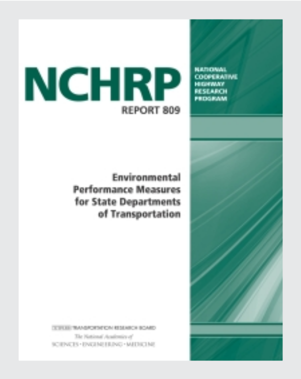

Environmental Performance Measures for State Departments of Transportation

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 809

Environmental Performance Measures for State Departments of Transportation

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TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Recognizing this need, the leadership of the American Association of State Highway and Transportation Officials (AASHTO) in 1962 initiated an objective national highway research program using modern scientific techniques—the National Cooperative Highway Research Program (NCHRP). NCHRP is supported on a continuing basis by funds from participating member states of AASHTO and receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine was requested by AASHTO to administer the research program because of TRB's recognized objectivity and understanding of modern research practices. TRB is uniquely suited for this purpose for many reasons: TRB maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; TRB possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; TRB's relationship to the Academies is an insurance of objectivity; and TRB maintains a full-time staff of specialists in highway transportation matters to bring the findings of research directly to those in a position to use them.

The program is developed on the basis of research needs identified by chief administrators and other staff of the highway and transportation departments and by committees of AASHTO. Topics of the highest merit are selected by the AASHTO Standing Committee on Research (SCOR), and each year SCOR's recommendations are proposed to the AASHTO Board of Directors and the Academies. Research projects to address these topics are defined by NCHRP, and qualified research agencies are selected from submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academies and TRB.

The needs for highway research are many, and NCHRP can make significant contributions to solving highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement, rather than to substitute for or duplicate, other highway research programs.

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FOREWORD

By Lori L. Sundstrom
Senior Program Officer
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NCHRP Report 809: Environmental Performance Measures for State Departments of Transportation identifies potential key environmental performance measures that can be integrated into a state DOT's performance management program and provides a practical approach for adding environmental performance considerations to the suite of other performance topics that state DOTs routinely monitor, e.g., pavement conditions. The report establishes relationships between agency activities and environmental outcomes thereby providing a means for demonstrating progress and accountability for environmental performance. The report should be of immediate use to DOT executives and senior managers who set performance goals for their agencies, as well as for staff charged with designing and implementing an environmental performance program.

A spreadsheet-based "Measure Calculation Tool" was developed to help state DOTs interested in implementing the project's chosen performance measures. The tool can be used to record the component data needed to calculate the measures. The tool is available for download from the project summary webpage at http://www.trb.org/Main/Blurbs/173012.aspx.

Transportation performance management is an established and effective practice for building accountability and driving results in transportation agencies. The American Association of State Highway and Transportation Officials (AASHTO); the Federal Highway Administration (FHWA); and others are actively engaged in determining how to implement performance-based management of surface transportation programs in state departments of transportation (DOTs).

In 2004, the chief executive officers of the state DOTs established the NCHRP Project 20-24(37) series in recognition of the potential for comparative performance measurement to contribute to both continuous improvement and accountability. Nationally, Congress and the U.S. Department of Transportation have also expressed interest in incorporating performance measures in the identification and prioritization of federal investments in transportation infrastructure. A number of potential national comparative performance measures, including environmental performance measures, are suggested for further research in the NCHRP Project 20-24(37G) Report, "Technical Guidance for Deploying National Level Performance Measurements."

Under NCHRP Project 25-39, High Street Consulting Group, Inc., was asked to build on the research conducted under NCHRP Project 20-24(37G) and identify potential comparative environmental performance measures that would (1) be meaningful at a state level, (2) enable national comparisons, (3) be implementable in the near-term, and (4) contribute to informing investment decisions. Performance areas investigated included (1) air, (2) water, (3) materials and recycling, (4) energy, (5) greenhouse gases, and (6) biodiversity and habitat, but did not include social and economic impacts, environmental justice, or cultural resources. For each of the potential measures, the research team associated the measure with environmental outcomes; examined data requirements; calculation methodologies and how to set appropriate baselines; and suggested approaches for integrating the measures into planning, programming, project development, project delivery, and operations and maintenance functions.

NCHRP Report 809 should be useful to agency staff with responsibility for developing and maintaining agencywide performance management systems, and to executive and senior management in identifying policies and actions needed to improve an agency's environmental performance.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

SUMMARY

Environmental Performance Measures for State Departments of Transportation

OBJECTIVE

Start a national dialogue about the makeup of **a suite of core environmental performance measures** that help state DOTs understand and communicate the impacts of transportation on the environment and make more informed business decisions

FIVE FOCUS AREAS

- **Air quality**
- **Energy and climate**
- **Materials recycling**
- **Stormwater**
- **Wildlife and ecosystems**

PROOF OF CONCEPT TESTING (27 STATES)

CA, CO, DE, FL, GA, IL, IA, ME, MD, MN, MO, NE, NJ, NM, NC, ND, OH, OR, PA, SC, SD, TX, UT, VT, VA, WA, WY

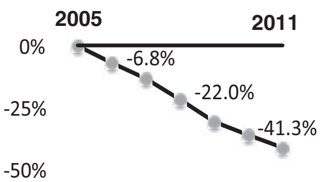
THE RESEARCH METHOD

Select **environmental focus areas** and identify universe of **200+ possible measures**;
Screen **suggested measures**, based on desired criteria;
Validate suggested measures in **proof of concept tests** with 26 states;
Create detailed methodology guidance for final measures

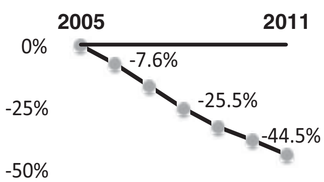
SUGGESTED AIR QUALITY MEASURE

Change in **statewide motor vehicle emissions** for NOx, VOC, and $PM_{2.5}$

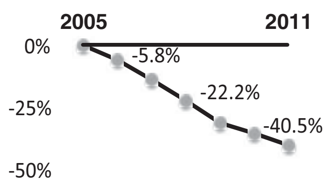
Avg. NO_x reduction for proof of concept states



Avg. VOC reduction for proof of concept states

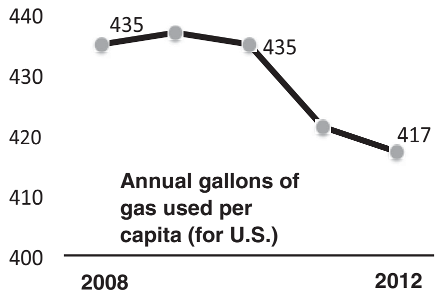


Avg. $PM_{2.5}$ reduction for proof of concept states

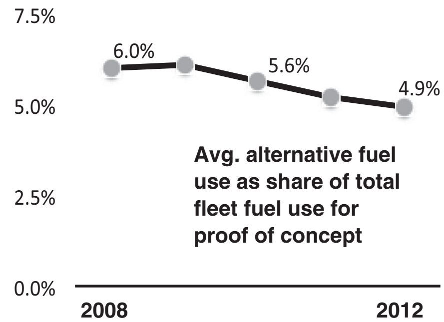


SUGGESTED ENERGY AND CLIMATE MEASURES

Statewide on-road **gasoline consumption per capita**

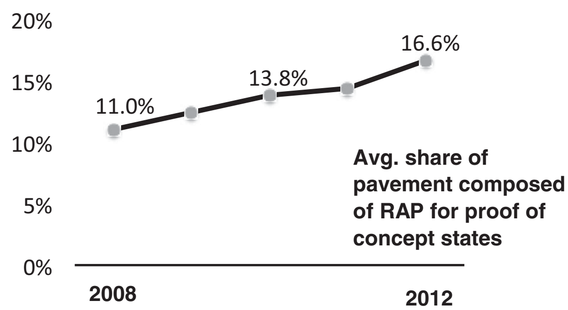


State DOT fleet **alternative fuel use** as percent of total fleet fuel use (by vol.)



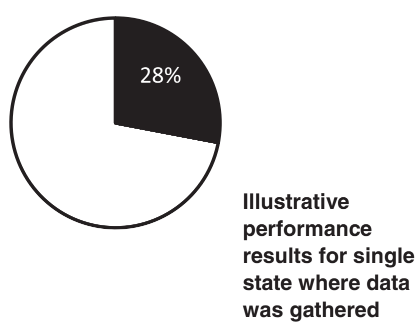
SUGGESTED MATERIALS RECYCLING MEASURE

Annual percent by mass of all roadway asphalt pavement materials composed of **reclaimed asphalt pavement (RAP)** used by state DOT



SUGGESTED STORMWATER MEASURE

Percent of state DOT-owned **impervious surface for which stormwater treatment is provided**



SUGGESTED WILDLIFE AND ECOSYSTEMS MEASURE

Self-administered ecosystems self-assessment tool (ESAT) composed of 41 questions that evaluate performance across all aspects of state DOT programs relevant to wildlife and ecosystems

MEASURE PROOF OF CONCEPT TESTING RESULTS

	Supports Consistent Application from State to State?	Data Exists or Is Easy to Generate?	Data Quality Is Credible and Defensible?	Implementation Readiness
Vehicle Emissions	●	◑	◕	Ready for use by many DOTs today
Alternative Fuel Use	◕	◕	●	Ready for use by many DOTs today
Gasoline Consumption	●	●	●	Ready for use by many DOTs today
RAP Usage	●	◑	◕	Ready for use by many DOTs today
Stormwater Treatment	◑	◔	◔	Suitable for use by DOTs in longer term
Ecosystems Self-Assessment Tool	◑	●	◑	Suitable for use by DOTs in longer term

Key

● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

CHAPTER 1

Introduction

1.1 Transportation, Environment, Performance Management, and MAP-21

Transportation supports ease of movement, access, and economic health for the businesses and communities it serves; but building and operating transportation systems also have indisputable impacts on the air, the water, and the natural ecosystems that constitute the biophysical environment, which sustains lives and supports livelihoods across the United States.

Over the last decade and longer, performance management has emerged as a mainstream business practice widely used among state departments of transportation (DOTs), in which performance measures and targets are lynch pins that link agencywide organizational strategic goals—like safety, access, mobility, or economic prosperity—with decisions about how to make best use of staff resources and funding to influence desired outcomes (*1*).

Beginning in 2016, state DOTs and their partners at Federal Highway Administration (FHWA) will undertake a congressionally mandated initiative required by the Moving Ahead for Progress in the 21st Century Act (or MAP-21) to require common national-level measures of performance for safety, infrastructure condition, and system performance, featuring standardized measures across states, consistent target setting practices, and regular performance reporting.

While state DOTs are increasingly harmonized in their approaches to performance measurement for areas like infrastructure preservation, safety, and congestion, their strategies for measuring environmental performance could fairly be described as a scattered assortment of hundreds of measures with each state left to reinvent its own wheel. No guidance existed for practitioners, prior to this report, on which measures might be most useful, or how to use them.

By establishing and demonstrating the practicality of a suite of core environmental measures, this report's purpose is ultimately to kick-start a nationwide conversation among transportation practitioners and their stakeholders about the kind of environmental performance measures that might complement the national-level transportation measures now emerging in other areas.

1.2 Report Framework

This report is based on the findings of National Cooperative Highway Research Program (NCHRP) Project 25-39. It suggests a suite of core environmental performance measures designed to help state DOTs better understand and communicate the impacts of transportation on the biophysical environment and ultimately to make more informed business decisions that build stronger, more efficient linkages between transportation and the environment and provide greater accountability for their impacts on the environment.

Each of the report's suggested measures has been tested with available data gathered from state DOTs. The proof of concept testing shows that several of the proposed measures are broadly ready to implement, while two (for stormwater and for wildlife and ecosystems) will require capacity building, but offer great potential. The report includes the following:

- **Suggested Focus Areas and Measures.** Suggestions on a core set of environmental performance measures built around common environmental focus areas that are relevant to all or many states (Chapter 2 and Chapter 3);
- **Proof of Concept Demonstrations.** Testing each measure, based on real-world data provided by a group of 27 volunteer state DOTs, to gauge its validity, practicality, and value (Chapter 4);
- **Advice on Using and Reporting Environmental Performance Measures.** Almost as important as the measures themselves is the report's identification of compelling and easy-to-implement approaches for using and reporting performance results that encourage their rapid adoption (Chapter 5 and Chapter 6);
- **Measure Methodology Guidelines for Core Measures.** Detailed guidance for state DOTs that describes the data sources and methods for calculating each of the measures (Chapter 7); and
- **Conclusions.** Including suggestions for future research (Chapter 8).

Overall, this report proposes a succinct set of road-tested and broadly applicable environmental measures suitable for comparative performance analysis among state DOTs that takes the field beyond the current state of the practice. Its intended audience is state DOTs that are seeking to develop better environmental performance measurement programs and policy makers interested in strengthening their use of performance measures.

1.3 A Word of Caution

The measures suggested in this report should be considered neither perfect nor permanent. As in other areas where state DOTs are attempting to measure their performance, the search for the ideal measure is best characterized as a continual journey whose path is regularly redirected by shifts in industry practices, technology, or politics, among many other factors. Nonetheless, the measures proposed here should be considered a useful map for the path ahead in developing more robust state DOT environmental performance measures. Chapter 8 contains some directions for future research.

CHAPTER 2

Environmental Focus Areas

Transportation policy makers sometimes speak of the environment as a single strategic priority, alongside other concerns such as safety, infrastructure preservation, or congestion. In reality, however, the environment is a complex and multi-faceted topic for which performance cannot easily be captured by a single metric. As a result, the measures proposed in this report are based on a set of five major focus areas within the broad universe of the biophysical environment:

- Air Quality
- Energy and Climate
- Materials Recycling
- Stormwater
- Wildlife and Ecosystems

These five focus areas were chosen because they are indisputably national-scale environmental concerns where transportation is generally accepted to contribute to adverse impacts. Together, they comprise a comprehensive and broadly shared set of environment-related interests held by most or all state DOTs that provides a credible foundation from which to create strong measures.

2.1 Air Quality

Motor vehicle air pollution is a concern in urban areas of all states. Motor vehicles are a source of emissions of the precursors to ground-level ozone including nitrogen oxides (NO_x) and volatile organic compounds (VOC). Ground-level ozone can trigger a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis (*2*). There are 46 ozone nonattainment areas in the United States, affecting 21 states.

Motor vehicles also produce emissions of fine particulate matter ($PM_{2.5}$). Many scientific studies have linked breathing particulate matter to significant health problems, including aggravated asthma, decreased lung function, and heart attacks (*3*). For $PM_{2.5}$, 32 regions of the United States are designated nonattainment areas, affecting 18 states.

Carbon monoxide is no longer a major air quality concern; there are no carbon monoxide nonattainment areas in the United States, although some carbon monoxide maintenance areas are still in place.

Under the federal Clean Air Act, states with air quality nonattainment areas are required to take planning steps to reduce emissions to meet national ambient air quality standards. Even in states that are in attainment for the federal ozone and $PM_{2.5}$ air quality standards, motor vehicle air pollution can still be a concern. Vehicle emissions can cause localized air pollution "hot spots" that contribute to adverse human health impacts. Motor vehicles also contribute emissions of toxic air contaminants, which are not regulated under the Clean Air Act but can cause adverse human health effects even in small quantities.

State DOTs have little direct control over vehicle emissions, which are primarily influenced by the amount of vehicle travel and by federal emissions standards that necessitate vehicle emission control systems. However, DOTs can help to limit air pollution from vehicles through their efforts to improve traffic flow and support multi-modal transportation systems that offer alternatives to driving.

2.2 Energy and Climate Change

In 2011, transportation was responsible for 28 percent of total primary energy consumption and 28 percent of all greenhouse gas (GHG) emissions produced in the United States (*4*). Transportation's share of total energy consumed and GHG emissions produced has risen steadily over time. The majority of transportation's impact on energy consumption and GHG production is caused by combustion of fossil fuels, particularly oil-based fuels.

Most scientists agree that increased concentrations of GHG in the atmosphere are the primary cause of climate change. Concentrations of GHG emissions in the atmosphere have risen steadily since at least the mid-20th century and are projected to continue to rise. The effect of GHG emissions is cumulative, because it takes many decades for these gases to break down in the atmosphere or be reabsorbed into land and water masses. Adverse effects of climate change include increasing average temperatures, more extreme weather events, and rising sea levels. These effects in turn lead to changes in ecosystems and threats to the built and natural environments. Impacts will vary from place to place, and some areas of the world will be affected by climate change more than others.

In addition to influencing climate change, energy consumed by transportation in the United States presents substantial financial and national security challenges. Fuel for transportation consumes nearly 4 percent of the average household's total budget, according to the U.S. Energy Information Administration, and net imports of petroleum accounted for 33 percent of all petroleum consumed in the United States in 2013, more than half of which was imported from Organization of the Petroleum Exporting Countries (*5*).

Reducing energy use and GHG emitted from transportation are the focus of numerous state and federal regulations. At the federal level, the U.S. DOT corporate average fuel economy regulations mandate fuel economy requirements for on-road vehicles, and the EPA Renewable Fuel Standard requires the use of minimum amounts of non-petroleum fuels. A number of states have established targets or mandates for GHG reduction or use of alternative fuels in transportation.

While transportation energy use is a major contributor to GHG emissions, state DOTs have relatively little direct control over the energy consumed and GHG produced by the transportation systems in their states. Economic and demographic trends; land use patterns; and federal, state, and local regulations all play a role in determining how much energy is used by transportation. State DOTs can promote, but not control, use of alternative fueled vehicles by the traveling public and development of multi-modal transportation systems that allow for more travel by transit and non-motorized modes.

State DOTs can control many aspects of their own energy use and GHG emissions. Many state DOTs have taken steps to establish or increase use of alternative fueled vehicles in their own fleets. Alternative fueled vehicles reduce the consumption of petroleum-derived fuels in most cases, and of GHG emissions in many cases. The most common types of alternative fuels used in state DOT fleets are ethanol, biodiesel, compressed natural gas (CNG), liquefied petroleum gas (LPG), and electricity. Hydrogen fueled vehicles may also be present in some state DOT fleets.

Large organizations like state DOTs have a distinct advantage in the use of alternative fueled vehicles. Most alternative fueled vehicles are available in limited model types and from just a few manufacturers. Some vehicle types are not available to the general consumer at all. State DOTs are better equipped to acquire vehicles through bulk purchases. More important, state DOTs have the economies of scale needed to make some types of emerging fuels viable. State DOTs can maintain their own fueling infrastructure and vehicle maintenance facilities required for some fuel types, which would be prohibitively expensive for individuals or for smaller fleets.

2.3 Materials Recycling

The transportation sector is one of the nation's largest users of virgin aggregates, asphalt, cement, and reinforcing steel. These four types of raw materials are needed in large quantities to build and maintain the country's highways. The U.S. DOT's FHWA estimates that an average of about 700 million tons of aggregates is needed each year to build and maintain America's roads, which consume about 30 percent of all aggregates used in the United States, according to the United States Geological Service (*6*, *7*). Many state DOTs seek to substitute either reclaimed pavement or recycled materials in place of virgin materials.

Aggregates including sand, gravel, and crushed stone account for about 94 percent by weight of all material required in highway construction, whether used alone as a base foundation, or in combination with binders to make asphalt and concrete pavement surfaces. After aggregates, the next largest categories of materials used in highway construction by weight are cement and asphalt, which are industrial products used as binders in combination with aggregates to create concrete or blacktop pavements; together they account for about 5 percent of the material consumed in highway construction. The other major material used in highway construction is steel, which is used in culvert pipes, reinforcements, and structural supports and accounts for about 1 percent of the material consumed in highway construction.

Use of aggregates, cement, asphalt, and steel in highway construction and maintenance is expensive and adequate supplies of materials—particularly virgin aggregates—are shrinking in many areas of the United States as land use changes and population growth restrict mining opportunities. Obtaining highway construction materials can also cause damage to the natural environment during extraction and processing, while transporting them from source to job site is often energy intensive. As a result, transportation agencies are continually investigating alternative material options that include reclaimed use of roadway materials and substitution of other recycled materials in place of virgin materials:

- **Reclaimed Asphalt Pavement.** Reclaimed asphalt pavement (RAP) is the term given to reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction or resurfacing. Although old asphalt pavements can be recycled at central processing plants, in-place recycling processes are increasingly common, which include partial removal of the pavement surface, mixing the reclaimed material with beneficial additives, such as virgin aggregate, binder, and rejuvenating agents to improve binder properties, and placing and compacting the resultant mix in a single pass. In 2007, the highway industry used as much as 100 million tons of RAP (*8*).
- **Reclaimed Concrete Material.** Reclaimed concrete material is made of reclaimed Portland cement concrete, and is sometimes referred to as either recycled concrete pavement or crushed concrete. Reclaimed concrete material can be used as an aggregate for either Portland cement concrete or asphalt concrete pavement. It can also be used as a bulk fill material.
- **Other Recycled Materials.** A wide range of alternatives to virgin aggregates can be used in highway construction including foundry sand, scrap tires, and waste glass. Some recycled materials, such as shingles, may be used as aggregate or binder. In addition, recycled products such as blast furnace slag and coal fly ash can be used as supplements to portland cement in concrete.

