliers conforming to ASTM D 6751 standards.

The lifecycle of alternative fuels is often an issue in estimating the GHG emissions reductions when compared to traditional fuels. Lifecycle emissions take into account the total emissions generated by a fuel, including upstream and downstream emissions such as those emitted from generation, production, use and disposal. For petroleum, the upstream emissions account for approximately 20% of total emissions.[60] However, for biofuels, electricity and hydrogen, upstream emissions from production can be signficant, and in some cases arguably outweigh the emissions diverted from traditional gasoline and diesel. For biofuels, land use changes that divert agriculture to fuel production can in certain situations outweigh the GHG benefits of displacing petroleum. Displaced agriculture often results in new land being used for intensive purposes. In cases where rainforest, wetland or other natural spaces are converted, land that once served in carbon sequestration is now emitting carbon. However, fuels created from waste or biomass residues often do not have such significant upstream emissions.

The U.S. EPA evaluated the lifecycle impacts of alternative and renewable fuels using Argonne National Laboratory's GREET model. Figure 5 demonstrates how each alternative fuel compares to standard petroleum fuel on an energy unit (btu) basis. The results show wide variablity in GHG emissions impacts from different fuels. However, it is similarly important to note that considerable variability in GHG impacts can exist even within the same type of fuel due to different processes. For example, the greenhouse emissions of electric vehicles can vary significantly depending on the energy source used to generate the electricity. Ethanol's GHG impact varies considerably based on the feedstock, with corn ethanol receiving average reductions of 21.8% and cellulosic ethanol reducing emissions by 90.9%. The variability in emissions within corn ethanol ranges from a 54% decrease when produced in a biomass-fired dry mill plant to a 4% increase in GHG emissions when produced in a coal-fired wet mill plant. Hydrogen benefits relative to petroleum also varied with a decrease in emissions of 41% for gaseous hydrogen and a 6.5% increase in GHGs for liquid hydrogen. These examples demonstrate the need to pay close attention to the feedstock, production and processes used for alternative fuels when estimating GHG mitigation impacts.

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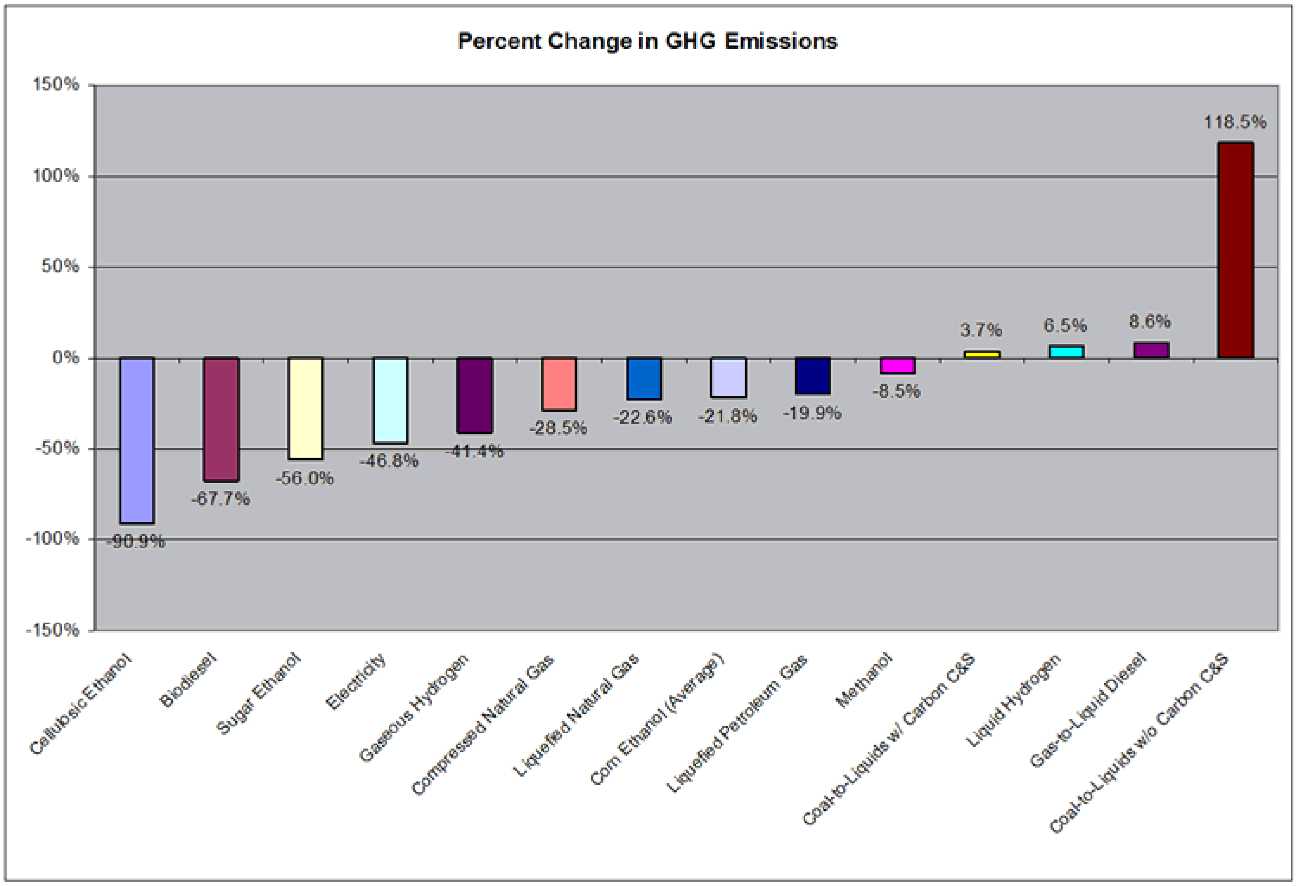
[60] Sperling, Daniel and Sonia Yeh, "Low Carbon Fuel Standards" Issues in Science and Technology," National Academies, Winter 2009.

Figure 5. GHG Emissions Reductions of Alternative Fuels Relative to Petroleum Fuel



Source: U.S. EPA. "Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuel Use," Office of Transportation and Air Quality, Report EPA420-F-07-035, April 2007.

VMT and Activity Reduction Measures

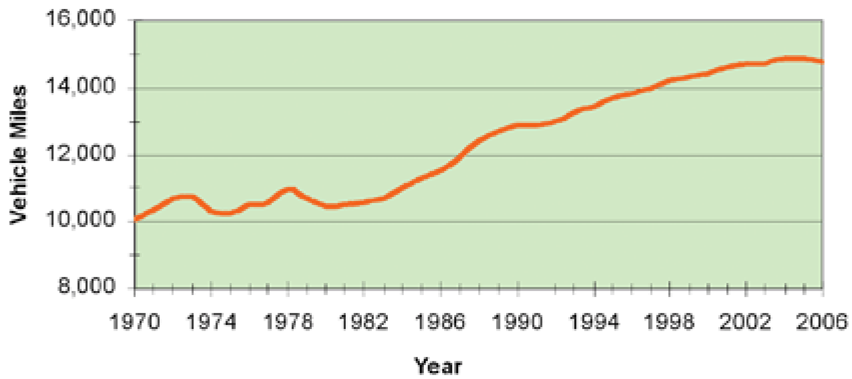
Reduced vehicle miles traveled can take several forms. Options include increased use of transit, carpooling, telecommuting, travel by foot or bicycle and land use policies that encourage mixed use development and limit low-density development. In the freight sector, strategies such as improved logisitcs and double stacked rail cars can eliminate trips.