2.4 Stormwater

The quantity and quality of untreated stormwater runoff from highways can harm water quality and aquatic ecosystems. Runoff occurs if stormwater generated by rain storms or melting snow cannot soak into the ground, and instead either flows directly into surface waters—such as lakes, streams, rivers, estuaries, oceans, and ground water—or is channeled into storm sewers that eventually discharge to surface waters. Runoff from impervious surfaces, such as pavement or buildings, can impair water quality in two ways:

- **Quantity: Erosion and Siltation.** Runoff may cause erosion and sedimentation. Excessive erosion during and after construction of roads, highways, and bridges can contribute large amounts of sediment and silt to runoff waters, which can deteriorate water quality and lead to fish kills and other ecological problems.
- **Quality: Anthropogenic Contamination.** Runoff may contain dissolved or suspended anthropogenic contaminants. The most common contaminants in highway runoff include metals, nutrients, organic compounds, bacteria, or suspended solids that accumulate on the road surface as a result of regular highway operation and maintenance activities. Once contaminants reach surface waters, they can cause water chemistry changes to water systems that threaten human health and ecosystems.

The federal Clean Water Act, as well as some state and local laws, require state DOTs to manage nonpoint source runoff from highways. As part of their compliance with these laws, state DOTs use many methods—called Best Management Practices (BMPs)—to treat highway runoff. Structural BMPs operate by physically trapping runoff until contaminants settle out or are filtered through the underlying soils. Examples of structural BMPs include vegetated swales and infiltration trenches along roadsides that allow highway runoff to settle and filter through grass and soil, and retention or detention basins that capture highway runoff and release it at very slow rates, allowing sufficient time for heavier particles to settle out, evaporate, infiltrate, or be absorbed.

2.5 Wildlife and Ecosystems

Diversity and abundance in wildlife and the integrity of natural habitats are important components of a healthy natural ecosystem. Farming, transportation, housing, and other common land uses have the potential to affect wildlife and natural habitat either by direct removal of habitats or by indirect effects, such as deterioration of habitat quality through fragmentation and influences such as increased light and noise. Habitat quality also affects adjacent lands; an intact forest, for example, can protect stormwater runoff quality and quantity in an adjacent stream.

Of all agencies operating within a given state, a state DOT is generally the only agency with a mission to conduct widespread construction on a statewide scale. Thus, a state DOT has the potential to affect ecosystems and the wildlife that depends on them. Potentially affected resources of greatest concern from both regulatory and environmental perspectives typically include wetlands, habitat for aquatic species, and streams; wildlife movement and migration corridors; invasive species; and threatened and endangered (T&E) species.

Natural habitats vary widely between states, and likewise, each state's resource agencies and DOT may put an emphasis on different natural resource management and preservation issues. For example, wetland functions and values vary greatly among states, depending on the abundance and types of that resource. Further, the impacts of transportation projects are not limited to one regulated habitat type. Thus, measuring the mitigation of impacts on any individual habitat type is not likely to be representative of a state DOT's performance as a whole. Instead, an effective measure should capture a state DOT's efforts on a wide range of natural resources and should be sufficiently flexible to be relevant to numerous states.

CHAPTER 3

Core Environmental Performance Measures

The five environmental focus areas described in Chapter 2 provide this report's high-level framework for a core set of environmental performance measures. In this chapter, a set of useful criteria for selecting effective environmental performance measures is identified and used to select six measures from a universe of almost 200 possible measure options. The measures presented here are subsequently subjected to proof of concept testing with selected states, as described in Chapter 4.

Performance measurement is often described as a journey, and the measures laid out in the second half of this chapter are those that come closest to meeting desired criteria given today's environmental and technological know-how and political constraints. None of the measures, however, is perfect; they should be treated as a step forward in providing DOTs with a practical, yet valuable set of environmental performance measures to be improved over time.

3.1 Measure Selection Process

Early in the research process for this project, the research team developed a list of almost 200 possible measures, based on literature searches and expert knowledge. Screening criteria were developed to aid in choosing the most effective measures from among this list. Appendix A contains the full listing of measures, organized by focus area.

According to the screening criteria developed for the project, in an ideal world, desirable environmental measures should strive to meet all or most of the following five basic conditions:

- **Does Measure Address Issue of Meaningful Significance?** Are changes in the measure's performance likely to have a significant effect on an issue that affects statewide environmental quality? For example, a measure of recycling rates inside a state DOT's office facilities addresses an area of concern, but will not significantly alter statewide recycling rates because the state DOT's waste stream comprises a small fraction of a state's total waste stream.
- **Does Measure Link to Desired Environmental Outcome?** Does the issue targeted by the measure directly create change in a desired environmental outcome, or is it only indirectly linked? For example, a measure of sediment in highway construction site discharges directly influences the environmentally desirable outcome of reduced sediment in receiving waters. A measure of BMP implementation, however, is less directly related to the outcome of reduced sediment in receiving waters.
- **Do State DOTs Have Influence Over Performance Results?** Does the measure track an issue state DOTs can influence? Many measurable aspects of environmental quality are not directly under a transportation agency's control. A state DOT may track vehicle emissions,

for example, but the trend in vehicle emissions is driven by many factors including federal regulations, vehicle technology limits, and travel behavior.

- **Are Measure Results Valuable to Decision Makers?** Does the measure track an issue that is critical to the environmental agenda of many state DOT decision makers in terms of investment or policy choices? In other areas of comparative measurement, measures address high-level issues such as fatalities, bridge conditions, or travel reliability where investment choices have real impacts on desired outcomes of statewide significance.
- **Is Measure Meaningful and Clear to General Public?** To gain public support, members of the public must both understand the measure and care about its outcome. Measures that are clear and meaningful to the public will ensure that elected officials and agency staff rely on the measure as well.

Via a combination of the research team's knowledge and consultation with the NCHRP Project 25-39 panel's experts, the initial list of possible environmental performance measures in Appendix A was winnowed down to a set of measures for proof of concept validation, as described in Chapter 4. In reality, no environmental performance measure is likely to fully meet all of the criteria desired in an ideal measure; the measures presented in the following sections of this chapter have been selected, however, because they were found to come as close as possible to the desired criteria described.

3.2 Air Quality Measure

Measure: Change in Statewide Motor Vehicle Emissions for Nitrogen Oxides, Volatile Organic Compounds, and Fine Particulate Matter

This measure combines information about each state's total vehicle miles traveled (VMT) with EPA emissions factors derived from emissions model outputs, to estimate statewide on-road motor vehicle emissions of ozone precursor pollutants, including VOC, NO_x, and $PM_{2.5}$, which are the Clean Air Act regulated pollutants of most widespread concern among states. A detailed description of the methods for calculating this measure is included in Chapter 7.

As part of the research for this report, several additional air quality–related performance measures were considered but ultimately not selected because they failed to meet desired criteria. Information on these measures is included in Appendix A.

Why Motor Vehicle Emissions Should be a Core Environmental Measure for State DOTs

- **Contribution of Motor Vehicle Emissions to Air Quality Problems Is a Significant Environmental Issue.** Air pollution is an environmental problem in many urban areas; the transportation sector and motor vehicles, in particular, are a major contributor to total air pollutants.
- **Motor Vehicle Emissions Directly Influence Air Quality.** While the measure does not report the ultimate outcome of interest, which is air quality, motor vehicle emissions are closely correlated to air quality and are the subject of national-level regulatory efforts to achieve air pollution reductions.
- **State DOTs Have Influence over Motor Vehicle Emissions.** While state DOTs do not have direct control over motor vehicle emissions, they can contribute to emissions reductions or a reduction in the rate of growth by planning and building multi-modal transportation systems that offer low-emission travel choices and by reducing recurring and non-recurring congestion that causes higher emissions, using operational strategies and targeted capacity improvements. A performance measure focused on vehicle emissions strikes the right

balance between level of state DOT control and the ultimate outcome of interest, which is improved air quality.

- **Motor Vehicle Emissions Can Be Easily Calculated.** The measure can be calculated by all 50 states or for metropolitan regions with existing tools and data sets.
- **Motor Vehicle Emissions Are a Meaningful Metric.** Motor vehicle emissions are widely used in air quality planning and are easy for a broader audience to understand.

3.3 Energy and Climate Change Measures

Measure 1: State DOT Fleet Alternative Fuel Use as a Percentage of Total Fuel Use by Volume

This measure combines information about the volume of alternative transportation fuels used, in gasoline gallon equivalents, by a state DOT's fleet with total transportation fuels used to show alternative transportation fuels as a percentage of all fuel use. A detailed description of the methods for calculating this measure is included in Chapter 7.

As part of the research for this report, several additional energy and climate–related performance measures were considered, but ultimately not selected because they failed to meet desired criteria. Information on these measures is included in Appendix A. In addition, some alternatives to a volumetric calculation of this measure are included and discussed in the Chapter 4 proof of concept testing, including percent of total fuel use on a GHG intensity basis and an energy intensity basis.

Why DOT Fleet Alternative Fuel Use Should be a Core Environmental Measure for State DOTs

- **Increased Use of Alternative Fuels Has a Direct Impact on GHG Emissions.** Substituting alternative fuels for conventional gasoline and diesel directly decreases GHG emissions.
- **State DOTs Have Full Control over Performance Results.** While budgetary and political considerations could influence how much a state uses alternative fuels, performance on this measure is a direct result of state DOT actions.
- **All DOTs Can Easily Measure Their Own Alternative Fuels Use.** Because this is a direct measure of the state DOT's own operations, documentation of alternative fuel use will usually be available within state DOT offices. It can be calculated for all 50 states, and the results are comparable across states.
- **The Measure Is Commonly Used and Is Easily Understood by State DOTs, Decision Makers, and the Public.** Familiarity with the measure will make resistance less likely, and more impactful for decision makers and the public.
- **Alternative Fueled Fleets Can Support Emerging Markets and Set a Positive Example in the State.** By using these vehicles, state DOTs help to support emerging alternative fuels industries and make alternative fuels viable for a wider market; state DOTs can act as demonstration projects and may also explore partnerships with the private sector and other public agencies to establish and promote alternative refueling facilities.

Measure 2: Statewide On-Road Gasoline Consumption per Capita

This measure uses state-level records of gasoline sales as a proxy for in-state gasoline consumption. While factors including cross-border travel and purchase of gasoline for non-road uses introduce some inaccuracies, this method has the advantage of using a measurement system that is consistent across states and based on observed data. A detailed description of the methods for calculating this measure is included in Chapter 7.

Why Gasoline Use per Capita Should Be a Core Environmental Measure for State DOTs

- **Consumption of Gasoline Is Directly Linked to GHG Emissions.** In 2012, transportation contributed approximately 28 percent of total GHG emissions contributed by the United States (*4*). The majority of transportation's impact is caused by combustion of fossil fuels, particularly gasoline.
- **Gasoline Consumption Is Relatable to Other Outcomes of Interest.** Aside from GHG emissions, a reduction in gasoline consumption is linked to other public sector goals such as improving fleet fuel efficiency, limiting dependency on petroleum fuels, and managing VMT growth.
- **State DOTs Have Influence over Motor Vehicle Gasoline Consumption.** While state DOTs do not have direct control over on-road gasoline consumption, they can contribute to reductions by promoting multi-modal transportation systems that improve the attractiveness of carpooling, transit, and non-motorized modes; reducing recurring and non-recurring congestion that contributes to higher gasoline consumption; and providing support for the deployment of alternative fueled vehicles and fueling infrastructure.
- **All States Can Estimate Gasoline Consumption, and Those Estimates Are Comparable across States.** Even without transportation models, it is possible for all states to develop estimates of this measure with current data sources. Gasoline sales data are updated annually and standardized by FHWA.
- **Gasoline Provides a Reliable and Easy to Understand Indicator of Transportation Energy Consumed.** Heavy-duty vehicles—which are largely powered by diesel—marine and air transportation, and fuel consumed in construction and other off-road equipment are excluded from the measure. Gasoline, however, is the principal transportation fuel used in the United States. By focusing on on-road gasoline consumption, the measure targets the sector of the transportation market over which state DOTs arguably have the most influence, which is light-duty vehicle travel.

3.4 Materials Recycling Measure

Measure: Annual Percentage by Mass of All Roadway Pavement Materials Composed of RAP Used by State DOT

This measure examines the annual percent by mass of all roadway asphalt pavement materials composed of RAP used by a state DOT. Reclaimed asphalt pavement is the term given to reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction or resurfacing. A detailed description of the methods for calculating this measure is included in Chapter 7.

As part of the research for this report, several additional recycling-related performance measures were considered, but ultimately not selected because they failed to meet desired criteria. Information on these measures is included in Appendix A.

Why RAP Use Should be a Core Environmental Measure for State DOTs

- **Pavement Materials Are Consumed in Large Quantities Throughout the United States.** State DOTs are constantly building, replacing, or resurfacing roadways. The scale of the nation's road system ensures that large amounts of pavement-related aggregates, binders, and filler will be needed on an ongoing basis to keep the system functioning.

- **RAP Is the Largest Category of Recycled Material among State DOTs.** Among state DOTs interviewed as part of the research for this project, RAP was used at least twice as much the next most popular recycled material, reclaimed concrete, and closer to ten times as much as most other recycled materials.
- **This Measure Is Directly Tied to the Outcome of Interest.** In many environmental areas, there are too many factors that affect the ultimate outcome to both directly measure it and isolate the state DOTs' impact on the outcome. For example, roadway stormwater runoff is only one of many contributors to water pollution. In this case, a measure of recycled materials used is a direct correlate to a reduction in virgin materials used.
- **All States Can Access RAP-Related Information with Moderate Effort.** Contractors know the mix of asphalt they are laying. By enlisting cooperation from contractors, this information can be collected by the state DOT with small changes to reporting rather than an entirely new data collection undertaking.
- **RAP Is the Only Reclaimed or Recycled Material Used Consistently across States.** States often use locally recycled materials that are byproducts of specific industries, such as blast furnace slag from steel manufacturing. Local availability of the various materials that can be recycled into pavement varies greatly across the country, resulting in inconsistent use of other recycled materials among states.
- **Incorporating RAP into Pavement Is Familiar to State DOTs and Is a Generally Accepted Practice.** States are familiar with the practice of incorporating RAP into pavement mixtures, so it does not require learning new operations. Even if some state DOTs do not yet have experience with high-RAP pavements, there are many states with extensive experience and an abundance of guidance on the topic available.
- **Contractors Can Realize Construction Cost Savings.** Because of lower transportation costs and reduced need for virgin materials, using reclaimed pavement is usually in the interest of contractors. This is particularly true in today's era of often expensive petroleum products, because RAP provides both aggregate and asphalt binder. This not only results in a more efficient overall scenario, but also makes cooperation from contractors easier and more likely.
- **Using RAP Decreases Landfill Waste.** During project construction, contractors must dispose of old roadway, a costly and energy-intensive task. If the old pavement is not reclaimed or reused, it is sent to increasingly overloaded landfills.
- **RAP Promotes Energy Conservation.** Reclaiming pavement reduces the need to transport both virgin materials to job sites and used materials to landfills. Old pavement can be brought to a local processing plant, and even can be processed at the construction site using in-place recycling. Given the magnitude and weight of the materials being transported, this results in valuable energy savings. Energy savings are further realized in the reduced need for aggregate extraction.
- **Reduced Use of Virgin Materials Conserves Natural Resources.** Demand for aggregates and petroleum-based binders is volatile, often resulting in higher prices and increased mining efforts to extract more materials. A decrease nationwide in materials needed for roads could impact demand and reduce the need for both the virgin materials themselves and the quarrying operations that negatively impact the surrounding environment.

3.5 Stormwater Measure

Measure: Percentage of State DOT-Owned Impervious Surface for Which Stormwater Treatment is Provided

This measure quantifies the share of impervious surface area owned by a state DOT that is treated. Treatment, for the purposes of this measure, refers solely to active treatment using a structural BMP. Measure input data requirements include an inventory of all structural BMPs; drainage areas for each BMP; and the impervious surface area of the road system of interest.

Few states today have all three data elements needed to calculate this measure. Research suggests, however, that state DOTs increasingly are undertaking BMP inventories to meet National Pollutant Discharge Elimination System (NPDES) permitting requirements and because of this trend, the measure will become feasible at more state DOTs over time. In the interim, a phased approach will likely be the most applicable for implementing this measure that enables progress toward implementing the full measure:

- **Phase 1: BMP Inventory-Based Measure.** A BMP inventory documents how many highway-related BMP structures a state DOT has and where they are located. BMP inventory data is needed as the first step for calculating the stormwater measure, but regularly updated BMP inventory data alone could be used for an interim measure such as *number of acres of untreated pavement retrofitted for stormwater treatment annually*. State DOTs increasingly are preparing BMP inventories as part of their compliance with statewide NPDES permits. Nebraska, Ohio, and Nevada, for example, which were contacted as part of the research project, are all in the initial stages of preparing a BMP inventory for their highway systems and BMP inventories will become more common over time.
- **Phase 2: Impervious Surface-Based Measure.** With a BMP inventory in place, BMP data can be conflated with data describing the amount of DOT-owned impervious area, which is the second step in calculating the proposed stormwater measure. This allows use of a measure like *number of BMPs per acre of impervious area* before a DOT begins calculating the drainage area of each BMP, which is the most analytically complex element of the final stormwater measure.
- **Phase 3: Complete Implementation.** Assignment of drainage areas to each BMP represents the final major step in the data gathering process. Ideally drainage areas would be recorded in a geographic information system (GIS) environment to allow for simple spatial analysis—finding the intersection of drainage areas and impervious surface is a standard process in all GIS software. At this point, a DOT is able to calculate the full performance measure.

A detailed description of the methods for calculating this measure is included in Chapter 7. As part of the research for this report, several additional water quality-related performance measures were considered, but ultimately not selected. Information on these measures is included in Appendix A.

Why Percentage of Impervious Surface Treated Should be a Core Environmental Measure for State DOTs

- **Stormwater Runoff Is a Recognized Environmental Concern.** Runoff from pavements is considered an environmental issue in many parts of the country where it contributes to impairment of water bodies. According to the EPA's *National Water Quality Inventory*, runoff from urbanized areas is the leading source of water quality impairments to surveyed estuaries and the third-largest source of impairments to surveyed lakes. Alternative measures, such as those that quantify specific pollutants or aspects of ecosystem health directly are usually site or region-specific, which makes them less desirable as broad indicators.
- **Structural Stormwater Treatments Affect Water Quantity and Quality.** This measure addresses water quality and the health of aquatic ecosystems, which are directly influenced by the presence of structural stormwater treatment BMPs. By contrast, non-structural BMPs, such as street sweeping, controlled deicing operations, and other good housekeeping measures can vary widely in their scale or scope and may be applied irregularly or inconsistently, making them a less reliable indicator of improved environmental quality.
- **Location of Structural BMPs Can Be Tracked.** By contrast to housekeeping BMPs, structural BMPs have an easily defined area of influence and their presence is either already recorded by a state DOT or can be mapped, which allows structural BMPs to be linked to impervious surface in areas of high importance, such as those near impaired water bodies.

- **State DOTs Have Influence over Structural Stormwater Treatment.** A state DOT's actions alone cannot ensure adequate water quality or ecosystem health. By contrast, state DOTs have direct control over the number of highway-related structural BMPs.
- **Performance Measures on Stormwater Are Relevant for Decision Makers.** Spending on structural stormwater BMPs is increasing, which is focusing the attention of decision makers on this topic area. Tracking performance helps to provide accountability for spending on stormwater BMPs and provides an indication of future needs.
- **All State DOTs Build and Maintain Structural Stormwater Treatment Facilities.** Every state DOT must follow federal laws that require treatment of nonpoint source runoff, including stormwater, with BMPs, which makes the measure relevant across states. Under the Clean Water Act's NPDES program, for example, state DOTs are all required to develop and implement a stormwater management program to reduce the contamination of stormwater runoff. Structural BMPs are universally used by DOTs as a major element of their stormwater management programs.

3.6 Wildlife and Ecosystems Measure

Measure: Ecosystems Self-Assessment Tool

This measure contrasts with the other measures in that it is a self-administered assessment composed of 41 questions that evaluate performance across all aspects of state DOT programs relevant to wildlife and ecosystems, including policy, planning, operations, and project implementation.

The overall goal of the Ecosystems Self-Assessment Tool (ESAT) is to take into account, and give credit for, almost any action that a transportation organization uses to reduce its impact on wildlife and ecosystems. As part of the research for this report, several additional wildlife- and ecosystems-related performance measures were considered, but ultimately not selected. Information on these measures is included in Appendix A. In particular, Appendix A contains a review of the reasons an early suggestion for a measure of mitigation success was investigated during proof of concept testing, but ultimately was not selected as a suggested measure. Appendix B contains the full content of the ESAT's 41 questions and a detailed description of the methods for calculating this measure is included in Chapter 7.