Reductions in passenger VMT has been difficult to sustain.[61] Until 2005, annual VMT rates had been steadily increasing since 1970, as depicted in Figure 6. The rise in gas prices is presumed to be a driving factor in the recent slow down of VMT, although demographic

[61] Greene, David L. and Andreas Schafer, "Reducing Greenhouse Gas Emissions from U.S. Transportation," Pew Center on Global Climate Change, May 2003.

changes, economy and public polices can also affect VMT. On average, VMT has increased roughly 2% a year. Forecasts from the 2005 EIA Annual Energy Outlook estimates that this VMT increase will remain relatively constant until 2025. In an effort to reduce greenhouse gas emissions, AASHTO has set a goal of cutting the VMT growth rate by 50% to 1% annually.

Figure 6. Annual Vehicle Miles Traveled per Licensed Driver, 1970-2006



Source: U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Statistics.

Vehicle/Systems Operations

Traffic congestion is the typical example of how vehicle and system operations can increase GHG emissions. Automobiles and trucks in clogged roadways waste fuel and time. TTI's 2007 Mobility Report found that in 2005, congestion burned an additional 2.9 billion gallons of fuel at a cost of $78.2 billion.[62] Congestion increases fuel consumption and emissions per mile, due to congestion's inefficient stop-and-go drive pattern. Driver behavior is important. Less aggressive driving can reduce emissions and accidents that cause congestion.

Mitigation Measures by Mode

Mitigation measures vary by transportation mode. For example, diesel vehicles have distinct alternative fuel options that are different from gasoline and vehicle operation varies significantly by mode of travel. In the freight sector, the emissions performance of various transportation modes can vary significantly by mode when compared on an energy unit (btu) or ton-moved basis, with trucking resulting in the most GHG emissions.

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[62] Schrank, David and Tim Lomax, "The 2007 Urban Mobility Report," Texas Transportation Institute, September 2007.

Table 7. Sample of GHG Emissions Mitigation Measures by Transportation Mode

Mode	Vehicle Measures	Fuel Options*	Activity Reduction	System Operations
Light-Duty Vehicles	• Fuel efficiency increases • Hybrid vehicles • Rebates to encourage fuel efficient purchases	• Ethanol, Propane, Natural Gas, Hydrogen, Electricity (ex. Plug-in hybrids)	• VMT reduction, such as increased transit, commute options and smart-growth land use strategies	• Congestion mitigation measures • Driver education
Heavy-Duty Vehicles	• Idle reduction • Aerodynamic devices • Low-rolling resistance tires • Hybrid trucks	• Biodiesel (B20)	• Double or triple trailers • Improved trucking logistics • Mode shifting	• Congestion mitigation measures • Driver education
Rail	• Light-weight cars • Idle reduction • Hybrid or gen-set locomotive • Improved rail lubrication	• Biodiesel (B20), Electrification, Natural Gas	• Use longer trains • Double stack trains	• Reduce rail congestion, increase rail capacity to enable shifting of cargo from truck to rail
Marine	• Newer, more fuel efficient vessels	• Biodiesel, Solar, Nuclear, more refined distillate, LNG	• Cold ironing or mobile power at port	• Operator education
Aircraft	• Increased engine efficiency • Electric wheel motor • Use of lighter materials	• Aviation biofuel	• Improved use of capacity	• Flight plan optimization • Improved operation procedures
Non-Transportation Sources**	• Idle reduction • Electrification in some instances	• Biodiesel (B20)	• Conservation tillage for agriculture	• Right-size equipment • Operator training

* Some fuel options have very limited applications.
** Examples include construction, agriculture, and utility equipment.

GREENHOUSE GAS POLICIES

There are countless GHG mitigation policies in place or being formed at the international, national, state and local government level. Nationally, GHG policies are largely in development or evolving. While many international markets have been directly addressing GHG emissions thorugh the Kyoto Protocol (discussed below) for many years, there have been several efforts underway nationally and especially at the state level that provide a window in the GHG polices that could shape the coming decades. This section examines national policies that are already in place to curb transportation related GHG emissions as well as policies that are being considered for future regulations. There is also substantial leadership taking place at the state and even local level that provide insights into alternate approaches for curbing GHG emissions

National Efforts to Reduce GHG Emissions

In 1992, the U.S. signed the United Nations Framework Convention on Climate Change (UNFCCC) treaty which commits nations to share information and best practices with regards to climate change. Of the 192 countries that are members of the UNFCCC, to date 184 of them have also signed the Kyoto Protocol, which is linked to the UNFCCC and establishes legally binding targets for GHG reductions. Signatories commit to reducing GHG levels by an average of 5% from a 1990 levels by 2012.

To date, the U.S. has not ratified the Kyoto Protocol. However, should the U.S. adopt the treaty, the nation would commit to meeting the target through three market-based mechanisms:

- Emissions trading or “carbon market”- countries with emissions credits to spare can sell them to countries that are over their GHG targets.
- Clean development mechanism – allows a country to gain creditable emissions reductions by implementing a certified emissions reduction project in a developing country.
- Joint implementations – Kyoto participating countries can earn emissions credits from investing in projects occuring in another participating country.

It is currently unknown whether the Obama Administration will try to move to U.S. to join the Kyoto Protocol. However, the Administration has declared that it wants to make the

U.S. "a leader on climate change" and reduce greenhouse gases by 80% by 2050 through a cap-and-trade program.[63]

Under the new Administration, the EPA recently submitted to the White House a finding that climate change endangers public health and welfare. The finding is an early key step in allowing the agency to regulate greenhouse gases under the Clean Air Act.[64]

Carbon Tax vs. Cap and Trade Programs

National policy discussions on how to reduce GHG emissions have largely centered on two market-based mechanisms:

- Carbon tax
- Cap-and-trade system

The two mechanisms could be used separately or combined. The benefits and drawbacks of each are outlined in Table 8. A carbon tax incentivizes emissions reductions that cost less than the carbon levy. A cap-and-trade system sets a limit on emissions and regulated entities would either keep emissions under the cap or buy allowances to offset emissions. A cap-and-trade system has been used nationally to reduce acid rain emissions from the electric generation sector and is utilized by the European Union to reduce CO_2 emissions.

[63] The White House, "Agenda: Energy and Environment" http://www.whitehouse.gov/agenda/energy_and_environment/ , accessed March 2009.

[64] Juliet Eilperin, "EPA Presses Obama on Climate Regulation," Washington Post, March 24, 2009.

Table 8. Advantages and Disadvantages to Carbon Tax and Cap-and-Trade Systems

	Carbon Tax	**Cap-and-Trade**
Advantages	• Provides certainty in the cost of emissions reduced • Low administrative costs and easy to implement	• Achieves cost effective emissions reductions • Provides more certainty in the amount of CO_2 reduced. • Is easier to harmonize with international efforts
Disadvantages	• Total amount of CO_2 reductions are uncertain • Would be more difficult to align with other international cap-and-trade programs	• Higher levels of uncertainty due to fluctuations in the cost of emissions reductions • Complicated and less efficient to implement • Caps could disproportionately or unfairly affect certain sectors

Sources: Congressional Budget Office, "Policy Options for Reducing CO2 Emissions," Washington DC, February 2008.
McKinsey & Company. "The Debate Zone: Carbon Tax V. Cap and Trade," March 17, 2009, http://whatmatters.mckinseydigital.com/the_debate_zone/carbon-tax-vs-cap-and-trade, accessed March 24, 2009.

A cap-and-trade system is more complex than a carbon tax and could be designed a variety of ways. A system could set minimum and/or maximum prices for emissions allowances that would curtail possible fluctuations in the price of allowances. Price ceilings are often referred to as a safety valve. A cap-and-trade system could allow for compliance flexibility through permitting the banking of emissions allowances, in which allowances could be transferred across time periods, or by allowing entities to borrow allowances, which is often referred to as a circuit breaker. A system could also employ a firm cap or a flexible emissions cap that could vary from year to year or on the bases of the price of allowances.

The European Union's Emissions Trading Scheme (ETS) is the largest cap-and-trade program for CO_2 emissions. One of the early lessons of ETS is the importance of utilizing credible and valid emissions data, rather than emissions estimations. The initial pilot phase of ETS suffered from inaccuracies in the historic estimations data that resulted in less stringent caps in the initial phase of ETS. Consequently market prices for allowances were initially artificially low.[65] However, this early ETS obstacle was overcome through revised procedures. Perhaps learning from Europe's lessons, the EPA has recently proposed a mandatory GHG reporting rule that aims to provide inclusive and accurate emissions data to provide the framework for future policies.[66]

Regardless of the market based carbon pricing system employed, analysis from the Congressional Budget Office (CBO) estimates that the resulting effects on passenger vehicle emissions will be minimal. A carbon tax or cap-and-trade system will charge a price for CO_2 emissions, which will presumeably result in an increase in gasoline prices. However, the rise in fuel prices is not expected to adequately curb VMT enough to significantly reduce GHG emissions from citizen travel. CBO estimated that a 2012 price of $28 per metric ton of CO_2 would lead to a price hike of $0.25/gallon of gasoline. While this would reduce total U.S. emissions for that year by 10%, it would decrease emissions from passenger vehicles by only 2.5% over time. In comparison, fuel economy mandates are expected to reduce CO_2 emissions by 28% per mile for new cars and an estimated 5% or more in overall emissions by 2035. The CBO analysis took into account citizen response to the increase in gasoline prices over the past few years and the European experience with taxing gasoline sales. The short-term inelasticity of gasoline prices is presumed to be due to the American dependency on the automobile and the small effect of an emissions price on gasoline relative to total price. However, sustained increases in gasoline prices could influence vehicle emissions in the long term as consumers choose more fuel efficient vehicles and choose to minimize work commutes and vehicle trips. The fuel price hikes necessary to influence this shift are likely more than would be required through carbon pricing.[67]

The CBO analysis implies that alternate or additional policies may be more appropriate for the transportation sector than a carbon tax or cap-and-trade system. The federal government

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[65] Dinan, Terry, "Policy Options for Reducing CO2 Emissions," Congressional Budget Office, February 2008, http://www.cbo.gov/ftpdocs/89xx/doc8934/02-12-Carbon.pdf, accessed February 12, 2009.

[66] U.S. EPA, "Proposed Mandatory Greenhouse Gas Reporting Rule," http://www.epa.gov/climatechange/emissions/ghgrulemaking.html, accessed April 10, 2009.

[67] Congressional Budget Office, "Climate-Change Policy and CO2 Emissions from Passenger Vehicles," Washington DC, October 6, 2008.

has already taken two sets of regulations to specifically address emissions from the transportation sector while simultaneously reducing dependency on foreign fuels.

Fuel Economy Regulations

The Corporate Average Fuel Economy (CAFE) program mandates fuel economy standards for new cars. The National Highway Traffic Safety Administration (NHTSA) establishes and reassesses the standards and EPA administers the testing program. Historically, passenger car miles per gallon standards increased to a peak of 27.5 mpg in 1990. Light-duty truck standards are lower and peaked in 1996 to 20.7mpg. The increasing market share of light-duty trucks has decreased the overall sales-weighted fuel economy, which reached a high of 22.1 in 1987 and 1988 and then declined to 20.8 in 2004.[68] In contrast, average fuel economy in Europe and Japan are more than 40 mpg.[69]

There have been a seriese of steps undertaken in the past few years to strengthen fuel economy standards. The Energy Indpendence and Security Act of 2007 (EISA 2007) raises CAFÉ standards for passenger and light duty vehicles combined to 35 mpg by 2020. This represents a 40% increase in fuel economy for cars and light duty truck combined. In April 2008, NHTSA proposed rules that would raise CAFÉ standards for cars to 35.7 and light duty trucks to 28.6 for model year 2011-2015. The Obama Administration issued a memorandum calling for new CAFE standards for solely model year 2011 to allow time for the consideration of more stringent fuel economy standards thereafter. Model year 2011 fuel economy standards have been raised to 27.3 for both cars and light duty trucks, which is estimated to save 887 million gallons of fuel over the life of the vehicles and reduce CO2 emissions by 8.3 million metric tons. CAFE standards for passenger cars are 31.2 mpg and 25 mpg for light duty trucks.[70] In May, the Obama Administration announced a proposal to establish new fuel economy

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[68] U.S. EPA, "Greenhouse Gas Emissions from the U.S. Transportation Sector: 1990-2003," March 2006. Report EPA420-R-06-003.

[69] The International Council on Clean Transportation, "Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update," http://www.theicct.org/documents/ICCT_GlobalStandards_2007_revised.pdf, accessed April 10, 2009.

[70] National Highway Traffic Safety Administration, "Final Rule: Average Fuel Economy Standards for Passenger Cars and Light Trucks, Model Year 2011," http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.43ac99aefa80569eea57529cdba046a0/, accessed March 30, 2009.

standards for 2012-2016 model years. The proposed standards will ramp up to a fleetwide average of 35.5 mpg in 2016, which is four years earlier than the original timeline established in EISA 2007. The announcement also explicitly ties the effort to greenhouse gas emissions reductions for the first time.[71]

EISA 2007 also seeks to pave a path for medium and heavy duty trucks. The Act calls for a National Academy of Science study to examine the establishment of fuel economy standards for medium and heavy duty trucks to be used for a future rulemaking on a fuel economy standard for this sector. In a separate study, the EIA's Annual Energy Outlook expects the freight sector's fuel economy to increase from 6 mpg in 2003 to 6.6 mpg in 2015.[72]

Renewable Fuel Legislation

The Energy Policy Act of 2005 established a renewable fuel standard (RFS) for the nation through annual mandates. These standards were increased in EISA 2007 to 36 billion gallons by 2022. RFS requires producers of motor fuel to incorporate a certain percentage of renewable fuels, which include ethanol and biodiesel. EISA 2007 also incorporates consideration of lifecycle GHG emissions. Lifecycle emissions include direct emissions from fuel and feedstock production and use to indirect emissions such as land use impacts. In order to qualify as a renewable fuel, most fuels have to achieve a minimum 20% reduction in lifecycle GHG emissions from the baseline gasoline or diesel dominant fuel. The Act also outlines required volumes of "advanced biofuels" and "biomass-based diesel" that have a minimum of 50% reductions in lifecycle GHGs and "cellulosic biofuels" with at least 60% reduction in GHG lifecycle emissions.[73] Current compliance with RFS has resulted primarily in the blending ethanol in gasoline up to 10%. However, future RFS standards will not be met with a simple

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[71] U.S. EPA and DOT, "Notice of Upcoming Joint Rulemaking to Establish Vehicle GHG Emissions and CAFE Standards," http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/Joint_CAFE_GHG_Emissions.pdf, accessed May 21, 2009.

[72] Energy Information Administration, "Annual Energy Outlook 2004, with projections to 2025". Washington DC, Figure 57.