- **ESAT Question Structure.** The ESAT is structured as a spreadsheet-based survey containing two worksheet tabs including a questionnaire and a scorecard. An additional tab contains instructions for completing the ESAT. Future iterations of the ESAT could be adapted to a web-based tool to improve accessibility and ease of use. An electronic version of the ESAT is available through the NCHRP Project 25-39 webpage at www.trb.org.

  Each of the 41 questions included in the ESAT questionnaire tab has two to four response options ranked on an ordinal scale from 0 to 3, where 0 is the lowest level of performance and 3 is the highest, as shown in Figure 1. Scores provide a range of four options wherever possible. There are also cells in which users can record the information sources that substantiate each response, as well as any other relevant notes. The column labeled 'Examples of Best Practices' lists sources identified from select state DOTs around the country that, in the research team's opinion, represent best practices for that measure. These best practice examples are incomplete, but are meant as sources to consult initially if improvement is desired.

  Although some questions are assessed quantitatively, many questions are scored qualitatively and therefore rely on the state DOT environmental representative to interpret the question and assess the program's performance. Whenever feasible, questions with quantitative score ranges are expressed as percentages or ratios rather than absolute values to enable meaningful comparison among states regardless of the size of their transportation network.
- **Question Categories.** The ESAT questionnaire was developed through a review of FHWA and TRB publications, including publications of the TRB's Strategic Highway Research Program

Question	*Wildlife collision hazard sites are prioritized for mitigation?*					
Scoring Values	**0 points** *None*	**1 point** *1-25% of state highway network*	**2 points** *25-50% of state highway network*	**3 points** *Greater than 50% of state highway network*		
Example of Best Practice	*Oregon DOT "wildlife collision hot spots map"*					
State DOT Planning Level	*Statewide Data/Strategy*					
State DOT Function Area	*Wildlife Movement Planning*					
Ecological Focus Areas	**General** ☐	**Wetlands** ☐	**Aquatic, Streams** ☐	**Wildlife Movement /Corridors** ☑	**Invasive Species** ☐	**T&E/ Sensitive Species** ☐

Figure 1. Example ESAT question.

and NCHRP, as well as actual examples of impact reduction measures undertaken in various states across the country. Ecosystem performance in the ESAT is measured at three levels in the state DOT workflow process: (1) policy level, (2) statewide data/strategy level, and (3) project implementation level. Strong policies for ecosystem and wildlife protection and mitigation are necessary to set the foundation for effective and consistent project implementation. Similarly, comprehensive data and strategies at the state level are needed to ensure that impacts to natural resources are effectively assessed and mitigated. Lastly, project-level practices are where the rubber meets the road. Questions were designed to fit into each of these three levels. Table 1 summarizes the desired practices, grouped according to workflow process levels.

Each question in the ESAT is categorized by the functional area within a DOT that it is related to and its relevance to one or more ecological focus areas. Table 2 summarizes the distribution of questions by state DOT functional area and ecological focus area. Questions were developed to span a wide range of state DOT functional areas and represent each of the ecological focus areas.

- **Scorecard.** The ESAT spreadsheet's scorecard tab automatically populates the results of the assessment as responses are entered, providing the user with an at-a-glance assessment of the points scored and percent of questions answered within each ecological focus area. The scorecard also assigns a score category based on the percentage of the total available points scored within each category:
  – *Outstanding achievement:* 66 percent to 100 percent of the total possible points
  – *Good performance:* 33 percent to 66 percent of total possible points
  – *Room for improvement:* 0 percent to 33 percent of total possible points

Why the ESAT Should Be a Core Environmental Measure for State DOTs

1. **ESAT Addresses States' Ability to Protect Wildlife and Ecosystems.** The ESAT is designed to provide a comprehensive self-assessment of a state DOT's ability to protect wildlife and ecosystems within the state.

Table 1. Practices assessed by ESAT, grouped by planning level.

Policy	• Biological resource conservation/mitigation and stormwater management practices incorporated into program guidance and manuals and staff training • Construction practices include compliance inspections for biological resource commitments and setting work periods to minimize disruption to fish and wildlife • Guidelines in place to evaluate the effects of noise/vibrations on aquatic life • Duration of wetland and other mitigation site monitoring extends beyond federal regulatory requirements • Coordination with state and federal resource agencies on biological resource and conservation issues enhanced through formal agreements and collaborative planning efforts
Statewide Data/Strategy	• Specific designs identified for culverts and wildlife crossing structures to promote habitat connectivity • Collaborative planning conducted with partner agencies to determine management and mitigation strategies for invasive species, streams and wetlands, wildlife corridors, and threatened and endangered species • Statewide geospatial data for resources such as wetlands, priority habitats, and public lands updated in the department mapping system and incorporated into long-range transportation plans • Systems in place for sharing data with partner agencies and tracking compliance with biological resource commitments • Wildlife collision hotspots identified and prioritized for mitigation • Use native seed mixes and native plants emphasized for re-vegetation activities • Functional assessments used to determine wetland mitigation requirements • Investments in ecosystem-focused research and deployment of new methods for biological resource mitigation/conservation
Project Implementation	• Projects quantitatively assess the impacts of noise/vibration on adjacent habitats • Impacts to streams and wetlands reduced through habitat mitigation and the installation of water crossings that improve habitat connectivity • Mitigation/conservation banks established in advance of foreseen impacts to ecological resources and mitigation goals met within specified time periods • Integrated pest management, monitoring, control strategies used to manage invasive species • Undeveloped land maintained as native vegetation • Mitigation and monitoring conducted at identified wildlife crossing with documented reduction in collisions • Water crossings installed to improve habitat connectivity

2. **State DOTs Have Influence over ESAT Performance Results.** Because the ESAT targets and gives credit for almost any action that transportation organizations use to reduce their impact on wildlife and aquatic life, state DOTs have a strong influence over their performance results.
3. **ESAT Measure Results Are Valuable to Decision Makers.** The score for each ecological focus area within the ESAT is meant to assist practitioners in identifying which areas need improvement and which areas already benefit from best practices. The ESAT's results are primarily intended for use internally by state DOTs.
4. **ESAT-Derived State-to-State Comparisons Should Be Used with Caution.** State-to-state comparisons between ESAT results should be made with caution because of the subjective nature of the questions and some scoring (see discussion in Proof of Concept Results section in Chapter 4).

Table 2. Number of questions by category groupings.

State Functional Area	Ecological Focus Area[1] *Wetlands*	*Aquatic, Streams*	*Wildlife movement /corridors*	*Invasive Species*	*T&E/ Sensitive Species*	*Data and Research*	Total
Habitat Mitigation	5	-	-	3	-	4	**7**
Information Tracking	2	2	-	2	-	2	**3**
Long-Range Plan Coordination	1	1	-	1	-	1	**1**
Maintenance and Procurement	1	2	3	1	-	1	**4**
Manuals	3	3	-	2	-	2	**3**
Noise Mitigation	1	2	-	3	-	1	**3**
Partnerships and Coordination	3	3	1	3	1	2	**7**
Planning and Construction	3	4	-	4	-	2	**4**
Research and Communication	1	1	1	1	2	1	**2**
Training	1	1	-	1	-	1	**1**
Wildlife Movement Planning	1	5	-	-	-	-	**6**
Total Number of Questions	**22**	**24**	**5**	**21**	**3**	**17**	**41**

[1] Each question corresponds to one or more ecological focus area; therefore, row totals are not additive.

5. **State DOTs Have Easy Access to Performance Data.** The ESAT has an estimated completion time of only 1 to 2 hours. The vast majority of information needed to complete the ESAT is likely to be readily available to or known by the state DOT respondent(s). Additional time may be required to coordinate with other staff or to compile information not readily available.
6. **Measure Is Meaningful and Clear to General Public.** The ESAT is generally intended as an internal resource for individual DOTs, and it deals with complex policy, program, and project-level issues. The simple scoring metrics of "*outstanding achievement*," "*good performance*," and "*room for improvement*" are easy to understand and communicate to non-technical audiences.

CHAPTER 4

Measure Proof of Concept Testing

Each of the suggested measures presented in Chapter 3 generally addresses an environmental issue of meaningful significance, while focusing on desired outcomes over which state DOTs have at least some control, and providing value to decision makers and clarity to the public. Without good data, however, none of these measures will be usable. In Chapter 4, the results from proof of concept testing research to validate suggested measures are presented.

Proof of concept testing was used to apply real data provided by 27 volunteer state DOTs to demonstrate the degree to which the measures in Chapter 3 are valid in terms of three key quantitative criteria:

1. **Can Measure Be Applied Consistently by All or Most States?** Does the measure allow fair comparisons among states as determined by a focus on a commonly encountered environmental issue that many states experience, availability of a common standard for data collection among states, and avoidance of bias created by factors outside a state DOT's control, such as highway system size, climate, ecosystems, or extent of urbanization?
2. **Can Measure Be Reported Easily with Existing Data Sources or Data that is Easy to Generate?** Can the measure easily be reported with existing data sources housed inside or outside the state DOT? This ensures the viability of the measure as one that multiple states are willing to invest in.
3. **Is Measure Data Quality Credible and Defensible?** Is the measure's credibility acceptable? Comparative measurement is weakened by use of measures whose credibility in terms of their accuracy, calculation methods, or connection to desired outcomes is in question.

Table 3 overleaf shows the states that participated in the testing for each measure. The proof of concept testing phase of the research reflects the disaggregated approaches in states today toward environmental performance measurement. No state could provide data for every one of the measures proposed in Chapter 3. Nonetheless, proof of concept testing demonstrates their viability within a subset of states. Each section in this chapter examines an individual measure and what was learned from the data collected for the states shown.

Overview of Testing Results

After proof of concept testing, the six measures ended up falling into one of three categories, which are described below. Table 4 provides a summary of testing results.

- **Air, Energy and Climate, and Materials Recycling Measures.** For the measures of air quality, energy and climate change, and recycling, proof of concept testing generally validated the availability of data and viability of measure calculation methods, suggesting these measures

Table 3. Summary of participating pilot states.

	Comprehensive Statewide Data Obtained				Experimental Data Obtained	
	Air	Energy/Climate Change		Recycling	Stormwater	Wildlife/ Ecosystems
	Statewide Vehicle Emissions (16 states)	Gasoline Consumption per Capita (All states)	DOT Fleet Alternative Fuels Use (15 states)	RAP as % of Total Pavement (11 states)	% of Roads Receiving Treatment (4 states)	Ecosystems Self-Assessment Tool (6 states)
CA	✓	✓	✓			
CO	✓	✓		✓		
DE	✓	✓		✓	✓	
FL	✓	✓		✓		
GA		✓				✓
IL	✓	✓		✓		✓
IA		✓	✓			
ME		✓	✓			
MD	✓	✓	✓		✓	✓
MN		✓	✓			
MO	✓	✓	✓	✓		
NE		✓	✓			
NJ	✓	✓		✓		
NM		✓	✓			
NC	✓	✓	✓	✓	✓	
ND	✓	✓		✓		
OH		✓			✓	✓
OR		✓				✓
PA	✓	✓	✓	✓		
SC		✓	✓			
SD	✓	✓		✓		
TX		✓				✓
UT		✓		✓		
VT	✓	✓	✓			
VA	✓	✓				
WA	✓	✓	✓			
WY	✓	✓	✓			

Table 4. Summary of proof of concept testing results.

Measure	Does Measure Support Consistent Application from State to State?	Can DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	Is Data Quality Credible and Defensible?	Implementation Readiness
Change in statewide motor vehicle emissions for NO_x, VOC, and $PM_{2.5}$	●	◑	◕	Ready for use by many DOTs today
State DOT fleet alternative fuel use	◕	◕	●	Ready for use by many DOTs today
Statewide on-road gasoline consumption	●	●	●	Ready for use by many DOTs today
Annual percent by mass of all asphalt pavement materials composed of RAP	●	◑	◕	Ready for use by many DOTs today
Impervious surface for which water treatment is provided	◑	◔	◔	Suitable for use by DOTs in longer term
Ecosystems Self-Assessment Tool	◑	●	◑	Ready for use by many DOTs today

Key

● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

can be adopted by several to many state DOTs in the near term. For these measures, comprehensive data was obtained for many states.

- **Stormwater Measure.** Prior to proof of concept testing, the stormwater measure was recognized to be more experimental than other measures, with the performance measurement capabilities of most state DOTs in this area best described as being nascent. For this reason, testing was confined to a handful of states for the stormwater measure. While the stormwater measure should not be considered implementation ready, testing results suggest it shows strong promise and continued efforts to expand on the potential of the stormwater measure are encouraged with phased adoption over time.
- **Wildlife and Ecosystems Measure.** While proof of concept testing results validated initial measurement suggestions for most of the measures considered in this report, the results for an initial wildlife and ecosystems measure "Percent of wetland and stream mitigation that achieves regulatory approval on, or ahead of, schedule based on the permitted monitoring period" demonstrated that the measure was unlikely to succeed. Proof of concept results for this original measure are included in Appendix A, but Chapter 4 contains additional information about proof of concept testing conducted to evaluate the ESAT in its place. The complete set of questions that make up the ESAT can be found in Appendix B.

4.1 Air Quality Measure: Proof of Concept Results

Measure: Change in Statewide Motor Vehicle Emissions for NO_x, VOC, and $PM_{2.5}$

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	●	☑ Ready for Use by Many DOTs Today
Can DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	◑	☐ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	◕	☐ Not Suitable for Use by Most DOTs

Overview

Pilot States: California, Colorado, Delaware, Florida, Illinois, Maryland, Missouri, North Carolina, North Dakota, New Jersey, Pennsylvania, South Dakota, Vermont, Virginia, Washington, Wyoming

Motor vehicle emissions are calculated as the product of two components: vehicle activity (reported as VMT) and emission rates. As an example, Figure 2 shows how these two components have changed over time for Vermont; the reduction in emissions has been almost entirely due to lower fleetwide emission rates, which are generated by the introduction of newer vehicles that meet more stringent EPA-mandated emission standards and the retirement of older, higher emission vehicles. These trends are very similar in other states. The tables that follow show performance results for the 16 pilot states in terms of NO_x, VOC, and $PM_{2.5}$, respectively, between 2005 and 2011.

Air Quality Performance Results

Tables 5, 6, and 7 summarize proof of concept performance results. See Appendix C for full state-by-state air quality data gathered.

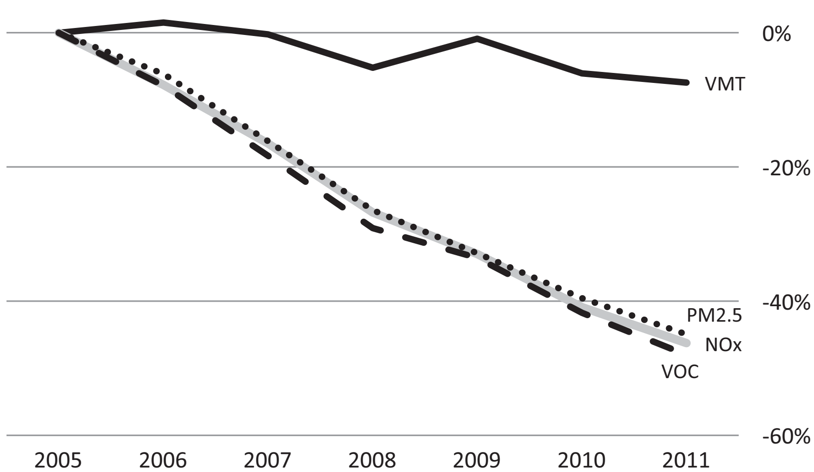


Figure 2. Illustration of relationship between VMT and emissions rates over time (Vermont).

Table 5. Annual change in NO_x emissions from 2005 base year.

	Trend 2005-2011	2005	2006	2007	2008	2009	2010	2011	Change 2005-2011
California		714,712	654,873	609,501	561,268	497,180	453,950	415,170	-41.9%
Vermont		22,935	21,152	19,155	16,792	15,371	13,557	12,329	-46.2%
Washington		255,658	241,920	227,552	206,155	188,020	176,963	164,130	-35.8%
Pennsylvania		279,829	257,313	237,824	217,207	186,708	166,890	152,621	-45.5%
Virginia		209,649	194,251	181,234	165,662	144,770	134,851	122,530	-41.6%
Wyoming		31,361	29,594	27,338	25,197	22,291	20,007	18,339	-41.5%
S Dakota		27,397	26,904	24,374	22,358	19,447	17,928	16,696	-39.1%
N Dakota		24,133	22,742	21,104	19,226	17,663	16,468	16,656	-31.0%
N Carolina		248,307	228,042	213,917	191,834	171,687	156,710	146,002	-41.2%
New Jersey		161,692	152,224	142,294	126,983	111,822	102,632	94,268	-41.7%
Missouri		183,778	168,763	153,699	139,805	124,471	117,911	105,347	-42.7%
Maryland		129,530	122,642	114,172	102,665	91,373	85,179	78,719	-39.2%
Illinois		269,780	242,775	225,901	205,153	180,917	166,311	149,505	-44.6%
Florida		471,765	442,237	413,975	368,808	325,919	300,298	271,901	-42.4%
Delaware		21,762	19,878	18,476	16,005	14,365	13,042	12,183	-44.0%
Colorado		127,526	118,591	109,939	99,331	84,446	78,606	72,385	-43.2%

Table 6. Annual change in VOC emissions from 2005 base year.

	Trend 2005-2011	2005	2006	2007	2008	2009	2010	2011	Change 2005-2011
California		90,493	82,533	75,222	69,558	62,512	57,271	51,251	-43.4%
Vermont		3,268	3,011	2,670	2,317	2,171	1,905	1,700	-48.0%
Washington		116,229	110,568	103,669	94,947	90,022	85,339	78,180	-32.7%
Pennsylvania		48,417	43,824	39,587	35,773	30,873	27,606	24,588	-49.2%
Virginia		36,096	32,911	30,112	27,543	24,345	22,827	20,250	-43.9%
Wyoming		3,029	2,858	2,548	2,342	2,099	1,909	1,705	-43.7%
S Dakota		3,045	2,997	2,628	2,374	2,069	1,903	1,732	-43.1%
N Dakota		2,807	2,652	2,341	2,123	1,961	1,834	1,815	-35.3%
N Carolina		36,662	33,661	30,744	27,371	24,454	22,412	20,584	-43.9%
New Jersey		23,533	21,567	19,513	17,110	15,098	13,825	12,429	-47.2%
Missouri		25,136	22,513	20,291	18,025	16,106	15,211	13,267	-47.2%
Maryland		16,835	16,072	14,283	12,565	11,149	10,402	9,395	-44.2%
Illinois		37,204	34,049	31,161	28,469	25,821	24,223	21,884	-41.2%
Florida		80,556	72,810	65,406	57,051	50,106	45,846	40,214	-50.1%
Delaware		3,287	2,915	2,614	2,225	2,005	1,815	1,637	-50.2%
Colorado		16,097	14,690	13,060	11,581	9,901	9,274	8,300	-48.4%

Table 7. Annual change in $PM_{2.5}$ emissions from 2005 base year.

	Trend 2005-2011	2005	2006	2007	2008	2009	2010	2011	Change 2005-2011
California		25,094	23,454	21,510	19,633	17,057	15,909	14,616	-41.8%
Vermont		754	708	632	555	506	456	415	-44.9%
Washington		8,230	7,846	7,269	6,587	6,001	5,727	5,328	-35.3%
Pennsylvania		9,241	8,633	7,868	7,209	6,178	5,630	5,171	-44.0%
Virginia		6,835	6,414	5,885	5,401	4,688	4,447	4,053	-40.7%
Wyoming		1,018	971	880	812	720	658	602	-40.8%
S Dakota		861	857	766	704	613	577	540	-37.3%
N Dakota		759	726	665	608	560	533	542	-28.7%
N Carolina		7,943	7,404	6,854	6,168	5,494	5,117	4,797	-39.6%
New Jersey		5,622	5,370	4,952	4,431	3,879	3,639	3,365	-40.2%
Missouri		5,893	5,484	4,913	4,472	3,958	3,813	3,420	-42.0%
Maryland		4,586	4,271	3,894	3,499	3,094	2,936	2,720	-40.7%
Illinois		9,066	8,261	7,573	6,892	6,056	5,684	5,137	-43.3%
Florida		14,400	13,567	12,432	11,016	9,513	8,868	8,057	-44.1%
Delaware		690	641	589	516	458	423	398	-42.3%
Colorado		4,175	3,912	3,572	3,237	2,757	2,613	2,416	-42.1%

Air Quality Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **Measure Is Most Meaningful in States with Air Quality Problems.** Thirty-four have Clean Air Act–designated nonattainment or maintenance areas within their boundaries. Therefore the measure may not be considered relevant in the remaining states and within the affected states, not all pollutants included in the measure are necessarily significant issues. There are 46 ozone nonattainment areas in the United States, involving 21 states. For $PM_{2.5}$, 32 regions are designated nonattainment areas, involving 18 states.
- **Use of Nationally Accepted Data Supports Comparative Measurement.** The air quality measure's reliance on a standardized model (EPA's Motor Vehicle Emissions Simulator [MOVES]) and a consistent source for VMT data (FHWA's *Highway Statistics* series) makes it appropriate for comparisons among states. Notably, California uses the EMissions FACtors (EMFAC) model in place of MOVES and parameters in the EMFAC model, such as statewide VMT, may differ from parameters in MOVES and *Highway Statistics*; thus, California results using EMFAC will not be directly comparable with other states.