[73] Energy Independence and Security Act of 2007, Sections 201- 205.

blending of ethanol into gasoline and more substantial efforts at incorporating renewable fuels into the mass market will have to be explored.[74]

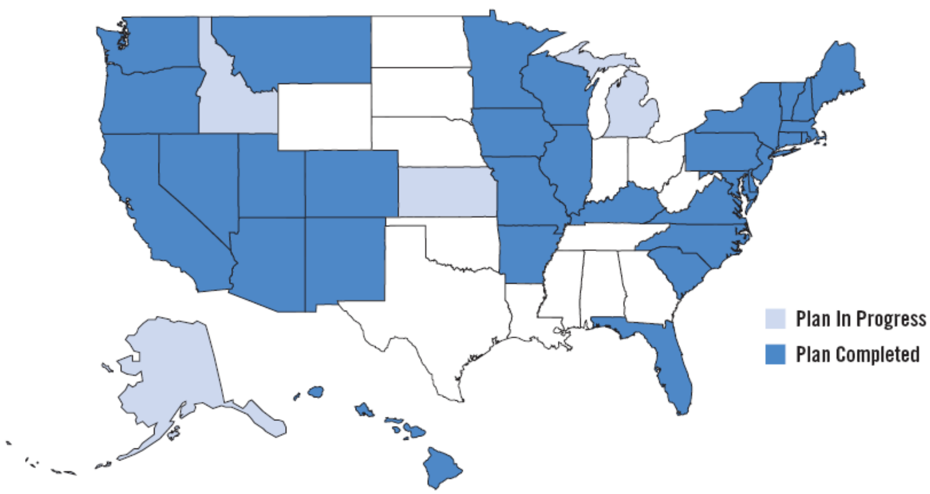
State and Local Action

While federal legislation is addressing the vehicle and fuel-related options for GHG emissions, there has been less action dedicated to reducing activity use such as VMT. These strategies are primarily dedicated to the state and local level, which indicates that state and local entities may have a larger, or at least different, toolbox for reducing GHG emissions from their federal counterparts in the transportation sector.

Many state and local governments have taken action independent of any federal lead. At least forty states have developed GHG inventories and more that 28 have developed climate plans (see Figure 7). Many states with climate action plans have set goals for greenhouse gas reductions. These target reductions vary slightly in the year chosen for baseline emissions and the level of reduction. However, many are similar to those recommended by climate scientists at the IPCC, as shown in Table 9. While Texas does not have a statewide plan for reducing GHG emissions, there are a number of state programs to reduce GHG emissions primarily in the electric generation sector. Examples include a renewable portfolio standard, a suite of energy efficiency programs and incentives for biofuels.

[74] Biomass Research and Development Board. "National Biofuels Action Plan," October 2008, http://www1.eere.energy.gov/biomass/pdfs/nbap.pdf, accessed April 10, 2009.

Figure 7. States with Climate Action Plans



Source: Pew Center for Global Climate Change, "Climate Change 101: State Action," January 2009. http://www.pewclimate.org/docUploads/Climate101-State-Jan09_1.pdf , accessed April 13, 2009.

Table 9. Greenhouse Gas Targets

Entity	Target
Climate scientists	80% below 1990 levels by 2050
California, Montana, Florida	80% below 1990 levels by 2050
Oregon	75% below 1990 levels by 2050
Massachusetts, Vermont, New Hampshire, Connecticut, Maine, Rhode Island	75-85% below 2001 levels by 2050
Colorado	80% below 2005 levels by 2050
New Mexico	75% below 2000 levels
United Kingdom	60% below 1990 levels by 2050

Source: Cynthia Burbank, "Global Climate Change: Transportation's Role in Reducing GHG Emissions" Presentation at AASHTO Annual Meeting, October 19, 2008.

State and Regional Cap and Trade Programs

Many state and regional entities have established cap and trade programs for curbing CO_2 emissions. Currently ten states are participating in a cap and trade program through the

Regional Greenhouse Gas Initiative (RGGI). The program currently affects only the electric generation sector in participating states, which include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. States enact by rule or law CO_2 limits for power plants, and then auction CO_2 allowances to regulated entities. Offsets are available.[75] The Western Climate Initiative is a newer effort similar to the RGGI that involves seven U.S. states (AZ, CA, MT, NM, OR, UT, WA) and several Canadian provinces.[76] Lastly, the Midwestern Greenhouse Gas Reduction Accord will establish a multi-sector cap-and-trade program that plans to extend beyond emissions from the electric sector. These states include Illinois, Iowa, Kansas, Michigan, Minnesota and Wisconsin.

Chicago Climate Exchange (CCX) is a voluntary cap and trade system program that contains legally binding commitments for member organizations. CCX members establish GHG reduction commitments, reduce GHG emissions that are third-party verified and purchase emissions offsets when GHG reduction targets are not met by the specified target dates. More than 80 private-sector companies are members, along with several universities, municipalities, counties and a few states.[77] Among its transportation sector participants are Amtrak, the San Joaquin Regional Rail Commission and the Houston Advanced Research Center.

Action at the Local Level

At the local level, more than 900 mayors have signed the U.S. Conference of Mayors Climate Protection Agreement. Partcipating cities commit to meet or exceed Kyoto Protocol targets, urge U.S. state and federal governments to meet or exceed the Kyoto Protocol target for the United States (7% below 1990 levels by 2012) and urge Congress to establish a national emissions trading system. In Texas, twenty-five localities have signed the Agreement including Arlington, Austin, Carrollton, College Station, Dallas, Denton, El Paso, Fort Worth, Laredo, Plano, Richardson, San Antonio and Sugar Land. The Agreement calls for creating an inventory of GHG emissions, setting reduction goals and establishing a plan. Suggested strategies for reducing transportation related GHG emissions include promoting alternative transportation

75 Regional Greenhouse Gas Initiative (RGGI), http://www.rggi.org/, accessed March 12, 2009.

76 Western Climate Initiative. http://www.westernclimateinitiative.org/Index.cfm , accessed March 12, 2009.

77 Chicago Climate Exchange, Member List: http://www.chicagoclimatex.com/content.jsf?id=64, accessed March 12, 2009.

options such as bicycle trails, commute trip reduction programs, incentives for car pooling and public transit, increasing the average fuel efficiency of municipal fleet vehicles; reducing the number of vehicles, launching an employee education program including anti-idling messages and converting diesel vehicles to biodiesel.

State and Local Examples

While there are dozens of state and local governments whose efforts are worth noting as a case study for reducing GHG emissions, there are specific reasons for chosing California, New York and the City of Austin. California is granted unique authority by the Clean Air Act to adopt stricter vehicle and fuel standards if EPA grants the state a waiver. Once granted, other states can adopt California's standards. This unique authority sets California apart, along with the state's comprehensive approach to mitigating GHG emissions. New York State is also unique in the way it has chosen to incorporate GHG emissions into the planning process. Lastly, the City of Austin represents a Texas example of a local government undertaking a comprehensive approach to reducing GHG emissions. While both San Antonio and Dallas are developing GHG inventories for city activities, Austin has added to that task the goal of becoming carbon neutral by 2020.

California

California has undertaken a suite of programs to address climate change under the California Global Warming Solutions Act of 2006, also known as AB32. Transportation emissions are a key target for reducing GHG emissions since the state's inventory revealed that 39% of California's total emissions come from transportation.[78] California's programs provide a multi-pronged stratey that includes unique regulations normally reserved for the federal sector. Transportation-related activities that are designed to help meet the state's goal include:

- Automobile Regulations - would set GHG engine emissions standards and test procedures for passenger cars, light and medium duty trucks
- Low-Carbon Fuel Standard - performance standard for fuel that calls for at least 10 percent reduction in the carbon intensity by 2020

[78] California Energy Commission, "California Climate Change Portal: Assembly Bill 32- The Global Warming Solutions Act of 2006," http://www.climatechange.ca.gov/ab32/index.html#transportation, accessed April 13, 2009.

- Heavy-Duty GHG Emissions Reduction Regulation (Proposed) – requires certain tractors and trailers to use of certain SmartWay technologies, such as aerodynamic devices and low-rolling resistance tires
- Alternative and Renewable Fuel and Vehicle Technology Program - authorizes $120 million annually for projects that increase the use of alternative and renewable fuels.
- Bioenergy Action Plan - includes plans to increase the use of biomass for ethanol and biodiesel.
- Land Use Changes - the Land Use Subcommittee of the Climate Action Team recommends the establishment of emissions targets on a regional or local level and providing measurement guidances and best practices for reaching emissions targets.
- Fuel Efficient Tire Program - will establish a fuel efficiency rating system for tires used on passenger vehicle and light duty trucks
- California Hydrogen Highway Program - funds hydrogen stations, cars and shuttle buses and transit buses. For the past three years, more than $6 million has been granted annually.
- Mobile Vehicle Air Conditioning systems (MVAC) Programs - As of early March 2009, seven different regulations were put in place to control HFC emissions from MVACs.

In 2004, California estimated that its climate change emissions control regulations for motor vehicles would have reduced GHG emissions from new vehicles by 30% by 2016.[79] California is the only state that can establish vehicle emissions standards that are more stringent than the federal government. However, this ability is predicated on EPA granting California a waiver which EPA denied in 2008. Sixteen other states pledged to adopt California's GHG vehicle regulations if approved. In February, under new leadership from the Obama Administration, EPA announced that it is reconsidering California's waiver request. This May, the Obama Administration announced a proposal to significantly increase fuel economy standards similar what California had orinially proposed (but with a longer timeframe for

[79] California Air Resources Board, "Clean Car Standards - Pavley, Assembly Bill 1493," http://www.arb.ca.gov/cc/ccms/ccms.htm, accessed March 25, 2009.

compliance). California played a key role in the development of the new standards.[80] If the California waiver- and its associated GHG reductions- had been federally prohibited, the State had planned to obtain equivalent emissions reductions from feebates. Feebates involve fees for high-emitting new vehicles and rebates for low-emitting new vehicles. Surcharges on high emitting vehicles are used to provide the revenue needed for providing rebates on low-emitting vehicles. Analysis show that feebates can be as effective as California's proposed emissions regulations in curbing GHG emissions and could be an option if the State does not achieve enough GHG reductions from the newly proposed federal fuel economy standards.[81,82]

California's Low Carbon Fuel Standard (LCFS) is a performance standard that affects all transportation fuel providers, with the exception of aviation and maritime fuels. LCFS mandates a 10% reduction in carbon intensity by 2020. Like a cap-and-trade program, emissions credits can be bought and sold among producers in order to keep costs down. Based on total amount of carborn emitted per unit of fuel energy, it allows fuel producers to choose their own method of compliance. LCFS takes into account the entire lifecycle of the fuel, which enables fuel producers to gain credit through production energy efficiency measures. Accounting for lifecycle emissions from biofuels is complex because land use changes can significantly impact the GHG emissions and will vary according to the individual situation. Biofuels can emit GHGs through land use changes that convert natural landscapes serving as carbon sinks into a source of carbon emissions. Accounting for land use changes from biofuels is one of the more challenging aspects of implementing the standard. [83,84] Currently, eleven northeastern states are considering low-carbon fuel policies similar to California's LCFS.[85]

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[80] Sullivan, Colin. "Vow of Silence Key to White House-California Fuel Economy Talks," New York Times, May 20, 2009.

[81] McManus, Walter S. "Economic Analysis of Feebates to Reduce Greenhouse Gas Emissiosn from Light Vehicles for Californi," University of Michigan Transportation Research Institute, Report Number, May 2007, UMTRI-2007-19-2.

[82] Greene, David, "Feebate Policy Consultation Meeting," Presentation to CARB on February 26, 2009, http://www.arb.ca.gov/research/econprog/feebates/feebates.htm, accessed March 25, 2009.

[83] Alexander E. Farrell, Daniel Sperling, A.R. Brandt, A. Eggert, A.E. Farrell, B.K. Haya, J. Hughes, B.M. Jenkins, A.D. Jones, D.M. Kammen, C.R. Knittel, M.W. Melaina, M. O'Hare, R.J. Plevin, and D. Sperling, "A Low-Carbon Fuel Standard for California Part 2: Policy Analysis," August 1, 2007, *UC Berkeley Transportation Sustainability Research Center.* Paper UCB-ITS-TSRC-RR-2007-3.

At the project level, California has started the process for incorporating GHG emissions in the state's California Environmental Quality Act (CEQA). The CEQA process is California's state version of the NEPA process. The preliminary draft guidelines for GHG incorporation provides considerable discretion to regional and local agencies, but also encourages entities to quantify the GHG emissions from proposed project, determine the level of significance and identify mitigation measures if appropriate. The state recognizes that determining the appropriate level of significance will be difficult and has asked CARB for guidance on establishing appropriate thresholds.[86]

New York

New York is similar to California in that it has incorporated GHG mitigation efforts into the regional and MPO level. The State's Energy Plan requires transportation plans and TIPs to include GHG analysis for all significant projects that could lead to VMT increases. The MPOs quantify the level of energy/CO_2 emissions associated with both the direct and indirect emissions associated with a project. Direct emissions account for the impact of the facility post-construction and include the emissions from vehicles using the infrastructure. Indirect energy impacts include construction and maintenance of the facility, along with any significant land-use changes or mode shifts. MPOs conduct energy analyses comparing Build/No Build scenarios according to the methodological guidance provided by NYSDOT. Data availability at the MPO level is often the biggest challenge with estimating transportation-related GHG emissions at the

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[84] Alexander E. Farrell, Daniel Sperling, S.M. Arons, A.R. Brandt, M.A. Delucchi, A. Eggert, A.E. Farrell, B.K. Haya, J. Hughes, B.M. Jenkins, A.D. Jones, D.M. Kammen, S.R. Kaffka, C.R. Knittel, D.M. Lemoine, E.W. Martin, M.W. Melaina, J.M. Ogden, R.J. Plevin, D. Sperling, B.T. Turner, R.B. Williams, and C. Yang, "A Low-Carbon Fuel Standard for California Part 1: Technical Analysis," May 29, 2007, *UC Berkeley Transportation Sustainability Research Center*. Paper UCB-ITS-TSRC-RR-2007-2.

[85] Galbraith, Kate, "Northeastern States Push Toward Low-Carbon Fuel Standard," New York Times, January 5, 2009.

[86] California Office of Planning and Research, "Preliminary Draft CEQA Guideline Amendments for Greenhouse Gas Emissions," January 8, 2009, http://opr.ca.gov/index.php?a=ceqa/index.html, accessed March 26, 2009.

MPO level.[87] However, current results indicate that most proposed projects *reduce* at least 10% of emissions when compared with the business-as-usual case.[88]

New York is currently revising its State Energy Plan and has released an Interim Report for the 2009 State Energy Plan to be finalized in October 2009. The report stresses that a variety of approaches will be needed to address GHG emissions from transportation. In the short and mid-term, the state expects to focus on tansportation systems efficiencies, increased public transit and alternative fuels. New York has an interagency work group evaluating methods for reducing VMT by 10% or more from projected levels in the year 2020.[89] The state is also in discussions with other northeastern states about adopting a regional low carbon fuel standard and is evaluating the environmental and land use implications of biofuels.[90]

New York is also looking at the long-term effects of reducing GHG emissions from transportation. The State interim report states that "Addressing greenhouse gas emissions from the transportation sector may require a level of technology and infrastructure development not seen since the creation of the Interstate Highway System began more than 50 years ago." In addition to looking at funding implications, one of New York's long term strategies for reducing GHG emissions is the electrification of transportation. The State is devoting resources to research extending battery life and energy storage and is assessing the needs and impacts of plug-in hybrid electric vehicles.

City of Austin

The City of Austin's Climate Protection Plan aims to make all City facilities, fleets and operations carbon neutral by 2020. Carbon emissions that can not be eliminated will be mitigated to achieve carbon neutrality. Other goals in the plan aim to reduce GHG emissions

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[87] ICF Consulting, "Estimating Transportation-Related Greenhouse Gas Emissions and Energy Use in New York State," March 18, 2005.

[88] Zamurs, John, "New York State DOT Strategies for Climate Change," Presentation at the Northeast Association of StateTransportation Officials (NASTO) Annual Conference, June 9, 2008, Pittsburgh, Pennsylvania.

[89] New York Department of Transportation, "Climate and Energy Report: April 1, 2008," https://www.nysdot.gov/divisions/engineering/technical-services/trans-r-and-d-repository/NYSDOT Energy and Climate Change Report.pdf, accessed May 25, 2009.