Do State DOTs Have Easy Access to Data/Is Measure Easily Calculated?

- **Use of MOVES Drives Ease of Calculation.** If a state DOT has in-house expertise in using MOVES, calculation of the measure requires only modest effort; however, not all state DOTs have staff fluent in the operation of MOVES, which may somewhat reduce the simplicity for calculation of this measure.

Is Data Quality Credible and Defensible?

- **Use of Nationally Accepted Data Strengthens Data Quality/Credibility.** The air quality measure's reliance on MOVES and FHWA's *Highway Statistics* series lends credibility to this measure. The measurement approach follows EPA guidance for statewide emission inventories; however, the suggested calculation approach is more simplistic than the county-by-county calculations states perform as part of the triennial National Emission Inventory, so results will not match the National Emission Inventory data.
- **Measure Data Is Not Sensitive to State DOTs' Congestion Relief Efforts.** The measure's defensibility is somewhat limited because it does not reflect a state DOT's congestion relief efforts. Emissions rates increase as speeds drop below 35 miles per hour, are relatively flat between 35 to 55 miles per hour, and increase above 55 miles per hour. Efforts to tackle very heavy congestion are recognized to result in emissions reductions at the corridor scale because they move speeds into the range where emission control technologies are most effective. At the state level, however, aggregate average speeds typically fall in the 40 to 50 miles per hour range and vary little from year to year. In that speed range, small changes in average speed will have no significant impact on emissions.

4.2 Fleet Alternative Fuels Measure: Proof of Concept Results

Measure: State DOT Fleet Alternative Fuel Use (as percentage of total fuel use)

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	◕	☑ Ready for Use by Many DOTs Today
Can DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	◕	☐ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	●	☐ Not Suitable for Use by Most DOTs

Key
● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

Overview

Pilot States: California, Iowa, Maine, Maryland, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Carolina, Pennsylvania, South Carolina, Vermont, Washington, Wyoming

Use of alternative fuels in place of conventional gasoline and diesel generally reduces GHG and criteria (Clean Air Act–regulated) pollutant emissions. Use of alternative fuels can also lessen dependency on petroleum, which has associated costs for society and can subject vehicle fleet owners to volatile fuel prices. Although the fuel consumed by state DOT fleets represents only a small fraction of total transportation fuel use, state DOTs control some of the largest public sector fleets. Their actions can support emerging markets and set a positive example that helps make alternative fuels viable for a wider market.

"Alternative" transportation fuels include any fuel other than gasoline or diesel such as the following:

- **Ethanol.** Ethanol is a renewable fuel made from various plant materials. As an alternative fuel, ethanol is typically blended at 85 percent with gasoline, known as E-85.
- **Biodiesel.** Biodiesel is a renewable fuel made by reacting animal or vegetable fats with alcohol. Most biodiesel is used in low-level blends, usually 5 percent or 20 percent biodiesel blended with conventional diesel, referred to as B-5 or B-20, respectively. Most diesel vehicles can use low-level biodiesel blends without modification; higher-level blends require vehicle modifications.
- **Natural Gas.** Natural gas is an odorless, gaseous mixture of hydrocarbons, predominantly composed of methane. Natural gas can be used as transportation fuel in CNG or liquefied natural gas (LNG) form.
- **Propane.** LPG is commonly referred to as propane. Propane is mainly used in light-duty pickup trucks as well as some off-road equipment.
- **Electricity.** Electricity can be used to power battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), collectively known as plug-in electric vehicles (PEVs). All PEVs draw electricity from off-board electrical power sources, that is, the electricity grid, and store the energy in batteries. Conventional hybrid electric vehicles are not considered alternative fuel vehicles.

Note that virtually all gasoline sold in the United States contains 10 percent ethanol. Ethanol is added to gasoline to boost octane levels, meet air quality requirements, or satisfy mandates such as the EPA's Renewable Fuel Standard. This ethanol fraction is not considered an alternative fuel for the purposes of this study, because it is considered the conventional and default gasoline blend for all fleets.

Figure 3 shows how the pilot test states performed over time in terms of the performance measure. See Appendix C for full state-by-state fleet fuel use data gathered. The following pilot states

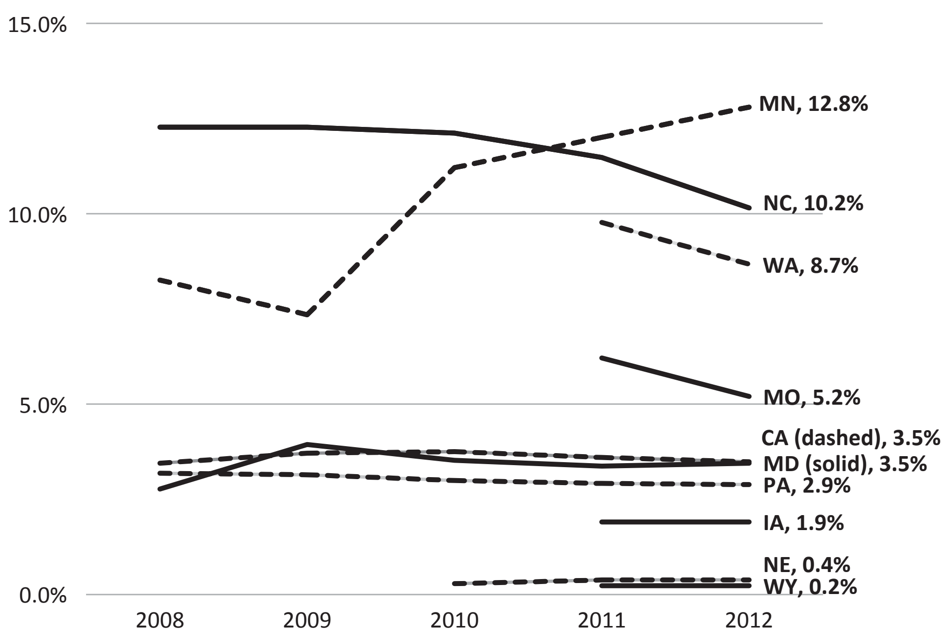


Figure 3. Alternative fuels as percentage of total DOT fleet fuel consumption volume basis: 2008 through 2012.

report that they do not use any alternative fuels in their fleet: Maine, Montana, New Mexico, South Carolina, and Vermont; therefore, they are not shown in Figure 3 or subsequent figures and tables.

Other State DOT Fuel Use Performance Measure Formulations

In its suggested format, this performance measure is calculated on a volumetric basis, which means that one gallon of gasoline, diesel, ethanol, biodiesel, or propane has the same weight when calculating the percentage of alternative fuel use for a state, regardless of each fuel's energy content. An exception is natural gas, which is usually reported in terms of gasoline gallon equivalents and therefore already accounts for differences in energy content. As part of proof of concept testing, several other formulations of this measure were evaluated including formulations based on energy content, GHG intensity, and trends in fuel use:

- **Alternative Fuels Measure Based on Energy Content.** An alternative formulation for this measure is to normalize all fuel use by its energy content. Most alternative fuels have lower energy content per gallon than conventional fuels. For example, pure ethanol has about 33 percent less energy than gasoline and pure biodiesel has about 6 percent less energy than conventional diesel.

  To calculate the measure on an energy content basis, the volume of each fuel would be multiplied by the energy content of the fuel (in megajoules) per gallon. The energy for conventional fuels and alternative fuels would each be summed, and the ratio would serve as the alternative metric.

  Table 8 compares the alternative fuels measure for the ten pilot states for 2012 on a volume basis versus an energy basis. The alternative fuels fraction is slightly lower in all cases.

If this measure were calculated by energy content rather than on a volume basis, states that use large volumes of E-85 would tend to see their performance drop more than states that use large volumes of biodiesel, natural gas, or propane (see Figure 4). This is because ethanol's energy content is lower than most other alternative fuels.

In theory, a measure based on energy content could incentivize state DOTs to focus their efforts more on alternative fuels with higher energy content. Since the fuel options for state DOTs are limited, and because equipment type often dictates fuel choices, the energy content formulation for this measure would likely have little or no practical effect on their actions.

- **Alternative Fuels Measure Based on GHG Intensity.** Fuel use information can also be used to calculate GHG emissions from a state DOT fleet. (One of the primary benefits of using alternative fuels is their GHG benefit.) To properly compare the climate change impacts of various fuels, GHG emissions should be calculated on a "well-to-wheels" basis that reflects emissions associated with fuel production and distribution as well as vehicle tailpipe emissions.

  The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model developed by Argonne National Laboratory can be used to obtain "well-to-wheels" GHG emission factors for each fuel. Fuel use (by type) is multiplied by the appropriate emission factor, and the results summed to obtain total state DOT fleet GHG emissions. The magnitude of each state DOT's GHG emissions would correlate roughly to the size of the state DOT's fleet. To enable meaningful comparisons among states, the GHG emissions should be normalized, for example, by dividing GHG emissions by a measure of fuel use, such as total energy content. This approach

Table 8. Comparison of alternative fuels measure on volume and energy basis (2012).

	CA	IA	MD	MN	MO	NC	NE	PA	WA	WY
Volume Basis	3.5%	1.9%	3.5%	12.8%	6.2%	10.2%	0.4%	2.9%	8.7%	0.2%
Energy Basis	3.1%	1.9%	3.3%	9.7%	5.9%	9.8%	0.2%	2.8%	8.4%	0.2%

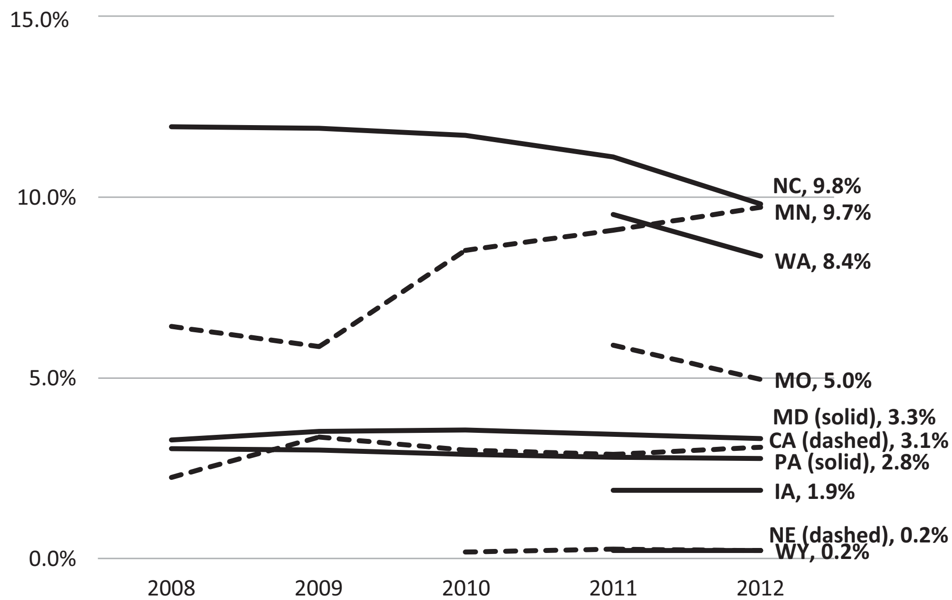


Figure 4. Alternative fuels as percentage of total DOT fleet fuel use energy content basis: 2008 through 2012.

would create a composite GHG emission factor for a state DOT's fleet that allows state-to-state comparisons. Table 9 shows this value for the 10 pilot states for 2012. A lower number is considered better because it indicates a fuel mix that produces less climate change impacts per unit of energy delivered. Figure 5 shows the trend over time on GHG intensity basis for pilot states.

A GHG-based performance measure is attractive because it more closely tracks one of the primary environmental outcomes of interest (reduced climate change impacts). However, the measure based on GHG intensity is less transparent and understandable to the public. Moreover, alternative fuels have benefits other than GHG reduction, such as reduced criteria pollutant emissions and reduced dependency on petroleum and its associated price volatility.

There is uncertainty, and in some cases controversy, with regard to the upstream emissions associated with alternative fuels, particularly biofuels. While the GREET model is widely considered the most authoritative source of lifecycle GHG emission factors for motor vehicles, there continues to be research on the indirect land use effects of biofuels. These upstream GHG emissions depend heavily on the fuel feedstock and can vary by state. Notably, California has its own version of GREET. While these uncertainties are present in every model to some degree and do not represent a fatal flaw, they are likely to limit the adoption of a measure based on GHG intensity in some states and reduce the measure's transparency.

- **Trends in Total Fuel Use.** Fuel use data can also be used to track trends in a state DOT's fleet consumption and fuel efficiency. In addition to environmental implications, fuel is a major operating expense for state DOTs, and agencies seek to minimize fuel use through operational improvement such as less vehicle idling or technology improvements like using more fuel-efficient vehicles. If a state DOT maintains data on the annual mileage of all its vehicles, it can calculate an aggregate fleet fuel economy either for the entire state DOT fleet or separately for

Table 9. State DOT fleet composite GHG intensity in grams CO_2-equivalent per megajoule (2012).

	CA	IA	MD	MN	MO	NC	NE	PA	WA	WY
Carbon Intensity	72.3	73.0	72.5	68.9	71.2	66.8	76.7	74.0	69.9	74.5

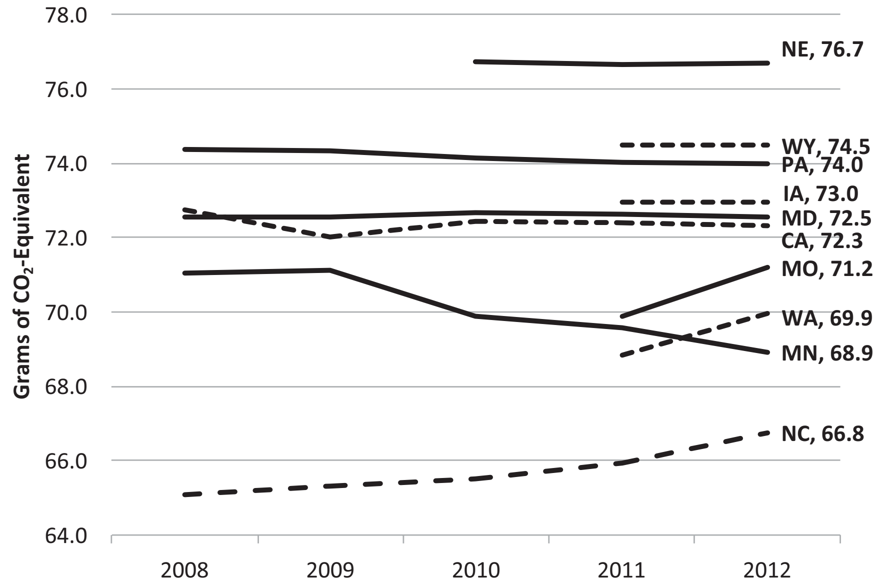


Figure 5. Composite GHG intensity of DOT fleet fuel use in grams of CO_2-equivalent per megajoule (2008 through 2012).

light-duty and heavy-duty vehicles. This metric would facilitate comparison among states as well as performance tracking within a single agency.

Some states do not have accurate records of the mileage of all their vehicles, so calculating aggregate fuel economy is not possible. An alternative is to track total fuel use, which reflects both the efficiency of the fleet and the use of the fleet. The benefit of this metric is that it would capture a state DOT's efforts to reduce travel. A disadvantage of this metric is that variations in fleet usage may obscure miles per gallon improvements. For example, if a state DOT experiences a year with heavy demands on its fleet, such as a heavy snow fall year, it could see an increase in fuel use even if its efficiency improved. A metric based on total fuel use is also difficult to compare across states. One way to facilitate comparison is to report the percentage change in fuel use in relation to a given base year. Figure 6 shows the trend over time in fleet fuel use for selected pilot states.

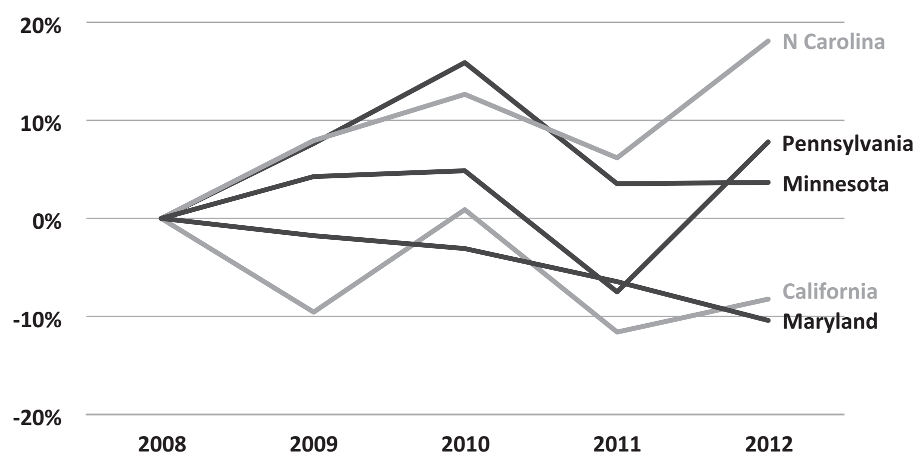


Figure 6. Percentage change in total DOT fleet fuel use (base year 2008).

Alternative Fuels Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **Standardized Fuel Records and State DOT Control of Fleets Enables Fair Comparisons.** In general, the measure supports state-to-state comparisons because of the consistent and accurate state DOT records on fleet fuel use and the relatively high degree of state DOT control over vehicle and fuel purchasing decisions.
- **Some External Factors Can Influence State DOTs' Alternative Fuel Use.** While the amount of alternative fuels being purchased and used in state DOT vehicles is partly an agency decision, external factors that vary from state to state may affect usage:
  - **Alternative Fuel Mandates Promote Use.** Alternative fuel use in some states is driven by state mandates. Minnesota, for example, began requiring a 2 percent biodiesel blend for all diesel sold in the state in 2005, increasing to 5 percent in 2007. Beginning in July 2014, 10 percent biodiesel will be required from May to October of each year. Minnesota DOT scores well on this measure in part because of these state mandates, although Minnesota DOT has also exceeded the state requirement through its own actions. Similarly, since 2009, Pennsylvania has required that all diesel sold in the state contain a minimum of 2 percent biodiesel.
  - **Supply Challenges Can Limit Use.** Some state DOTs may also experience limits on their performance as a result of alternative fuel supply issues. In Vermont, VTrans was forced to curtail biodiesel use when their fuel vendor stopped supplying biodiesel in the state. Other states may have individual fleets or districts that lack alternative fuel supply. The remote location of Caltrans District 9, for example, prohibits use of E-85 that is used in most other Caltrans districts. Conversely, biofuels supply and fueling infrastructure is abundant in many Midwestern states.
  - **Climate Can Limit Use.** In cold weather states, some fleets have experienced problems with higher biodiesel blends in winter because the fuel can gel at low temperatures; thus, state DOTs in cold weather states may face limits on their ability to use biofuels.
  - **State Purchasing Rules Can Limit Use.** State purchasing rules—which are outside the direct control of a state DOT—can constrain the opportunities to use alternative fuels. In some states, state DOTs must purchase new vehicles through a statewide general services purchasing agreement. If these agreements do not include alternative fuel vehicle options, the state DOT will be unable to acquire such vehicles.

Despite these limitations, the alternative fuels measure as presented in this report is a good one for all state DOTs to use for reporting. The measure is based on readily available data, enables comparison among states as well as progress tracking over time, reflects environmentally beneficial practices at state DOTs, and is an area of growing interest.

Do State DOTs Have Easy Access to Data/Is Measure Easily Calculated?

- **Measure Based on Reported Fuel Use.** State DOT records of fuel purchases are considered highly accurate. The measure is not, therefore, subject to the risk of error or uncertainty that can be caused by modeled or estimated data.
- **Data on Alternative Fuels Is Readily Available at Many State DOTs.** Use of alternative fuels in state DOT fleets is usually simple to measure because state DOTs themselves generally maintain the data required.
- **Adjustments to Tracking Methods Are Needed in Some States, but Are Surmountable.** In some states, including North Carolina and Vermont, the state DOT owns and maintains records only for heavy-duty vehicles. In these instances, light-duty vehicles used by the state DOT are managed by a state "motor fleet" department or general services administration and the state DOT may not have ready access to fuel records for the light-duty vehicles it uses. Some states do not use centralized fueling stations because their vehicles are fueled at commercial stations and their fuel purchase card technology may not support tracking of

alternative fuel purchases such as biodiesel blends or E-85. In these cases, additional effort may be needed to collect fully accurate data.