[90] New York State, "2009 New York State Energy Report: Interim Report," March 31, 2009, http://www.nysenergyplan.com, accessed April 6, 2009.

from homes, buildings, businesses, behaviors and from the municiple utility. Steps that the City is undertaking to work toward carbon neutrality in their fleet include:

- alternative work schedules,
- use of biofuels,
- hybrid and electric vehicle purchases,
- bicycle and segway fleet available for travel between city offices,
- use of electronic exchanges rather than hard copy mailings,
- proper tire inflation incentives,
- use of electric landscaping equipment and reducing mowing cycles,
- CNG garbage trucks and fueling station,
- Construction of a transfer station to reduce trips,
- Maintain vehicle at peak performance through good maintenance and repair,
- Use of conference calls, instead of meetings, and
- Downtown development initatives to encourage non-auto travel.

In addition, the City is conducting a public awareness campaign to reduce GHG emissions from citizen travel. This effort includes carbon calculators for assessing emissions and resources for reducing automobile emissions. These include electric vehicle incentives, bike, hike and public transportation information, rideshare and car share resources, and shopping locally. Austin will also unveil its first commuter rail line this year. Austin Energy, which is spearheading the City's climate protection efforts, won an EPA Climate Protection Award for 2008 for the organization's clean energy efforts. In addition, Austin increased its urban sustainability ranking to number 13 in a national ranking of cities by the group SustainLane.com.[91]

CONCLUSIONS ABOUT GREENHOUSE GAS EMISSIONS AND TRANSPORTATION

As greenhouse gas policies develop and mature in the United States, one issue that will become clarified is the role of federal, state and local institutions in climate change policies. While some efforts in New York State aim to "institutionalize climate change and energy

[91] SustainLane, "2008 US City Rankings," http://www.sustainlane.com/us-city-rankings/cities/austin, accessed April 14, 2009.

efficiency in everything we do,"[92] it remains to be seen how much of the institutionalization of climate concerns will be required of state and local transportation departments.

Recent movement at the federal level suggests that some key transportation-related GHG policies are likely to bypass the state governmental level. The Obama Administration's recent negotiations with California and others on the proposed raising of fuel economy standards indicates that previous allowances for more stringent engine standards from California-led efforts will be substituted for the currently proposed unified federal standard. Similarly, states have small to nonexistent roles in implementing the federal renewable fuel standards that reduce fuel GHG emissions. In addition, EPA's recently proposed GHG emissions reporting rule bypasses the role of states in collecting, validating and reporting information and instead requires affected entities to report GHG data to EPA directly.

The legislative mechanism for regulating GHG emissions, if pursued, will also define the roles of state and local transportation entities. If GHG emissions are regulated through the Clean Air Act (CAA), transportation agencies would presumeably add GHG emissions to the list of pollutants they already manage through CAA and NEPA regulations. However, GHG regulations through a national cap-and-trade program will require a new and different management structure. A cap-and-trade system would most likely impose a carbon fee either upstream at the terminal rack or refinery or downstream at the individual emitter (household, business) level. Either way, transportation entities could expect to see their own fuel tax revenues decrease (due to reduced fuel consumption) while fuel costs related to their own activities would increase. Transportation or environmental agencies would likely need to help to coordinate existing state fuel taxes with a new cap-and-trade collection system, but transportation agencies may conceivably be required to do little else in terms of cap-and-trade administration.

One area where state and local transportation agencies will continue to play a key role is land use issues and factors that influence VMT. However, the federal government could start to exert influence over decisions by creating incentives for activities to increase transportation efficiency while reducing VMT and establishing new deterrents for projects that increase transportation activity and system inefficiencies. Examples of tools for exerting more influence

[92] Zamurs, John, "New York State DOT Strategies for Climate Change," Presentation at the Northeast Association of StateTransportation Officials (NASTO) Annual Conference, June 9, 2008, Pittsburgh, Pennsylvania

over the process could include pricing policies, the establishment system of use-related performance standards for state and local entities, or linking funding allocations to GHG emissions outcomes.

The current allocation of highway trust funds to states creates a disincentive for reducing VMT and Congress may choose to address this and the insufficient levels of highway funds through a revised allocation scheme or a different funding mechanism. One option would be for the federal government to allocate revenues from a cap-and-trade system to transportation projects that adapt to climate change, reduce VMT or address GHG emissions.

Accountability as it relates to GHG emissions could likely be a new feature of transportation relations among federal, state and local transportation agencies. State and local entities may be tasked with reporting on GHG-related factors and/or establishing GHG inventories and tracking emissions trends. Any national GHG reduction goals could similarly be passed down to states in the form of regional emissions targets and GHG action plans. Should this occur, the experience of California, New York and Austin presented in this technical memo can provide guidance.

Global warming and the effects of GHGs are new to federal, state, and local policy actions and have not yet reached true regulatory status. However, it appears that GHGs will come under increased attention and possibly regulation. As a result, while there are many uncertainties regarding the future GHG policies and their effects on state and local transportation agencies, the need to monitor and begin to reduce GHG emissions is evident. Climate change is likely to significantly affect the transportation system through more extreme weather events and patterns. While not covered in the scope of this technical memo, there is much research on adapting to climate change in the transportation sector and the need to protect infrastructure through preparing for upcoming climatic changes. This interest is increasing in Texas, too. For example, earlier in 2009 TxDOT issued a request for proposals for one RMC project to address the effects of climate change on the Texas transportation system.

4. OPTIONS AND OPPORTUNITIES

The behavior, public health consequences and impacts of MSATs and greenhouse gases are very different. Yet, the two share similar (current) mitigation strategies, with a few notable exceptions. In this section, options that reduce *both* non-criteria pollutants are identified. These options will avoid a trade-off between pollutants since some measures could reduce one group of pollutants and increase the other.

However, the approach and management of the two classes of pollutants will differ. MSAT and GHG emissions differ in a key factor that sets the context for reduction: exposure. For MSAT emissions, their proximity to humans is an integral component of increasing the risk of human health effects and the locality or proximity of emissions is important. Reducing exposure to vulnerable populations such as children, the elderly and infirmed is particularly important. In contrast, the harm created by GHG emissions is not one of localized human exposure, but of global balance. A ton of carbon reduced in Pecos, Texas is of equal benefit to a ton of carbon reduced in downtown Houston.

In addition, the two non-criteria pollutant classes are under a different regulatory framework. MSAT emissions are a part of the environmental review process and EPA regulates MSAT emissions at the manufacturer level. In contrast, there are currently no federal GHG regulations to date, although there has been much action at the state levels. For these reasons, options regarding the management of MSAT and GHG emissions will be handled separately.

SHARED EMISSIONS STRATEGIES FOR MSAT AND GHG EMISSIONS

While reducing MSAT and GHG emissions is important each in its own right, efforts can be leveraged by identifying strategies that reduce both classes of emissions. Table 7 outlines various emissions reduction strategies and whether they have a positive (symbolized by a "+"), negative (symbolized by a "-") or unknown (depicted by a "?") impact on emissions. Some strategies may have a positive effect on some particular pollutants within a class and a negative effect on others. These strategies are depicted with a "±" symbol and are most common among the alternative fuel strategies. For example, ethanol usage decreases benzene and 1, 3-butadine emissions but increases formaldehyde and acetaldehyde.

As shown in Table 10, there are plenty of emissions reduction strategies that reduce both classes of pollutants. Some of the positive strategies simply reduce the total amount of emissions per unit of output, and can be technology, land use or behavior based, such as VMT reductions or driver/operator behavior. Other strategies provide a smoother or smarter transportation system and decrease inefficiencies within the system.

The only class of strategies that do not consistently reduce emissions of both pollutant classes is non-electric alternative fuels. Rather than eliminate these strategies from consideration, alternative fuels merely require an additional level of detail for evaluating emissions reduction impacts. As previously discussed, the feedstock and production process for alternative fuels significantly influence greenhouse gas reductions. For MSAT reductions, more study is needed to provide the level of detail required to predict the emissions impacts of many alternative fuels. For example, EPA has not determined biodiesel's effects on benzene and 1, 3-butadiene, which is affected by feedstock, production process and the presence of fuel additives.

Regardless of the complexity of fuel strategies, a focus on shared emissions reduction strategies that reduce both MSAT and GHG is important for leveraging efforts. Reduction efforts focused on one pollutant are leveraged for reducing another. For example, policies that reduce idling for air toxic benefits should also be seen as a GHG reduction strategy. Similarly, criteria pollutant strategies that also reduce MSAT or GHG emissions should be valued for their multi-pollutant reductions.

Table 10. Emissions Strategies for Reducing MSAT and GHG Emissions

Category	Emissions Strategy	Reduces Emissions from: MSAT	Reduces Emissions from: GHG
Vehicle Measures	Fuel Efficiency	+	+
	Idle Reduction	+	+
	Aerodynamic devices	+	+
	Low rolling resistance tires	+	+
	Newer engines[1] (vehicle or engine replacement)	+	+
	Diesel Retrofits[2] (ex- diesel particulate filters, diesel oxidation catalysts, selective catalytic reduction systems)	+	+, ±
Fuel Options	Ethanol	±	+
	Biodiesel	+, ?	+
	Natural Gas (CNG, LNG)	±, ?	+
	Hydrogen[3]	+	±
	Electricity[4]	+	+
Activity Reduction	VMT reductions (increased transit, non-SOV travel, land use strategies)	+	+
	Mode shifting (truck to rail or marine)	+,? †	+
	Improved logistics	+	+
System Operation	Congestion mitigation	+	+
	Driver/Operator education	+	+
	Right sizing equipment	+	+

[1]Many vehicle and engine replacements to newer standards will reduce GHG emissons, but the benefit will depend on the replacement engine meeting stricter fuel economy standards.

[2] Diesel retrofits reduce PM and/or NOx, which are indirect GHGs. However, some DPFs have fuel economy effects.

[3]Hydrogen GHG emissions will depend on whether the hydrogen is liquid or gaseous.

[4] Assumes the national average fuel mix for emissions coming from electric generation.

† Overall MSAT emissions reductions can be reduced overall through mode shifting, but will depend upon human proximity to rail or marine emissions.

MSAT OPTIONS AND OPPORTUNITIES

Unlike GHG emissions, MSATs require human exposure to pose a public health risk. For this reason, there are strategies unique to reducing MSAT emissions. Also in contrast to GHG emissions, MSAT concerns are formally integrated into the environmental review process and are regulated by EPA. As mentioned previously, FHWA has provided interim guidance for the appropriate level of MSAT analysis required for different projects. This research did not uncover any substantial evidence that this guidance is insufficient to date. Similarly, the more detailed and rigorous five tiered approach provided in NCHRP 25-25 Task 18 provides useful guidance for large projects with a high level of potential MSAT effects. However, several relevant research and modeling efforts are underway that may provide more information in the future on how MSAT emissions should be handled in the transportation process. FHWA is currently evaluating its interim MSAT guidance to see if revisions are appropriate.[93]

MSAT Analysis Consistency

Federal guidance does not stipulate detailed methodology and data sources required for different levels of MSAT analysis, and the result is an inconsistency among MSAT analyses. Projects in some areas may undergo a thorough and rigorous analysis, while other areas may rely on assumptions and shortcuts. Providing consistency in the MSAT analysis process for developing “quantitative” analysis cited in the FHWA interim guidance could eliminate discrepancies, irregularity and possible laxity in the quality of analysis.

North Central Council of Governments’ (NCTCOG) EmiLink could be adapted to other areas to provide the consistency in methodology needed for a project level quantitative MSAT review. This tool is considered by NCTCOG to be appropriate for projects that have an annual average daily traffic (AADT) volume of 140,000 or more. The EmiLink module is used on the back end of a regional travel demand model to estimate emissions for every roadway link hourly, daily and annually. It can consistently incorporate MOBILE 6 emissions factors and Highway Performance Monitoring System (HPMS) and Automatic Traffic Recorder data for VMT and volume calculations. NCTCOG is prepared to update EmiLink to utilize EPA’s MOVES model

[93] Clagget, Michael, FHWA Air Quality Modeling Specialist, personal communication, October 28, 2008.

inputs when they are finalized.[94] Links that are expected to have a volume change (of ± 5 or 10 percent) are identified, along with VMT changes. The emissions impacts of a project's affected links are calculated, and outputs allow for easy build and no-build comparisons of MSAT levels.

NCTCOG used EmiLink to estimate MSAT emissions on the Loop 12 project and results were consistent with traditional modeling techniques performed by TTI. NCTCOG has since used EmiLink for several projects and experience has found that EmiLink reduces calculation time and cost while also providing analytical consistency.[95]

TxDOT could help other regions acquire EmiLink's benefits in MSAT analysis by encouraging the adaption of EmiLink to other areas. Most regions in Texas depend upon TransCAD software, which is used by EmiLink and eases the adaption process, when compared to other software platforms. The Houston-Galveston area does not use TransCAD, but is exploring whether to adapt EmiLink for their purposes or develop something similar. Fostering use of the module statewide would have the added benefit of building off of NCTCOG's experience and precedence with using the tool for MSAT analysis.

Reduce Public Exposure

While EPA currently states that the tools are not available for conducting quantitative local hot-spot analysis, there is evidence that emissions concentrated near roadways (within 200 meters) can have adverse public health consequences, and that pollutant concentrations associated with roadway emissions decrease exponentially with distance.[96,97,98] Therefore,

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[94] Madhusudhan Venugopal, NCTCOG, Air Quality Technical Planning and Analysis Section, personal communication, April 22, 2009.

[95] Christopher Klaus, M. Venugopal, et al, "EmiLink: A Quantitative Mobile Source Air Toxics (MSATs) Analysis Tool for the Dallas Fort Worth Region: Loop 12 Roadway Alternative, A Case Study," Presented in 2008 at the 17th Annual International Emission Inventory Conference: Inventory Evolution - Portal to Improved Air Quality, Portland, OR.

[96] Lin, S., J. P. Munsie, S. A. Hwang, E. Fitzgerald, and M. R. Cayo, "Childhood Asthma Hospitalization and Residential Exposure to State Route Traffic," *Environmental Research*, Vol. 88, 2002, pp. 73-81.

[97] Zhu, Y., W. C. Hinds, S. Kim, S. Shen, and C. Sioutas. Study of Ultrafine Particles near a Major Highway with Heavy-Duty Diesel Traffic. *Atmospheric Environment*, Vol. 36, 2002, pp. 4323-4335.

[98] David Allen, A. DenBleyker, et al, "Draft Report: Air Pollutant Concentrations Near Roadways," Submitted to Texas Commission on Environmental Quality, 2007.

reducing the exposure of high levels of roadway emissions to vulnerable populations close to the roadway, where possible, should be a consideration in the transportation process, as outlined in FHWA interim guidance.

There are several studies underway that will provide valuable insight on MSAT mitigation. FHWA's near roadway study will provide dispersion data and illustrate the behavior of roadway emissions. EPA is currently studying the effects of vegetation and barriers to reduce exposure to MSAT emissions. TxDOT may benefit from utilizing the study results when they are available and want to pass them on to MPOs for local use.