Is Data Quality Credible and Defensible?

- **Measure Does Not Easily Capture Use of Electric Vehicles.** This measure captures use of all liquid alternative fuels, but is likely to omit use of electricity as a transportation fuel. Among the state DOTs contacted for this pilot, only one reported owning a PEV as of 2013 (a single Chevrolet Volt owned by Washington State DOT). However, more states are expected to purchase and operate PEVs in coming years. Most state DOTs are unlikely to maintain data on grid-derived electricity supplied to PEVs. State DOTs that wish to capture electricity used in transportation can estimate it based on the VMT of BEVs and PHEVs. For BEVs, a simple fuel economy rating can be multiplied by VMT to derive total energy use. For PHEVs, the state DOT would need to estimate the portion of miles driven in all-electric mode, and estimate gasoline and electricity use for these vehicles.
- **Measure Is Easy to Understand.** A volume-based measure is simple to calculate and easy for the public to understand. A measure based on fuel energy content or GHG intensity will be less easy to understand and communicate.

4.3 Gasoline Consumption Measure: Proof of Concept Results

Measure: Statewide On-Road Gasoline Consumption per Capita

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	●	☑ Ready for Use by Many DOTs Today
Can DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	●	☐ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	●	☐ Not Suitable for Use by Most DOTs

Key
● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

Overview

Pilot States: All 50 States

On-road gasoline consumption per capita captures the environmental and energy intensity of a state's highway transportation system. Carbon dioxide, which is the most important GHG, and gasoline use are directly correlated. Transportation agencies can contribute to a reduction in gasoline use through improvements in highway system efficiency, support for alternative modes, and deployment of fuels and vehicle technologies that displace gasoline. This measure generally provides a strong correlation with personal travel in light-duty vehicles. Gasoline engines power the vast majority of personal travel on roadways. The measure does not capture the activity of diesel powered trucks or alternative fuel vehicles. Diesel is primarily used for long-haul freight, the demand for which is often created outside of a state. Performance results for 2011 are shown in Figure 7. See Appendix C for complete state-by-state gasoline consumption data gathered.

Gasoline Consumption Performance Results

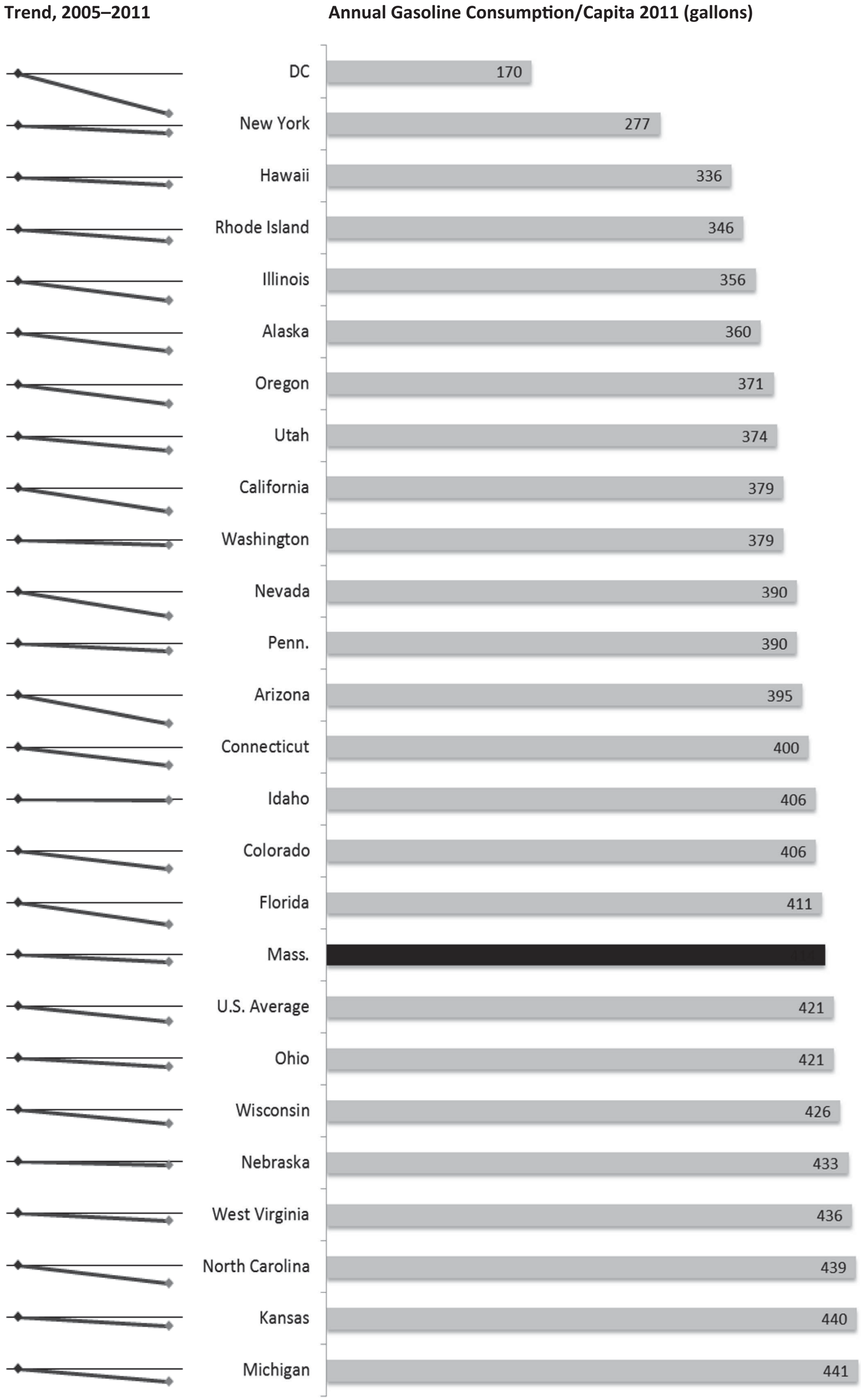


Figure 7. Annual gasoline consumption per capita (2011).

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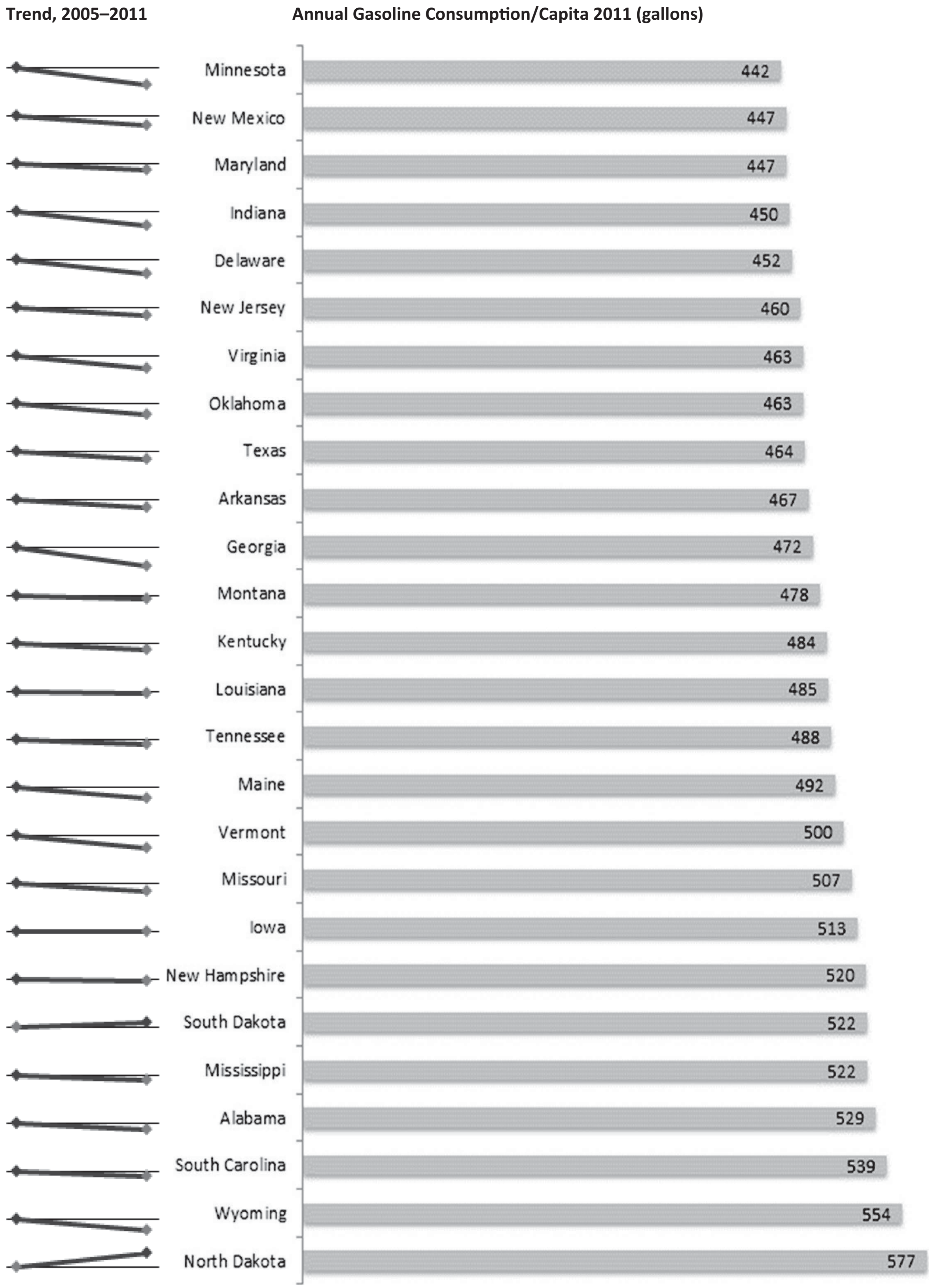


Figure 7. (Continued).

Gasoline Consumption Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **State DOTs Have Limited Control over Gasoline Consumption.** State DOTs do not directly control gasoline consumption and have only limited ability to influence this metric. Statewide gasoline use per capita is influenced by a variety of technological and behavioral factors. For example, the introduction of more fuel-efficient vehicles into the fleet will tend to reduce gas consumption over time, as will greater use of alternative fuels. The other major influence on this metric is VMT per capita, which reflects a complex phenomenon affected by demographics, economic conditions, and land development patterns, among other influences. By supporting a multi-modal transportation system, however, state DOTs can affect the energy consumption impacts of current policies, programs, and practices. State DOTs may also participate in efforts to provide alternative transportation fuels, such as electric vehicle charging infrastructure. The measure is responsive to actions by a broader spectrum of public agencies including state, regional, and local transportation agencies, environmental and energy agencies, and local planning departments.
- **Economic Growth Is Not a Predictor of Growth in Gasoline Consumption.** Annual changes in the measure are partially influenced by economic factors, but the research team's analysis suggests the measure does not closely track a state's economic growth. The scatter plot in Figure 8 shows all 50 states plotted according to the percentage change in median income versus the percentage change in gasoline use per capita, from 2005 through 2011. North Dakota is an outlier, with high growth in both variables. But for the remainder of states, there is not a strong relationship between income and gasoline use.
- **Level of Urbanization Is Related to Gasoline Consumption.** Differences between states in gasoline use per capita are partly explained by their degree of urbanization. Residents in dense, metropolitan areas tend to drive less, so states with a relatively large share of population in such areas often have lower VMT per capita. For example, Hawaii is the third lowest state in terms of gasoline use per capita. The state is the sixth most urban (92 percent urban), and with most of the population concentrated in Oahu, the opportunities for long distance travel on highways are limited. Conversely, the least urban states,

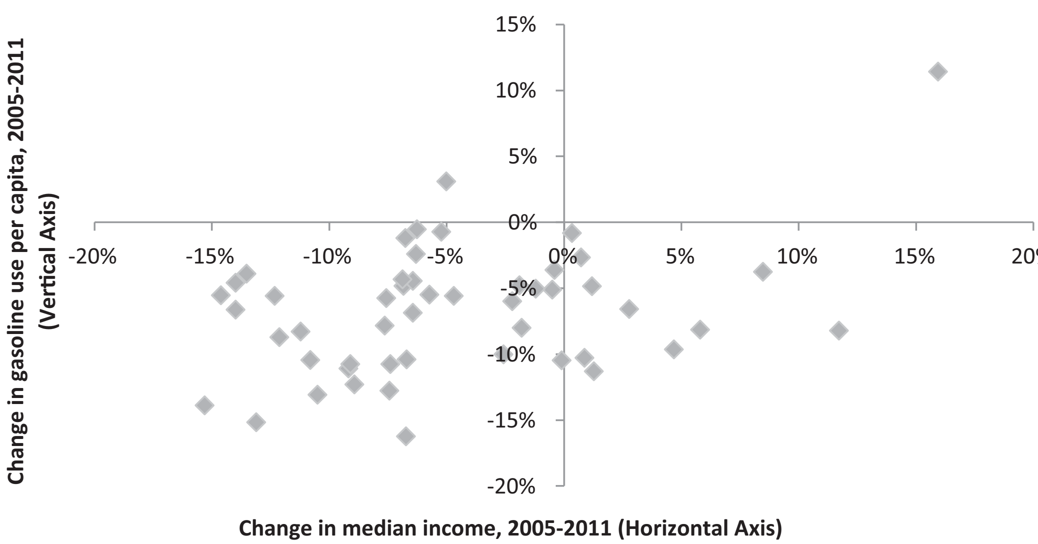


Figure 8. Change in gasoline use per capita versus change in median income (2005 through 2011).

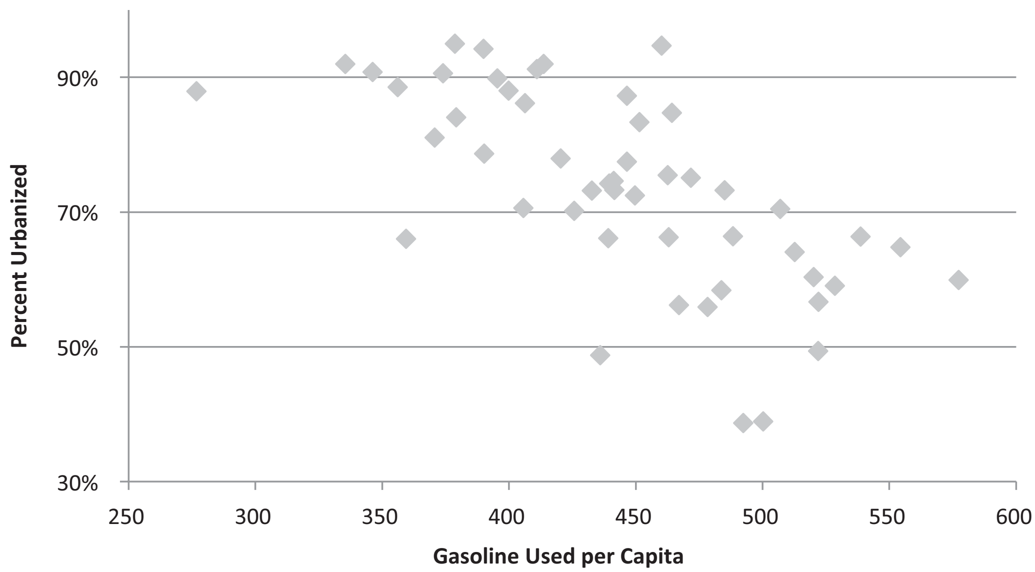


Figure 9. Percentage urbanized versus gasoline use per capita, 2011.

such as Maine (39 percent urban) and Vermont (39 percent urban), also rank among the 10 highest states in terms of gasoline consumption per capita (41 and 42). There are some exceptions, however. Alaska ranks 6th lowest in gasoline use per capita but ranks 38th in level of urbanization. In Figure 9, a scatterplot shows urbanization versus gasoline consumption.

Do DOTs Have Easy Access to Data/Is Measure Easily Calculated?

- **Gasoline Sales Data Are Easily Obtained for All States.** This measure relies on FHWA-provided data on gasoline sales by state, which are listed in the publication *Highway Statistics.* Annual on-road gasoline sales for every state are reported in Tables MF-21 and MF-27 of *Highway Statistics*, making data collection simple, fast, and reliable. In these tables, sales of pure gasoline are combined with sales of gasohol (low-level blends of ethanol with gasoline).

Is Data Quality Credible and Defensible?

- **FHWA Gasoline Sales Data Is Robust.** FHWA obtains data on statewide purchases of gasoline from state motor-fuel tax agencies, which collect taxes at the point of sale. FHWA makes adjustments so that the data is uniform and complete for all states. FHWA's data for on-road motor fuels are used to allocate highway funding and are generally considered to be more accurate than other sources.
- **Gasoline Sales Are a Generally Acceptable Proxy for Gasoline Use.** Use of FHWA data for this measure assumes that gasoline *sales* are an acceptable proxy for gasoline *use.* In many states, the two metrics are nearly identical. In some situations, however, there is potential for discrepancy between the place of fuel sales and the location of travel activity and consumption of fuel. This can be an issue particularly for states that have a lot of traffic across state lines or where fuel tax rates differ widely across state boundaries. For instance, given its size and the large amount of through traffic it experiences, Maryland DOT has found that fuel sales do not provide as accurate a basis for estimating GHG emissions as VMT-based methods. Similarly, New York State DOT determined that fuels sales underestimated VMT in the state because many New York travelers

purchase fuel in New Jersey. This is an issue in so few states, it should not preclude its use as a measure.

4.4 Materials Recycling Measure: Proof of Concept Results

Measure: Annual Percentage by Mass of All Roadway Asphalt Pavement Materials Composed of Reclaimed Asphalt Pavement

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	● (fully consistent)	☑ Ready for Use by Many DOTs Today
Can DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	◑ (somewhat consistent)	☐ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	◕ (mostly consistent)	☐ Not Suitable for Use by Most DOTs

Key
● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

Overview

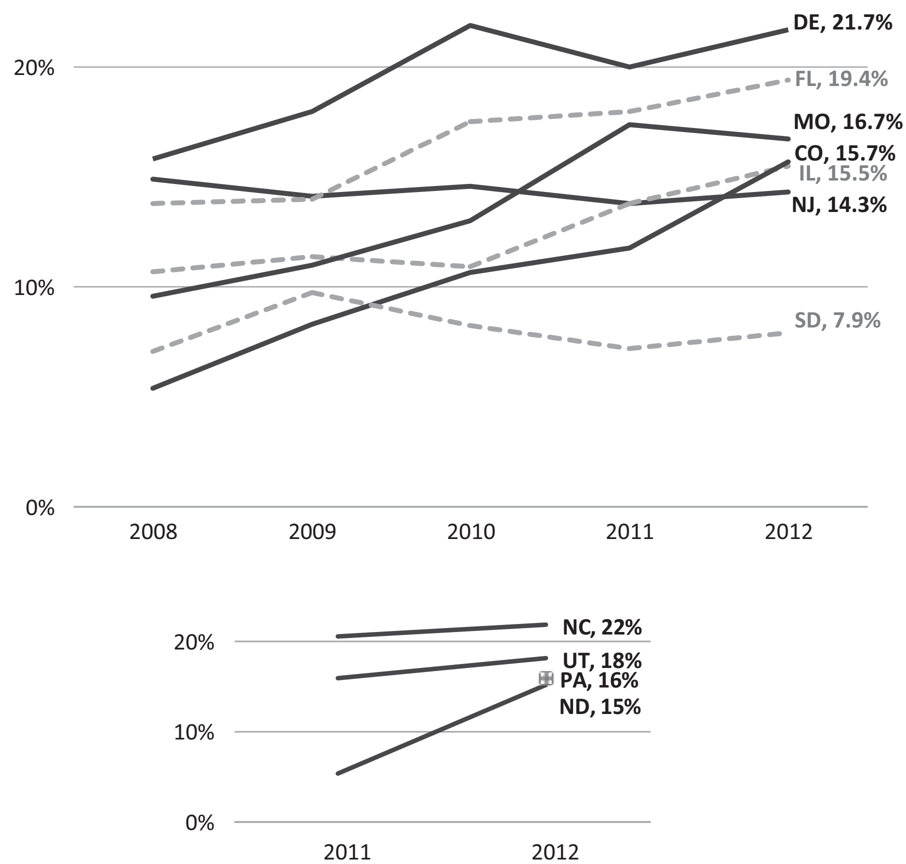
Pilot States: Colorado, Delaware, Florida, Illinois, New Jersey, Missouri, North Carolina, North Dakota, Pennsylvania, South Dakota, Utah

Reclaimed asphalt pavement is the term given to reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction or resurfacing. Although old asphalt pavements can be recycled at central processing plants, in-place recycling processes are increasingly common, which include partial removal of the pavement surface, mixing of reclaimed material with beneficial additives (such as virgin aggregate, binder, and rejuvenating agents to improve binder properties), and placing and compacting the resultant mix in a single pass. This measure examines the annual percent by mass of all roadway asphalt pavement materials composed of RAP used by a DOT. Performance results are shown in Figure 10. See Appendix C for complete state-by-state RAP data gathered.

Materials and Recycling Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **RAP Is Widely Used by State DOTs.** All state DOTs allow use of RAP to some extent, and while precise specifications can vary, RAP is used in essentially the same way across the country. A 2010 survey by the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Materials collected information on RAP use by state DOTs; it found that of the 36 states that responded to the survey, all reported allowing RAP in some circumstances. Such a high level of acceptance among practitioners makes national use of this measure feasible, and success in its implementation more likely.
- **Little Variation in Ability to Use RAP among States.** All states are able to use RAP. While climate conditions may have some influence on appropriate pavement mixes, the use of RAP is not greatly hindered by climate. States that currently allow high RAP



Note: PA is represented by a single data point, not a line.

Figure 10. RAP as a percentage of asphalt laid annually (2008 through 2012).

percentages include both cold weather states (e.g., Maine) and warm weather states (e.g., Arizona).

- **DOTs Influence RAP Use.** State DOTs have control over the amount of RAP used in pavements because they establish specifications for pavement composition. Note, however, that most state specifications establish a maximum RAP percentage for pavements. Interviews with pavement engineers by the research team indicate that RAP availability is not limited—in many cases, DOTs have large surpluses of RAP. These factors point to increased ability for DOTs to influence performance of the measure.
- **Limits on RAP Content May Affect Performance, but States Are Increasing RAP Limits.** The percentage of RAP allowed in new pavement varies among states—typically ranging from 15 percent to 40 percent. In some states, RAP use is approaching the maximum allowed by the state's specifications. For example, RAP made up 92 percent of the maximum allowable amount in Colorado DOT's 2012 projects. If state DOTs do not increase RAP limits, usage may flatten in many states.

Use of RAP in projects, however, has been increasing steadily in the past decade as materials and best practices have matured. Many state DOTs have increased the maximum amounts of RAP allowed in their specifications and this trend appears to be continuing. Furthermore, many asphalt producers do not always use the maximum allowable amounts. For example, when there are different limits for different courses, contractors will sometimes create one mix meeting the lowest minimum amount for multiple pavement layers rather than produce two mixes.

Do DOTs Have Easy Access to Data/Is Measure Easily Calculated?

- **Records of Necessary Data Exist, But May Require Additional Effort to Compile.** Contractors must track materials usage as part of their contract requirements and DOTs' specifications monitoring, therefore it is possible to track down the total quantity of RAP versus other pavement inputs in most states. What is not being done universally, however, is compilation of project-level information to allow ongoing monitoring at the statewide level. Implementing a reporting system by contractors or charging division engineers to gather this decentralized information will thus be necessary in some states. Virtually all state DOTs keep track of the total amount of asphalt laid each year.
- **Tracking Efforts Appear to Be Increasing at DOTs.** Several DOTs contacted by the research team indicated that they just started tracking RAP use, suggesting that the collection of information needed for this measure is increasing.

Is Data Quality Credible and Defensible?

- **RAP Data Collection Practices Vary from State to State.** While use of RAP is widespread, recordkeeping practices vary widely from state to state. Many DOTs maintain data on RAP use on individual projects and thus are able to accurately calculate this measure. However, just as many do not appear to maintain accurate records on use of RAP. For example, the DOTs in Ohio and New York set allowable RAP percentages in their asphalt pavement specifications, but allow the contractors to develop their own mix designs; the DOT does not maintain records of the mix design employed by the contractors. Among the 29 states contacted, 11 were able to provide RAP use data. However, there is some contradictory information on the tracking of RAP use; an FHWA survey found that only 3 of the 18 respondents indicated that they track the amount of RAP used.

4.5 Stormwater Measure: Proof of Concept Results

Measure: Percentage of State DOT-Owned Impervious Surface for which Water Treatment is Provided

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	◑	☐ Ready for Use by Many DOTs Today
Can DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	◔	☑ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	◔	☐ Not Suitable for Use by Most DOTs

Key
● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

Overview

Pilot States: Delaware, Maryland, North Carolina, Ohio

This measure quantifies the share of impervious surface area owned by a DOT that is treated. "Treatment," for the purposes of this measure, refers solely to active treatment using a structural BMP. Runoff from roadways can also be sufficiently treated by natural landscapes and non-engineered structures, but more research must be done to account for these elements. In addition, this measure treats all impervious area the same in terms of its need for treatment, when in reality some areas are in less need of treatment than others.

Three major data inputs are needed to complete the measure: (1) an inventory of all structural BMPs, (2) drainage areas for each BMP, and (3) the impervious surface area of the road system of interest. Few states currently have all data elements readily available.

Research undertaken as part of the pilot testing finds that state DOTs increasingly are undertaking BMP inventories to meet NPDES permitting requirements, so the measure will become feasible at more DOTs over time. The focus of proof of concept testing for this measure centers on four states where some or all of the three major data elements are available: Delaware, Maryland, North Carolina, and Ohio. Data from each of these states reflects widely differing data collection practices and therefore, *data for the stormwater measure should not be considered suitable for comparisons from state to state.*

Maryland (Statewide Results Available)

Maryland's State Highway Administration (SHA) currently tracks a similar performance measure: number of acres of untreated pavement retrofitted for stormwater management controls each fiscal year (see Table 10). The information used for their performance measure is easily translated into the suggested measure through simple GIS operations and because SHA maintains data for the whole state system, the performance measure can be calculated for the whole state.

Delaware DOT (Newcastle County Results Available)

DelDOT's impervious surface data includes impervious areas both owned and not owned by the state DOT. To estimate the fraction that is DOT-owned, and therefore the amount DelDOT is responsible for treating, GIS was used to analyze a 15-meter buffer around the DOT's linear road network (see Table 11). Only impervious area within this buffer was counted in the denominator.

Ohio DOT (Cuyahoga County Results Available)

Drainage areas associated with structural BMPs were not available from the Ohio DOT, so estimated drainage areas were calculated using GIS tools on a digital elevation model for Cuyahoga County (see Table 12). In the future these calculations could be verified by an engineer or validated with fieldwork. Total impervious area was calculated by summing each road segment's width and shoulder width, which are recorded in the attribute table of the state DOT's GIS file of the road system.

North Carolina DOT (Statewide Primary Roadway Results Available)

The North Carolina DOT provided a spreadsheet of BMPs located on the state's Primary Road System. Thirty newly installed BMPs had estimates of the drainage areas, as well as the amount of impervious surface in the drainage areas (see Table 13). The average size of these drainage areas

Table 10. Maryland stormwater results.

Maryland (Statewide) Results	
State highway system impervious area	32,259 acres
Treated highway area (by SHA BMPs)	9,025 acres
Percent of DOT-owned impervious surface for which treatment is provided*	28.0%

**Does not account for surface that is passively treated or that does not require treatment.*

Table 11. Delaware stormwater results.

Delaware (Newcastle County Only) (Excludes DelDOT maintenance facilities and rest areas)	
State system impervious area	4,077 acres
Treated area:	
All (includes locally owned)	899 acres
DelDOT owned only	399 acres
Percent of impervious surface for which treatment is provided:*	
All (includes locally owned)	22.0%
DelDOT owned only	9.8%

**Does not account for surface that is passively treated or that does not require treatment.*

Note: Much of the impervious area treated by DelDOT's BMPs is locally owned or private developments. How much this treatment area should count is a question that will need to be resolved before widespread implementation. In the meantime, the results are shown with and without this area not owned by the state DOT.

Table 12. Ohio stormwater results.

Ohio (Cuyahoga County Only) (Excludes ODOT maintenance facilities and rest areas)	
State system impervious area	4,184 acres
Treated area	49.9 acres
Percent of DOT-owned impervious surface for which treatment is provided	1.2%

**Does not account for surface that is passively treated or that does not require treatment.*

Table 13. North Carolina stormwater results.

North Carolina (Statewide Primary Roads)	
Primary roadways impervious area	94,730 acres
Treated area	4,644 acres
Percent of DOT-owned impervious surface for which treatment is provided	4.9%

**Does not account for surface that is passively treated or that does not require treatment.*

(Drainage areas and impervious area calculations are based on a sample of 30 BMPs.)

and the average share of imperviousness were applied to all other BMPs for which this information was not available. North Carolina DOT staff indicated there is nothing notably different about these BMPs compared with other BMPs around the state. The results are therefore a preliminary estimate, and a more reliable measure would require more data gathering and analysis.

Stormwater Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **The Amount and Type of Stormwater Treatment Needed Varies by State.** Not all roads need the same amount of stormwater treatment. Largely rural and arid climate states in the southwest, for example, likely have many miles of roadway that require minimal treatment, while population centers in the wetter Pacific Northwest need more stringent treatment. Holding these two areas to the same standards may not give a true sense for how well a state DOT is meeting the *need* for treatment. Establishing limiting criteria across the board, such as by population or rainfall amounts, can address this issue.

- **States with More Stringent NPDES Requirements Are Best Equipped to Calculate This Measure.** A state DOT's degree of focus on runoff treatment is often influenced by the requirements of the agency's NPDES permit. Maryland's NPDES regulating agency was one of the first to require a full inventory of stormwater treatment BMPs, because of concerns about the Chesapeake Bay, and the Bay states have long had one of the most rigorous treatment programs. State DOTs often undertake an inventory of BMPs only after it becomes a requirement in their permit. Those states with newer BMP inventory requirements—such as Ohio and North Carolina—are less prepared for this measure than those with longer-standing requirements, such as Maryland and Delaware.

Do State DOTs Have Easy Access to Data/Is Measure Easily Calculated?

- **Most States Today Have Limited Access to BMP Data.** Conversations with selected state DOTs, suggest that—with the exception of Maryland and Delaware—most are unlikely to have enough data to fully calculate the stormwater measure, as proposed. State DOTs' stormwater data capabilities are rapidly evolving as stormwater policy requirements and technology in the area of GIS mapping advance swiftly.
- **Phased Approach for Measure Implementation Is Viable.** Most state DOTs today lack sufficient data in the area of stormwater to calculate the measure, as proposed. Trends in stormwater policy and data, however, suggest a favorable outlook for phasing in such a measure over time by gradually adopting the following interim measures as more data becomes available:
  - **Phase 1: BMP Inventory-Based Measure**. A BMP inventory documents how many highway-related BMP structures a state DOT has and where they are located. BMP inventory data is needed as the first step for calculating the stormwater measure, but regularly updated BMP inventory data alone could be used for an interim measure such as the *number of acres of untreated pavement retrofitted for stormwater treatment annually.* State DOTs increasingly are preparing BMP inventories as part of their compliance with statewide NPDES permits. Nebraska, Ohio, and Nevada who were contacted as part of this study, for example, are all in the initial stages of preparing a BMP inventory for their highway systems and the team expects that BMP inventories will become more common over time.
  - **Phase 2: Impervious Surface-Based Measure.** With a BMP inventory in place, BMP data can be conflated with data describing the amount of state DOT-owned impervious area, which is the second step in calculating the proposed stormwater measure therefore allowing use of a measure like *number of BMPs per acre of impervious area* before a state DOT begins calculating the drainage area of each BMP, which is the most analytically complex element of the final stormwater measure.
  - **Phase 3: Complete Implementation.** Assignment of drainage areas to each BMP represents the final major step in the data gathering process. Ideally drainage areas would be recorded in a GIS environment to allow for simple spatial analysis—finding the intersection of drainage areas and impervious surface is a standard process in all GIS software. At this point, a state DOT is able to calculate the full performance measure.

  Even under a phased approach, the stormwater measure would require most states to dedicate considerable staff hours to the labor-intensive process of inventorying their treatment network and delineating individual treatment areas.
- **GIS Tools Are Key to Stormwater Data Accessibility.** GIS-derived latitude and longitude data that can be linked to a BMP inventory enables easy delineation of drainage areas based on topography. It also better enables users to analyze the results at varying geographic

levels (county, district, statewide) and with varying road characteristics (road class, traffic volume, population, urban/rural, proximity to impaired water bodies, etc.).

Is Data Quality Credible and Defensible?

- **Stormwater Measure Implementation Will Require Resolution of Analytic Issues.** Full implementation of the stormwater measure will require answers to a variety of nuanced questions on the details and parameters of the measure:
  - **Do All Roads Need to Be Part of the Measure?** For example, do arid areas or low-volume roads need to be treated to the same extent as areas with lots of rain and traffic? It may not be efficient to encourage the same treatment in these places.
  - **How Should "Treatment" Be Defined?** Large sections of state DOT right of way are sufficiently pervious and vegetated to provide natural water quality and flow treatment to runoff. These areas could be accounted for in the measure, either by counting as treatment or by reducing the total area in need of treatment (the denominator). Similarly, treatment of less engineered "green infrastructure," such as bio-swales should be resolved as part of the measure.
  - **Under What Conditions Does an Adequate BMP Need to Perform?** Some structures are built to accommodate a 2-year storm, but should they be able to withstand a more severe 10-year storm?
  - **Should Non-Structural BMP Activity Be Incorporated, and If So, How?** Because the measure looks only at BMPs that are discrete and easily quantified, that is, engineered, structural BMPs, a portion of water quality improvements, which includes all non-structural BMP activities, are not captured. DOTs undertake an array of activities to improve water quality, such as regular street sweeping, vegetation planting, and deicing improvements. These elements are not captured in the current form of the measure. (It is possible to develop a series of "impervious area equivalents" for non-structural BMP activities, as Maryland has started exploring for its program.)
  - **Is It Possible to Include the Quality of Treatment in This Measure?** This measure currently only takes into account how much pavement is in an area served by a structural BMP, based on original designs and functionality. It does not take into account whether each BMP is being adequately maintained, or how well the structure is working. These elements are also important to water quality assurance, and should be captured.

4.6 Wildlife and Ecosystems Measure: Proof of Concept Results

Measure: Ecosystems Self-Assessment Tool

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	◑	☐ Ready for Use by Many DOTs Today
Can State DOTs Report Measure Easily with Existing Data or Data That Is Easy to Generate?	●	☑ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	◑	☐ Not Suitable for Use by Most DOTs

Key

● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

Overview

Pilot States: Georgia, Illinois, Maryland, Ohio, Oregon, Texas

The wide variations in biological diversity among states make a single metric for wildlife and ecosystems extremely challenging. The ESAT is a tool state DOTs can use to assess their performance using a standardized questionnaire that attempts to capture the complexity of this topic area in a meaningful way. It is a relatively simple, yet comprehensive, self-administered assessment that evaluates performance in terms of avoiding, minimizing, or mitigating impacts in six ecological focus areas.

The ESAT has been tested in six pilot states; typically either the director of environmental services or senior biology staff conducted the pilot test in each state. DOT representatives from each pilot state that agreed to participate in proof of concept testing were provided the ESAT and an instructional memo that also included an overview of the project and the wildlife and ecosystems measure.

The mean overall score for the six participating states was 47 percent of the maximum points available. Given the small sample size, only basic statistical parameters were evaluated; however, the data suggest a relatively normal distribution of scores around the mean, with a minimum score of 22 percent and a maximum score of 69 percent. Scores were similarly distributed within each ecological focus area, as shown in Figure 11. The range of scores for each individual question were also well distributed, suggesting that the scoring system was capturing the range of DOT performance. Only one question had an identical response from all states. See Appendix B (Table B-3) for a complete summary of scores from proof of concept testing.

Wildlife and Ecosystems Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **Subjective Interpretation and Scoring for the ESAT Makes Comparisons between States Challenging.** Given the wide range of practices and experiences of DOTs across the country, or even between different divisions or individuals within a given program, answers may vary

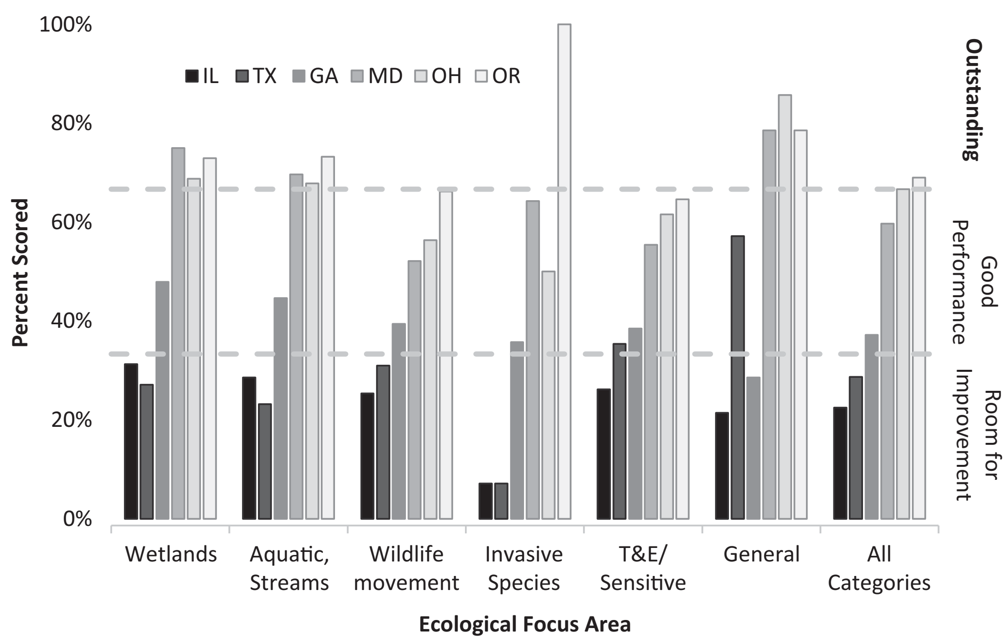


Figure 11. ESAT proof of concept score comparison for six pilot states.

because of divergent interpretations of the questions rather than actual differences in practice. Qualitative questions are the most difficult to compare because they draw upon the DOT respondent's own interpretation and experiences to assess performance. Additionally, the ESAT does not provide explicit instructions for calculating responses that are based on quantitative data because of the absence or impracticality of using a single, nationwide standard for tracking this information. Therefore, calculation methodologies and associated responses may vary somewhat between programs.

Do State DOTs Have Easy Access to Data/Is Measure Easily Calculated?

- **The ESAT Evaluates Many Practices Not Regularly Tracked by Most DOTs.** In cases where data is not readily available and would be burdensome to collect for the purposes of completing the ESAT, DOTs may select an answer based on the best available information on hand. For example, certain DOTs reported that they did not track the proportion of impacted streams or wetlands that have been mitigated over the last 5 years or were unable to calculate the average share of the DOT's annual research budget allocated to ecosystem-focused research over the last 5 years.

Is Data Quality Credible and Defensible?

- **Many Questions Are Subjective and Qualitative in Nature and Are Therefore Susceptible to Divergent Interpretations.** Scores for 18 of the 41 questions require DOTs to perform calculations or estimate their performance quantitatively; the remaining score ranges are qualitative. Even when quantitative scoring is applied, DOTs may vary in their interpretation. In addition, for most questions, the DOTs themselves are the authoritative source for information on their program's practices. Responses could be externally verified if DOTs choose to provide an online source for each response; however, providing this information is optional and no verification system is currently in place.

CHAPTER 5

First Principles for Using Environmental Performance Measures

This three-part chapter examines: (1) performance-based decision making in DOTs, (2) using environmental measures in a DOT, and (3) first principles for using performance targets.

The environment is a more multi-faceted topic compared with other major strategic issues in a state DOT's portfolio, such as bridge condition, safety, or congestion. (Under the umbrella of "environment," for example, energy issues are quite unrelated to endangered species issues.) Furthermore, some environmental issues are partially or completely outside a DOT's control, which means environmental performance outcomes are not always greatly influenced by the kinds of decisions a DOT has authority to make, and targets met (or missed) are not necessarily a result of DOT actions. As a result, use of each measure in target setting or decision making should reflect the function(s) it is best suited to supporting and its applicability to different elements of a DOT's mission:

- **Function of Measures within a DOT.** Research indicates that measures in a DOT mostly serve one or more of three broad functions: (1) some function best as ways to build external *accountability* and enhance a DOT's credibility, (2) others function as analytic and internally oriented *decision-support* tools, and (3) some serve as *management* tools for signaling where staff should focus their efforts.
- **Applicability of Measures to Core DOT Mission Elements.** A DOT's mission can be broken into a series of elements that begin with strategic planning and go through long-range plan development, to short-range programming, project planning, design, construction, and end with system operations and maintenance. Different measures have different degrees of relevance to each of these elements.

Each suggested environmental measure should be integrated into target setting and decision making according to the particular function(s) it best serves and the DOT mission element(s) for which it has greatest relevance.