In the absence of clear mitigation guidance, several transportation projects have included mitigation measures that TxDOT could employ for significant projects with high levels of exposure to vulnerable populations or projects that have elevated levels of public concern (such as Houston's recent Katy Freeway project). Mitigation efforts close to major highway facility improvements could include:

- High efficiency air filtration systems in schools, daycare centers, nursing homes, hospitals and facilites for seniors;
- Diesel retrofits of school buses, emergency vehicles or other diesel sources that serve vulnerable populations; and
- Contract provisions with construction contractors that limit public exposure to construction activities.

Nevada Department of Transportation's litigation settlement for I-95 included the monitoring of MSAT concentration levels at schools near the highway, the installation of air filtration devices and the relocation of some school buildings and playgrounds. California Department of Transportation has also used air filtration systems to reduce MSAT concerns near roadways. Filter systems with a high Miminum Efficiency Reporting Value (MERV) in excess of 13 can remove particles sized less than 1.0 µm. Highly efficient systems rated 17 or more can remove particles that are smaller than 0.3 µm, which would include a significant portion of diesel particulate matter.[99]

Diesel retrofits of school buses, hospital vehicles and other diesel sources used in proximity to vulnerable populations can also be effective in reducing exposure. Diesel

[99] American Society of Heating, Refrigeration and Air-Conditioning Engineers, 1999. ANSI/ASHRAE Standards 52.2.

particulate filters can reduce particulate matter by 90%. Similarly, construction contract provisions requiring the retrofit of equipment, idle control and location of diesel equipment away from the public and building air intakes can reduce potential health risks during the construction process. The Northeast Diesel Collaborative (NEDC) has developed a model contract specification that limits diesel emissions and exposure to the general public. While Texas DOT also has clean contracting incentives, they could be strengthened for projects with a high potential for MSAT effects. State transportation agencies for Connecticut, Illinois, Maryland, Massachusetts and Oregon have also adopted construction provisions.[100]

GREENHOUSE GAS OPTIONS AND OPPORTUNITIES

Global climate change and GHG emissions are international issues that will rely on the collective efforts of individuals and all levels of government. Decisions are being made now on the national response to climate change. As the seventh largest emitter in the world, Texas could become a focus for emissions reductions and has a stake in policy discussions currently taking place. The following opportunities could help TxDOT and Texas move forward in proactively responding to GHG emissions.

Monitor and Analyze Federal GHG Efforts

While states have traditionally been the leaders in the nation's GHG efforts, the federal government is starting to take significant action. While the direction and form for regulating GHG emissions is not yet clear, the necessary groundwork is being laid. Just a few months after President Obama's inauguration, EPA proposed a mandatory GHG reporting rule. While the current version of proposed rule does not require state-level reporting, it will provide a mechanism for gathering the necessary information for the creation of a cap-and-trade program.

In April, 2009 EPA took a crucial step toward garnering the ability to regulate GHG emissions under the Clean Air Act by proposing to find that GHG emissions do endanger the public's health and welfare. The proposal cites that on-road vehicles are responsible for 24% of total US GHG emissions and more than 4% globally. This endangerment finding answers the question posed by the 2007 Supreme Court case *Massachusetts v. EPA* about the scientific

[100] U.S. EPA, "Construction Air Quality Language," http://www.epa.gov/cleandiesel/construction/contract-lang.htm, accessed April 21, 2009.

certainty underpinning an endangerment finding. Although the endangerment finding does not by itself trigger any GHG regulations on entities, it is a crucial step toward regulating GHG emissions under the Clean Air Act.[101] While EPA has prepared a path for GHG regulation under its auspices, Congress is also proposing alternate plans. The proposed American Clean Energy and Security Act of 2009, proposed by Henry Waxman and Ed Markey, would set emissions limits and establish and cap-and-trade program.[102]

The outcome of any federal GHG efforts is likely to significantly impact transportation systems. With new developments occuring frequently on climate change, it is clear that a close monitoring of GHG policy efforts will be needed if TxDOT and other transportation stakeholders are interested in providing input on the process. Since these decisions are being made now, it could be prudent for TxDOT to understand and participate in the policy development process through the appropriate means. Climate change and GHG issues are complex and TxDOT and other entities may need to make some management decisions to provide sufficient staff expertise and resources to effectively monitor and analyze ongoing GHG policy efforts. Specifics are provided in the following option.

Establish an Organizational Framework for Addressing GHG Issues

In addition to transcending borders, GHG issues transcend divisions, agencies and organizations. Establishing a network with other entities that have a similar stake in GHG issues will help leverage efforts and resources while keeping TxDOT informed and participating in policy developments. This organizational framework could include internal and external coordination.

Internal Organization - GHG issues touch multiple divisions, districts and departments. Planning, opearation, materials and maintenance all play a role in either contributing to GHG emissions or needing to eventually adapt to the effects of GHG emissions. Internal coordination across departments can be informal or formal, but would best be facilitated by central coordinator that is accountable for sharing information across departments and ensuring

[101] U.S. EPA, "Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act," http://epa.gov/climatechange/endangerment.html, accessed April 22, 2009.

[102] Power, Stephen, "Obama Officials Urge Cap on Greenhouse Gas Emissions," *Wall Street Journal*, April 22, 2009.

consistency with any agency positions. Adequate staff time and expertise would ideally be allocated to monitoring and participating in policy process while national climate change policies are being developed.

External coordination - The state executive branch and other state agencies such as the State Energy Office and the Texas Commission on Environmental Quality have stake in climate change and GHG issues. Designated TxDOT staff could maintain regular contact with the appropriate contacts within those organizations and provide technical assistance as necessary. Continued TxDOT participation in relevant groups such as the Technical Working Group for Mobile Source Emissions, the Texas Clean Air Working Group and AASHTO will be valuable.

Educating and providing resources to the Texas MPOs is also a crucial part of addressing GHG emissions. Land use, transportation policy and GHG emissions are irreversibly linked. TxDOT can help educate MPOs on GHG emissions, share relevant information across organizations and provide technical assistance as needed.

Senior Management Involvement - If Texas is to have a strong voice in policy and funding discussions, TxDOT senior management would need to help state policy makers stay abreast of significant GHG developments that affect transportation. As discussed previously, GHG policies and related funds are being currently being formulated and debated at the federal level, and will likely impact the state and transportation system. TxDOT officials may need to be equipped and prepared to assist state policy makers as appropriate with information on how proposed policies may affect the state. Senior TxDOT officials should be well briefed on the underlying science behind transportation-related GHG emissions and the issues, policy options and funding implications currently being discussed. This technical memo can serve as a starting point for these discussions.

Establish a Transportation GHG Emissions Inventory

Emissions inventories are critical components of pollutant management. They provide essential information for strategic policy making by identify major sources of pollution, providing the scale and scope of emissions and uncovering emissions trends. Emissions inventories lay the foundation for setting quantifyable goals and targets, as well as tracking progress towards benchmarks. Establishing a transportation GHG emissions inventory will help the state identify the modes, vehicle classes, trends and behaviors of GHG emissions. An inventory can illustrate where Texas' GHG emissions might differ from other states and reflect the unique commerce and transportation patterns in Texas. For example, an emissions inventory would account for the marine emissions along the inter-coastal waterway and the international freight traffic coming from borders and ports. As GHG policies develop nationally, a GHG inventory could also be instrumental in adapting and complying with new policy efforts.

Investigate Participation in Regional GHG Mitigation Efforts

Regional GHG policy efforts leverage the knowledge, experience and political support of other states, while also providing an effective means of reducing emissions. Currently in there are major regional efforts taking place to reduce transportation related GHG emissions through low carbon fuel standards. These efforts are more effective from both a compliance and air quality standpoint when they cover broad geographical areas and markets.

To date, three areas have or are forming a low-carbon fuel standard. While the neighboring states around Texas are not currently participating in the low carbon fuel efforts, Texas could consider forming a bridge to the midwestern fuel standards that are currently under development or provide a southern anchor for a separate but similar effort. The agency could undertake a future study to thoroughly investigate the potential, options and implications in adopting a low-carbon fuel standard.