5.1 Performance-Based Decision Making in DOTs

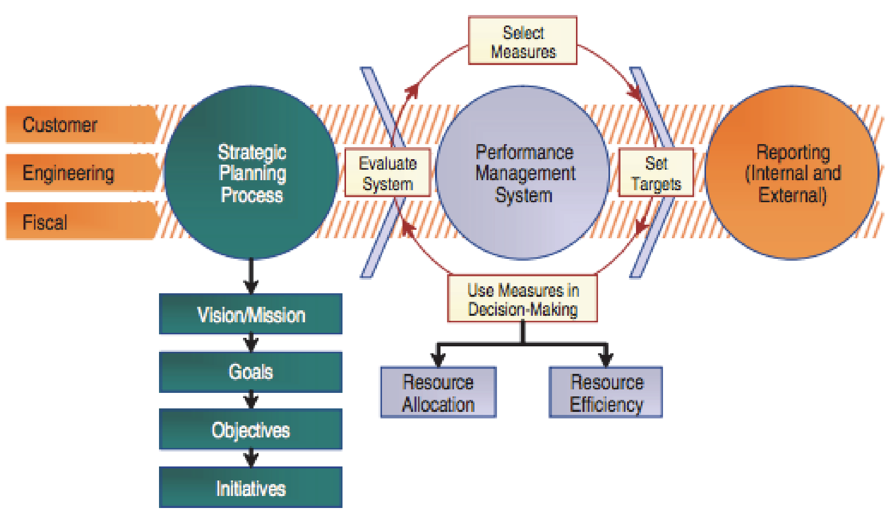
In this section, the research and literature on how DOTs are using performance-based decision making, performance measures, targets, and performance management are reviewed, and important lessons learned are highlighted.

Elements of Performance Management

Performance management is a business process widely used among DOTs, in which performance measures and targets are lynch pins that link agencywide organizational strategic goals—like safety, access, mobility, or economic prosperity—with decisions about how to make best use of staff resources and funding to influence outcomes. A generic framework for performance management at a state DOT contains the following basic elements:

- **Strategic Planning.** The first step in performance management is strategic planning, which has many variants, but generally includes setting a vision/mission, goals, and objectives; determining actions to achieve the goals; and mobilizing resources to execute the actions. A strategic plan describes how the ends (goals) will be achieved by the means (resources). An organization's senior leadership is generally tasked with creating its strategic plan.
- **Measures.** Well-chosen and carefully crafted measures give DOT staff, managers, or executives, and their stakeholders an objective and quantitative depiction of positive or negative trends in performance for strategic goals, and the pace at which change is occurring. The mere act of measurement is usually characterized as an important driver of "what gets measured gets done" (*9*).
- **Target Setting.** Effective performance management also requires targets that complement basic performance trend information. A target is a quantifiable point in time at which an assigned level of performance shall be achieved. As described in *NCHRP Report 666: Target Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies*, well-chosen targets show what performance is achievable in a world of competing objectives, funding constraints, and political considerations (*10*). MAP-21 requires state DOTs and metropolitan planning organizations (MPOs) to set targets for forthcoming national performance measures in the areas of infrastructure condition, safety, and system performance.
- **Decision Making.** To varying degrees and at various degrees of sophistication among different parts of their organizations, state DOTs are integrating strategic planning, measures, and targets to support decisions. At the advanced end of the spectrum, some DOTs have developed highly analytic and data intensive processes, particularly in the area of asset condition, that use performance information to inform complex decisions, such as if, when, where, and how to repair roads and bridges.

Together, performance measures and targets are used in conjunction with strategic planning to inform a cyclical decision-making process of (1) *diagnosing problems*, if any, that require action, (2) *informing decisions* on how to resolve them, and (3) *monitoring progress* toward eliminating problems. Figure 12 has been adapted from *NCHRP Report 660* and shows how these elements work together in a cyclical process.



Source: *NCHRP Report 660: Transportation Performance Management Programs: Insights from Practitioners* (2009).

Figure 12. Performance management elements.

Functions of Performance Management

Reports such as *NCHRP Report 660* and the NCHRP Project 20-24/Task 83 report titled *Alternative DOT Organizational Models for Delivering Service* identify three broad functions for performance management (*11*, *12*). Different measures and targets can serve all or some of these functions to varying degrees:

- **Accountability.** DOT leaders stress the vital importance of ensuring agency credibility with state legislatures, specific stakeholders, and the public. Gaining credibility often means, in part, ensuring performance meets stakeholders' expectations. The introduction by Congress of national performance measures under MAP-21 is now driving an even greater focus on accountability. In some instances, a target provides a clear focus on accountability, which DOT stakeholders are increasingly demanding. Targets can also highlight performance gaps when measure outcomes fall short, which can be helpful in making the case for additional resources, policy changes, or other steps required to address performance problems.
- **Decision Support.** State DOTs are being pushed to achieve greater efficiency and to "do more with less." This is occurring as agencies' roles are growing, staffing levels are being cut, and there is increased pressure to outsource. Together, these considerations are pushing DOTs to find ways to use data to make better decisions. For example, while strategic plans establish important priorities in qualitative terms, setting a target for performance provides a measure of the size of any performance gap, which can be valuable in helping a DOT calibrate its actions in response. Alternatively, performance targets provide a way to evaluate the probable effectiveness of proposed investment strategies or other policy initiatives. In long-range plans, for example, many DOTs now evaluate the potential performance impact of different investment scenarios.
- **Management.** Lastly, performance measures help management signal priorities to staff in a world where a combination of aging infrastructure, growing congestion, shrinking revenues, and other challenges create many competing priorities. Setting a target for performance can provide a clear aspirational goal for staff to work toward. Sometimes DOTs even link individual annual performance reviews of senior staff to achievement of targets.

DOT Mission Elements

Any DOT's mission is characterized by a series of basic work elements, which include policy development, long-range planning, programming, project planning and review for compliance with the National Environmental Policy Act (NEPA), project design, construction, maintenance, and operations:

- **Strategic Planning/Policy Development.** State DOTs have always operated in a shifting business environment; but this holds even truer today. Pressure to make government more efficient and more accountable, shrinking gas tax revenues, and a shift from building to maintaining the Interstate system are a few of today's big external drivers for change in DOTs. DOT leaders increasingly recognize strategic planning as a vital tool to help their agencies stay on track in an evolving business environment. Strategic planning involves establishing a core set of policies to guide agency direction. Performance data can be a vital input alongside stakeholder opinions, regulatory requirements, and political considerations in informing choices about policy direction.
- **Long-Range Transportation Planning.** The long-range planning process provides the means by which state DOTs translate complex national, state, and local transportation interests and anticipated funding availability into a vision for state transportation investment. States and regions develop their Long-Range Transportation Plans (LRTPs) through a range of approaches and plans take on many different forms from broad policy statements to specific preferred

investment strategies. An LRTP will often help quantify long-term needs, revenues, and funding gaps; identify and define investment strategies; and establish framework, priorities, or other guidance to drive shorter-term investment decisions.

While state DOTs have leeway in how they develop and use their LRTPs, their planning processes must comply with federal planning laws, regulation, and guidance. These requirements include the basic requirement that states self-certify their long-range transportation planning process in conjunction with the submittal of a Statewide Transportation Improvement Program (STIP) at least once every 4 years. States also develop plans around planning factors that have evolved over time and dictate the various considerations that must be incorporated into state planning processes. Long-range planning is a point at which expectations for performance can be discussed—particularly in terms of desired performance outcomes—and broad performance goals established that drive subsequent investment patterns.

- **Short-Range Transportation Programming.** State DOTs use capital programming to match up priority project-level transportation needs with funds to fulfill them. The short-range capital program is a generic term used to describe (1) an agency's list of high-priority transportation projects with well-developed scopes and precise budgets to be built in a defined timeframe and (2) the process used by a state to arrive at the list by deciding how money for transportation will be spent among competing project needs. An effective capital program should ensure immediate, project-level spending decisions are on track toward making progress in achieving long-term transportation goals that support national, state, and local interests. Development of a state or local capital program is usually a collaborative effort among the state DOT and their local and federal partners. Transportation programming is a point at which broad expectations about performance established in long-range planning can be translated into implementation of a specific set of projects.
- **Project-Level Planning.** Once a transportation project is identified in a capital program, project delivery begins with planning, which takes place before NEPA documents are prepared and which varies with projects and agencies. In general, planning efforts are most extensive for major projects with potential for the greatest environmental impacts. Minor projects, such as guardrail replacement, acquisition of new buses, or roadway resurfacing may involve little or no planning activity. The planning phase helps agencies to identify project needs, community concerns, and potential solutions. In many states, early consideration of environmental issues before a NEPA document is prepared is an increasingly common part of project planning. Project-level performance measures may be used to inform project-level planning decisions.
- **Project-Level NEPA Review.** Transportation infrastructure projects that receive federal support must follow an elaborate environmental review process designed to ensure that the impacts of federal actions on the environment are considered prior to project development. Environmental review procedures are guided by NEPA, which also functions as an umbrella process for assuring compliance with numerous other media-specific environmental laws and regulations that include permitting and consultation activities involving a variety of federal agencies. Frequent federal partners in this process include the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Advisory Council on Historic Preservation, EPA, and others. Most commonly, state DOTs lead the NEPA process, but it may be carried out by a transit agency or a large local transportation department. NEPA establishes three classes of environmental review actions for transportation projects, based on the magnitude of their anticipated environmental impacts including an environmental impact statement (EIS) for major projects where a significant environmental impact is anticipated, such as construction of a new segment of controlled access freeway. As in planning, project-level performance measures may be used to inform project-level NEPA decisions.
- **Project Design.** Once the NEPA process is complete and a basic horizontal and vertical alignment for the project is agreed upon, detailed engineering plans can be prepared. Most design

work is unrelated to environmental mitigation. Design work may include environmental compensation or enhancement features, such as stormwater control facilities, wetland mitigation, or noise walls. Permits from natural resources agencies, such as the U.S. Army Corps of Engineers, may also be required at this phase during project delivery and require time to prepare and approve. Permits may be required for wetland restoration, stormwater runoff control, conservation of historic resources, or special construction management techniques. Design, land acquisition, and permitting represent a point at which predictions that occur in planning and NEPA review can be verified on the ground and translated into outcome measures of performance.

- **Construction.** During construction, DOTs use contractors to build projects and DOTs typically retain an overall project management and oversight role. Many projects require erosion control practices that can reasonably be described as environmental costs.
- **Maintenance and Operations.** Once a project is built, it is maintained and operated by the state or local agency. This function provides for repairs and preventive maintenance of state highways and the various signs and structures within the highway right of way, such as winter plowing and sanding, and year-round repairs to the state highway system.

When Target Setting Is Not Helpful?

Under some circumstances, performance management may be neither practical nor desirable:

- **Issues outside a DOT's Control.** Measures that track issues outside a DOT's control may provide valuable transparency to stakeholders and an indication of an agency's commitment to improvement. In this context, however, a target may serve little purpose, since the DOT has no power to achieve it.
- **Recently Established Measures.** If a measure is newly created, target setting may be challenging because no historical precedent can be used as a yardstick for determining where to set the target. In this situation, any targets should be carefully portrayed as subject to revision once greater clarity emerges about performance trends.

In these circumstances, targets and review of data that together constitute performance management may be either inconsequential and unnecessary, or even harmful if it draws staff attention away from other issues or causes stakeholder confusion.

5.2 Using Environmental Measures in a DOT

In the second part of this chapter, the research team examines how each of the five environmental performance measurement goal areas of air quality, energy and climate, recycled materials, stormwater, and wildlife and ecosystems, can best be integrated into a performance management program within a state DOT. In particular, the team examines how the measures serve different functions and support different mission elements, as summarized in Table 14.

Air Quality

Change in Statewide Motor Vehicle Emissions

Measure Function(s):
- ● **Accountability**
- ○ Decision support
- ○ Management

Mission Element(s):
- ● **Strategic Planning/Policy Development**
- ◕ **Long-Range Planning**
- ○ Short-Range Transportation Programming

Table 14. Summary of suggestions for integrating measures.

	Measure Functions			Applicability to Mission Element						
	Account-ability	Decision Support	Manage-ment	Strategic Planning	Long-Range Planning	Program Development	Project Planning /NEPA	Project Design	Construction	Maintenance & Operations
Change in statewide motor vehicle emissions	●	○	○	●	◕	○	○	○	○	○
Statewide on-road gasoline consumption per capita	●	◔	○	●	◕	○	○	○	○	○
State DOT fleet alternative fuel use as a percent of total fleet fuel use	◔	○	●	○	○	○	○	○	○	●
Annual percentage by mass of all roadway asphalt pavement materials composed of reclaimed asphalt pavement (RAP)	◔	◕	●	◔	◔	○	○	◔	●	●
Percentage of state DOT-owned impervious surfaces for which stormwater treatment is provided	◕	◕	●	◕	◕	○	●	●	○	○
Ecosystems Self-Assessment Tool (ESAT) score	◔	◕	●	◔	●	●	●	●	●	●

Key
● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

- ○ Project-Level Planning/NEPA Review
- ○ Project Design
- ○ Construction
- ○ Maintenance and Operations

Target Setting: Not appropriate

State DOTs have marginal influence over total motor vehicle emissions, because the impact of project-level strategies to manage travel demand or congestion is dwarfed by changes in vehicle technology or fuels that reduce per vehicle emissions. The air quality measure is most relevant for states with air quality nonattainment areas; it provides an indication of trends in the transportation sector's contribution to various air pollutants. The measure is most useful as a way to communicate to the public the role of transportation in generating pollutants that harm air quality. Performance results may be influenced over the long term by planning and building multi-modal transportation systems that offer low-emission travel choices and by reducing congestion that causes higher emissions, by using operational strategies and targeted capacity improvements. Such direction is usually established during strategic or long-range planning, and any performance trend information can help inform these functions.

Energy and Climate Change

Statewide On-Road Gasoline Consumption per Capita

Measure Function(s):
- ● **Accountability**
- ○ Decision support
- ○ Management

Mission Element(s):
- ● **Strategic Planning/Policy Development**
- ◕ **Long-Range Planning**
- ○ Short-Range Transportation Programming
- ○ Project-Level Planning/NEPA Review
- ○ Project Design
- ○ Construction
- ○ Maintenance and Operations

Target Setting: Not appropriate

Energy consumption is a major environmental concern, but as with air quality, state DOTs have marginal control over energy consumption in the transportation sector because strategies to manage travel demand are much less effective than vehicle technologies or consumers' choices that reduce the amount of energy consumed per mile of travel. The gas consumption per capita measure provides a straightforward indication of the transportation sector's contribution to GHG emissions and share of overall energy use at a statewide level. As such, it helps shape strategies in the private and public sector for planning and building multi-modal transportation systems that offer energy-efficient travel choices. Such direction is usually established during strategic or long-range planning, and any performance trend information can help inform these functions.

State DOT Fleet Alternative Fuel Use as a Percentage of Total Fleet Fuel Use

Measure Function(s):
- ◔ **Accountability**
- ◔ **Decision support**
- ● **Management**

Mission Element(s):
- ○ Strategic Planning/Policy Development
- ○ Long-Range Planning

- ○ Short-Range Transportation Programming
- ○ Project-Level Planning/NEPA Review
- ○ Project Design
- ○ Construction
- ● **Maintenance and Operations**

Target Setting: Yes. Based on data gathered as part of this report, a plausible target might range from 2 percent to 10 percent initially, with targets increasing over time.

Considerations: All or some of the following factors may constrain a DOT's target for this measure: statewide availability of alternative fuel sources, state rules governing vehicle acquisitions/modification, fleet turnover rate. Conversely, state mandates for biofuels could help a DOT attain an alternative fuels target.

Alternative fueled vehicles reduce the consumption of petroleum-derived fuels in most cases, and of GHG emissions in many cases. Unlike the air quality or gasoline consumption measures described previously, many state DOTs can have an impact on fuel choices within their vehicle fleet and some already encourage or mandate use of alternative fueled vehicles. The fleet alternative fuel measure is thus valuable as a tool for driving management direction, particularly within a DOT's maintenance and operations practices. It is also helpful to a limited extent in demonstrating an agency's long-term commitment to improving the environment by promoting alternative fuel use.

Materials Recycling

Annual Percentage by Mass of All Roadway Asphalt Pavement Materials Composed of Reclaimed Asphalt Pavement (RAP)

Measure Function(s):

- ◔ **Accountability**
- ◕ **Decision support**
- ● **Management**

Mission Element(s):

- ◔ **Strategic Planning/Policy Development**
- ◔ **Long-Range Planning**
- ○ Short-Range Transportation Programming
- ○ Project-Level Planning/NEPA Review
- ◔ **Project Design**
- ● **Construction**
- ● **Maintenance and Operations**

Target Setting: Yes. Based on data gathered as part of this report, a plausible target might range from 15 percent to 25 percent initially, with targets increasing over time.

Considerations: All or some of the following factors may constrain a DOT's target for this measure: statewide availability of RAP and materials specifications governing how much RAP can be incorporated in asphalt.

State DOTs establish specifications for pavement composition; therefore, they have control over the amount of RAP used in pavements. The RAP measure is relevant to decision support; maintenance or construction engineers can review trends and determine whether to be more aggressive about the use of RAP. Likewise, they can use the measure as a management tool for encouraging staff to consider greater use of RAP. The measure is also helpful to a limited extent as an accountability measure in demonstrating an agency's long-term commitment to improving the environment by recycling and reusing.

Stormwater

Percentage of State DOT-Owned Impervious Surfaces for Which Stormwater Treatment is Provided

Measure Function(s):

- ◕ **Accountability**
- ◕ **Decision support**
- ● **Management**

Mission Element(s):

- ◕ **Strategic Planning/Policy Development**
- ◕ **Long-Range Planning**
- ○ Short-Range Transportation Programming
- ● **Project-Level Planning/NEPA Review**
- ● **Project Design**
- ○ Construction
- ○ Maintenance and Operations

Target Setting: As measure is developed by states, targets could be set, but target setting is premature at this time given the measure's experimental status.

Considerations: Not all roads need the same amount of stormwater treatment.

Runoff from pavements is an environmental issue in many parts of the country, especially in urban areas where it can contribute to impairment of water bodies. State DOTs are increasingly developing structural BMPs to help meet NPDES permitting requirements and therefore they can influence the proportion of state-owned impervious road surfaces for which treatment is provided. The stormwater performance measure's value cuts across all functions and many decision-making phases in a DOT.

Wildlife and Ecosystems

Ecosystems Self-Assessment Tool (ESAT) Score

Measure Function(s):

- ◔ **Accountability**
- ◕ **Decision support**
- ● **Management**

Mission Element(s):

- ◔ **Strategic Planning/Policy Development**
- ● **Long-Range Planning**
- ● **Short-Range Transportation Programming**
- ● **Project-Level Planning/NEPA Review**
- ● **Project Design**
- ● **Construction**
- ● **Maintenance and Operations**

Target Setting:	As measure is developed by states, targets could be set, but target setting is premature at this time given the measure's experimental status.
Considerations:	Applicability of some of the factors in the ESAT may vary from state to state. It may be most appropriate to use the ESAT to track trends for each state, rather than to set targets.

Key

● Measure completely applicable
◕ Measure mostly applicable
◑ Measure somewhat applicable
◔ Measure slightly applicable
○ Measure not applicable

5.3 First Principles for Using Performance Targets

Next, the team examines some first principles for beginning a performance management program and using performance targets.

First Principles of Performance-Based Decision Making

Together, *NCHRP Report 660* and the NCHRP Project 8-36/Task 47 report titled *Effective Organization of Performance Management* describe several success factors that characterize successful performance management programs (*11, 13*):

- **Begin by Taking on the Agency's Most Pressing Challenges.** Many of the programs evaluated as part of *NCHRP Report 660* began as a response to a clear and present problem faced by the agency, rather than a broad desire for performance management by virtue of its own merits. While a crisis is neither necessary nor sufficient to highlight the need for better, more informed decision making, a proposed program should initially highlight areas of concern that an agency wants most to address, and these areas of concern should be important to employees throughout the agency, not just the top executives.
- **Use Performance Measures as Agents for Change.** Just as performance management is most effectively implemented in response to specifically identified challenges, the underlying measures themselves are most useful when they provide a laser-like focus on a DOT's most challenging problems. To avoid the risk of "diluting" the original objectives of performance management, agencies should resist attempts to institute performance management in every aspect of an agency, especially early in program development. Furthermore, within a particular agency function the specific measures used should be tailored to the challenges at hand, even if the result is that certain aspects of that department or function are not measured.
- **Provide Bold Leadership Stemming from the Top of the Agency.** Leaders either bring a performance management philosophy to their position or imprint their own leadership style on an existing program. Particularly when performance management is implemented in response to concerns about agency accountability, it is often in conjunction with changes in leadership. To emphasize that a fundamental change is taking place in the way the agency does business, it is helpful to accompany these changes in philosophy and leadership style with a bold and identifiable new agency program or initiative. Many agencies that have successfully implemented performance management have done so through the introduction of a new agencywide initiative specifically aimed at promoting performance and accountability.
- **Focus on Initiating a Performance Management Program, Not on Completing It.** No agency ever "finishes" its performance management program. In fact, it is doubtful that a

"complete" performance management program is even possible or desirable. Rather, successful systems build on initial successes and continually refine their program, performance measures, and supporting data. Continuous improvement includes changing goals and objectives based on data analysis, improving data collection and use, changing fiscal or political constraints, and others.

- **Have Top-Level Leadership.** Commitment to performance measurement from a CEO-level leader fosters broad employee support. If an organization's leader promotes the use of performance data for decision making, resource allocation, and/or guiding agency direction, the performance measurement program is more likely to receive support from within the organization.
- **Have Career/Senior Management Leaders.** Championship of performance measures by career-level managers helps institutionalize a performance measurement program even through changes in administration or CEOs. These champions provide day-to-day leadership and continuity that help sustain performance monitoring on an organization's agenda, even when changes in administration occur.
- **Create Performance Measurement Culture and Employee Accountability.** Creating a culture where performance measurement is accepted and supported helps motivate employees to participate and strengthens program continuity over time. Ownership and employee buy-in are fostered when staff has an expectation that measurement reports will be regularly reviewed and acted on. A consistent and stable program can improve the value of an agency's performance measurement program over time and create an expectation that performance measurement is becoming a part of an agency's operation and not simply a short-term initiative.
- **Link Measures with Actions.** The process of reviewing measure results should be linked to decision making processes that allow appropriate actions to be taken, including resource allocation decisions, to support steps for addressing issues identified during review of performance results.
- **Establish Decentralized Responsibility.** Establishing widespread responsibility for performance measurement implementation is likely to ensure it has its greatest impact. The key is to identify effective participants across the agency, engage knowledgeable staff, and develop reporting mechanisms that expand responsibility for the program beyond a centralized overview of performance results.
- **Institute Cyclical Reporting on Performance.** Regularly scheduled reporting, especially for external audiences, is likely to increase agency accountability for decision making and delivery. Agency reports on key performance indicators establish expectations among legislators and other key decision makers for continued performance-based decision making that support program stability over time. Clear, regularly scheduled reports also provide a consistent discussion document when addressing resource needs.

First Principles of Performance Target Setting

Target setting is described in *NCHRP Report 551: Performance Measures and Targets for Transportation Asset Management* as a "delicate exercise" (*14*). Organizations must define baseline, reasonable, and "stretch" levels of performance and then reconcile them with existing and desired organizational competencies and goals. And the targets they set must motivate high performance without encouraging risky behavior or attempts to game the system. Several simple principles can help ensure targets are a useful part of the performance management process not a hindrance:

- **Establish a Framework for Performance-Based Management.** Targets and decisions should be anchored in a set of policy goals and objectives that identify an organization's desired direction and reflect its business environment.

- **Review Trend Data.** Targets should not be set in isolation; they should be based on reliable data, gathered over several years, that provides a long-term perspective on trends and pace of change to ensure targets are viable.
- **Work Collaboratively.** Target setting should be part of a continuing, cooperative, and comprehensive planning process for performance measurement that brings together affected entities inside (and outside, where appropriate) the state DOT. Unless performance targets are set with the concurrence of key decision makers and stakeholders, the effectiveness of performance measurement as a management tool is almost certain to be compromised.
- **Be Realistic and Consider Influences on Targets.** Many issues where performance is measured are somewhat, mostly, or completely beyond the state DOT's control. Targets should reflect the reality of conditions like political or legislative influence, customer and stakeholder perspectives, agency experience with targets, financial resources, timespans, risks, and strategic priorities.
- **Revisit Regularly.** The feasibility of targets should be assessed regularly and updated as needed to reflect evolving risks such as new revenue expectations, changing strategic priorities, political realities, ease of achieving targets, and increasing experience in performance management. Focus on continuous improvement by revising/adding new metrics as needed.
- **Be Patient.** Allow a reasonable amount of time for achieving targets because a measurable change may take considerable effort. In the short term, consider setting an easy short-term target, a moderately challenging target for the medium term, and a stretch target for the long term.
- **Guard against Unintended Consequences.** Consider how targets set for one measure could have unintended consequences for the performance of another measure due to resources shifting to other priorities.
- **Be Transparent.** Setting targets should be accompanied by a rationale for selecting the specific target value.
- **Track Progress.** Virtually all public and private organizations that employ performance management track the impact of their investments in achieving specific targets by preparing periodic performance measure "snapshots" in which red, yellow, and green colored shapes represent annual progress relative to targets.
- **Accountability and Rewards.** When employees understand that their job performance is gauged in part by the outcomes of appropriate performance measures, they are much more apt to see the "big picture" in their work, and to find management strategies that influence results. Therefore a crucial component of performance-based management is cultivating an agency philosophy that stresses the idea that "we're all in this together." Likewise, reward business areas that consistently meet targets and goals. Consistent achievement in meeting targets is a powerful motivator for behavior—success breeds success.

CHAPTER 6

Web-Based Measure-Reporting Template

Communicating performance results is often a key element in a state DOT's performance management program. This chapter outlines a conceptual template for a national-scale website that displays all participating states' environmental performance measure results.

In Figures 13 to 18, North Carolina's proof of concept data is used to showcase the website's functionality, including screenshots from the demonstration website template created as part of the project's research phase and some accompanying text explaining each element of the website template.

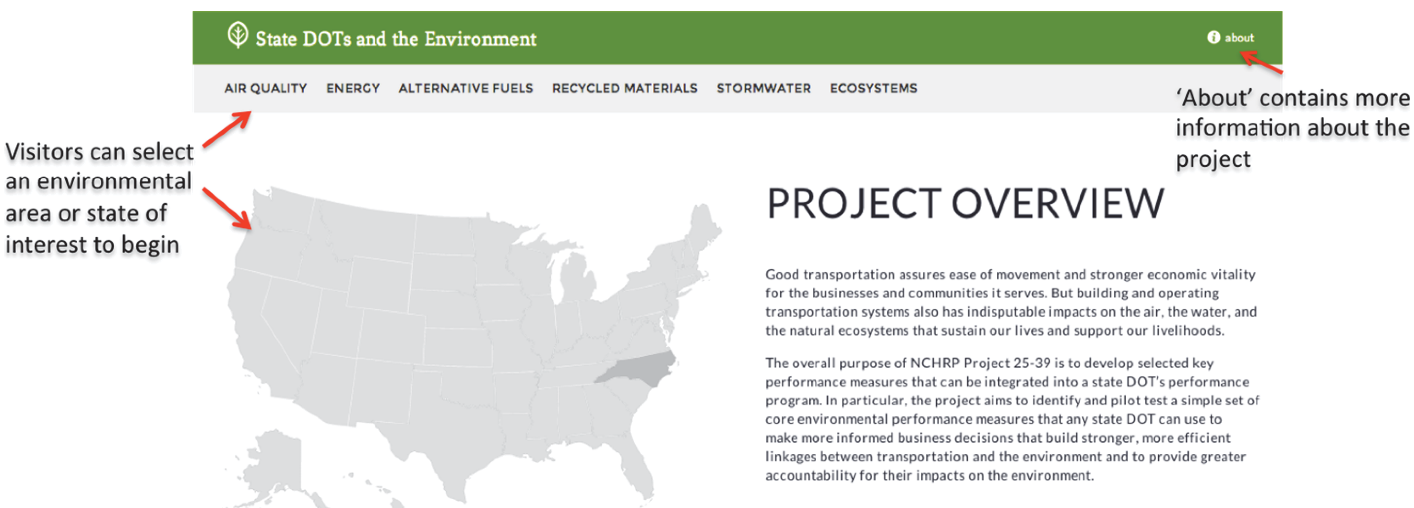


Figure 13. Website home page.

The **home page** gives an overview of the suite of environmental measures. More detailed information can be found by clicking on the "about" link at the top right of the page. Users can navigate back to this page at any time by clicking the "State DOTs and the Environment" heading, which remains in place on all of the website's pages. From the home page users can choose one of two directions: select a state of interest from the map or select an environmental area of interest from the list across the top banner.

A clickable map of the United States allows users to identify a single state's results. In the example, North Carolina is shaded darker grey to indicate performance results are available. A click takes users to North Carolina's custom **state overview page**, which displays an overview of its results across all measures, compared with the pilot state averages.

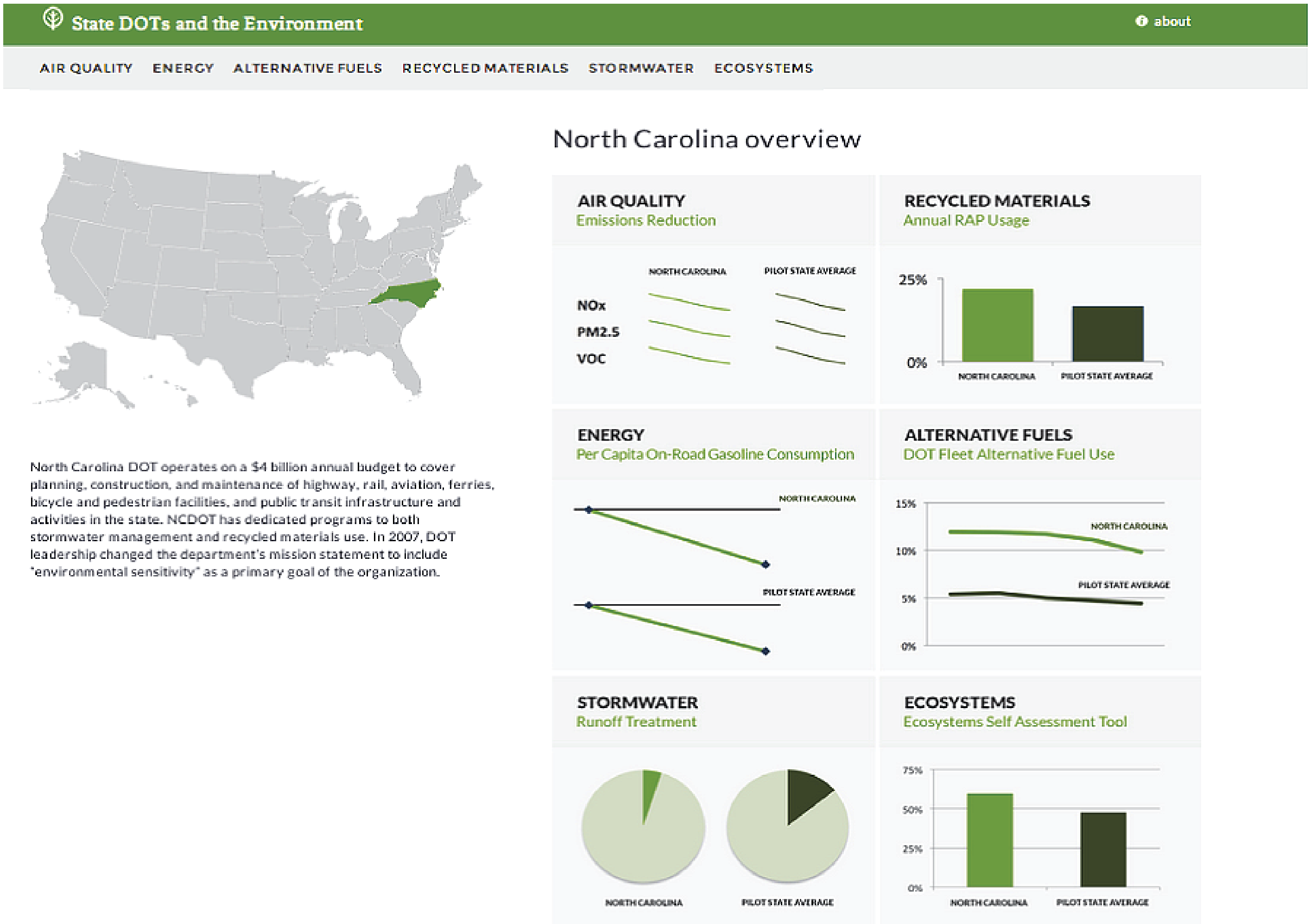


Figure 14. State overview page (North Carolina example).

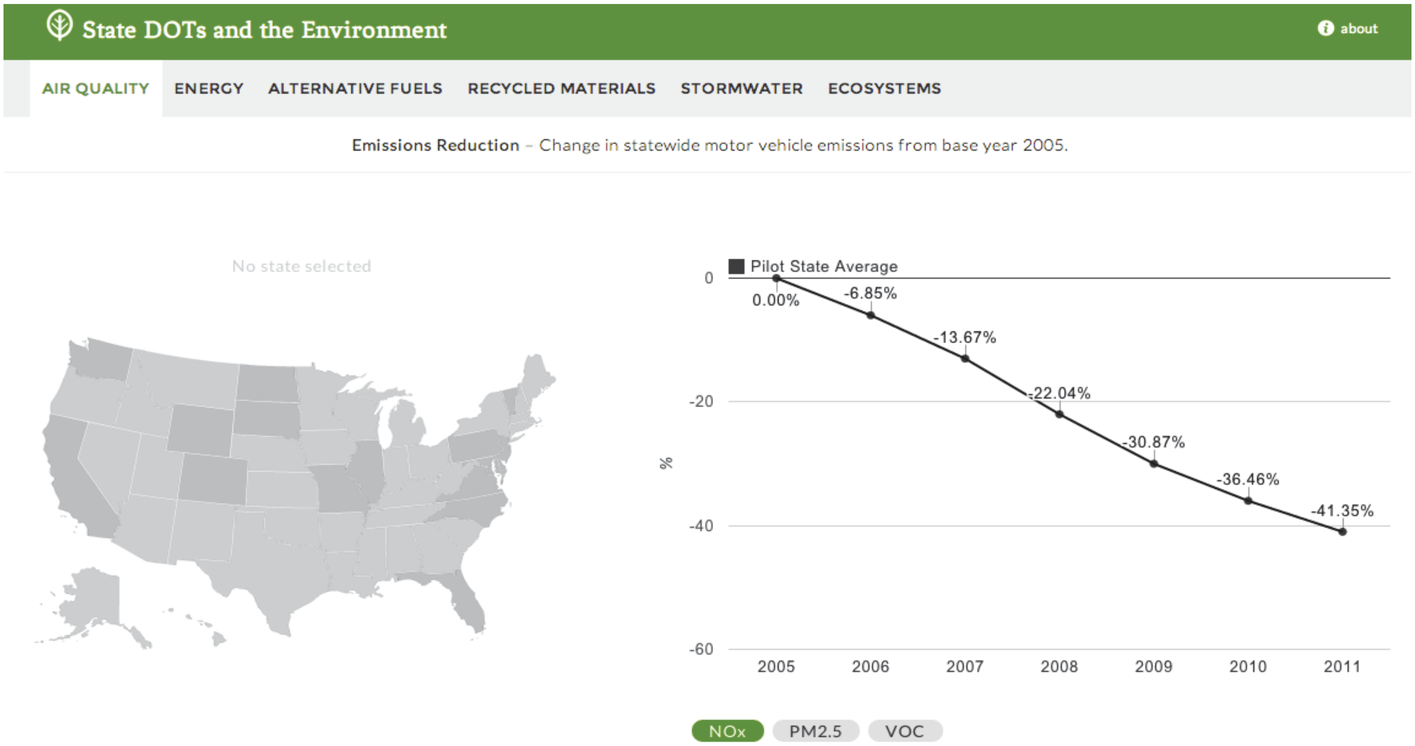


Figure 15. Measure overview page (air quality example).

Users can navigate to an environmental focus area from the website's homepage by using the menu bar at the top of the screen.

Hovering the mouse over a focus area displays the associated measure. Clicking on a focus area takes a user to its **measure overviewpage**, which displays average pilot state results.

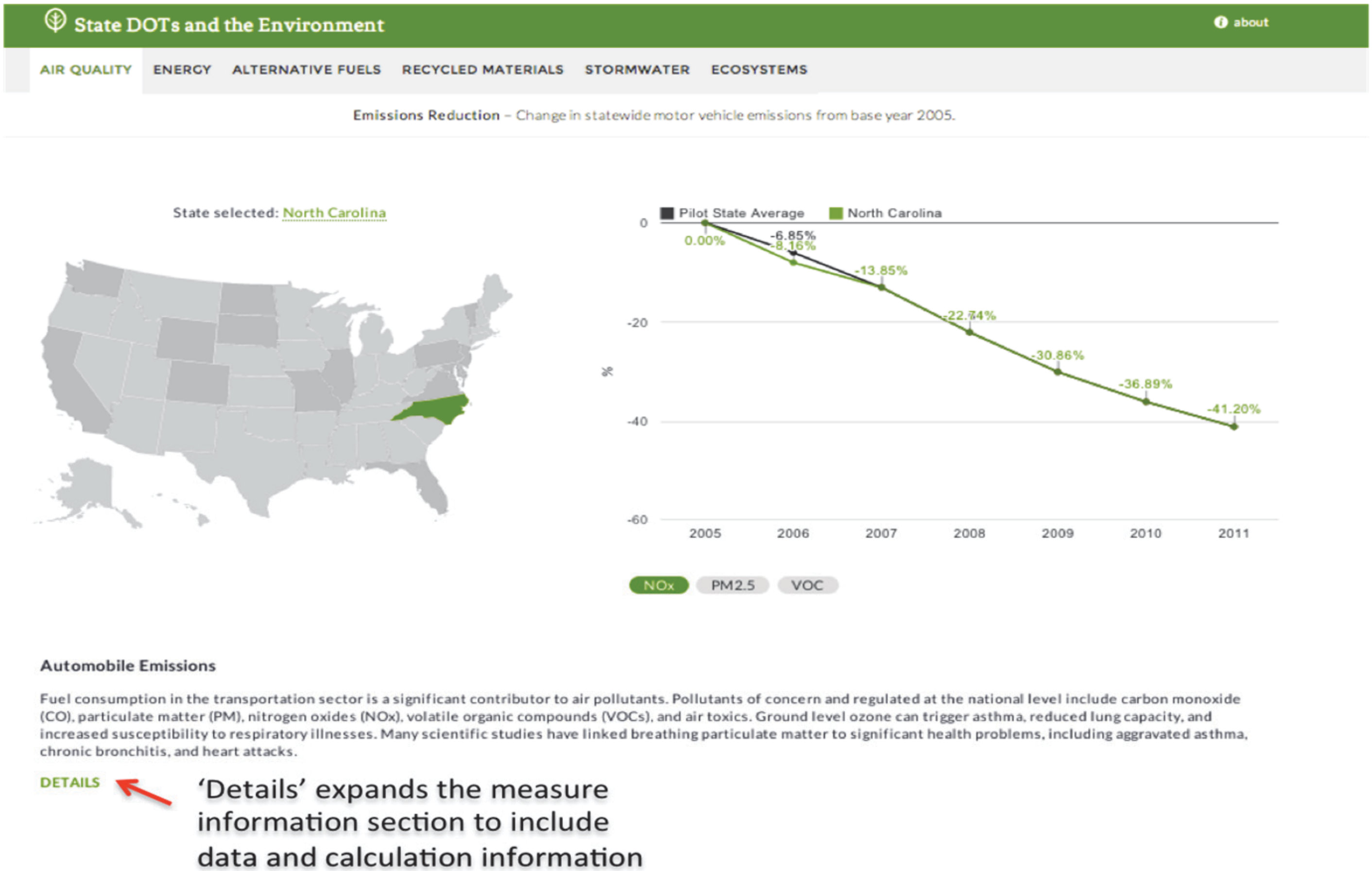


Figure 16. Focus area/state level measure results page (air quality example).

By clicking a state on the map, users can compare an individual state's results in a focus area with average pilot state results.

At the bottom of the measure overview page is a clickable "**Details**" link. It displays detailed information about the measure, including data sources, calculation details, and any caveats. Because some of the additional information is nuanced and lengthy, this information is only displayed if the user seeks it out. The default is to show users only the most succinct, high-level information so it is more easily processed, with more in-depth information available but not intrusive.

Automobile Emissions

Fuel consumption in the transportation sector is a significant contributor to air pollutants. Pollutants of concern and regulated at the national level include carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NOx), volatile organic compounds (VOCs), and air toxics. Ground level ozone can trigger asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses. Many scientific studies have linked breathing particulate matter to significant health problems, including aggravated asthma, chronic bronchitis, and heart attacks.

Estimating Emissions – The 'air quality' measures focus attention on trends in the transportation sector's contribution to air pollution and associated adverse public health impacts. The air quality measures combine information about each state's total vehicle miles traveled (VMT) with United States Environmental Protection Agency (USEPA) emissions factors (based on emissions model outputs) to estimate statewide on-road motor vehicle emissions of ozone precursor pollutants (Volatile Organic Compounds (VOC) and Nitrogen Oxides (NOx)) and fine particulate matter (PM2.5), which are the Clean Air Act regulated pollutants of most widespread concern among states.

Performance Measure – Change in Statewide Motor Vehicle Emissions for NOx, VOCs, and PM2.5.

Pilot States

California
Vermont
Washington
Pennsylvania
Virginia
Wyoming
S Dakota
N Dakota
N Carolina
New Jersey
Missouri
Maryland
Illinois
Florida
Delaware
Colorado

HIDE DETAILS

Figure 17. Details page (air quality example).

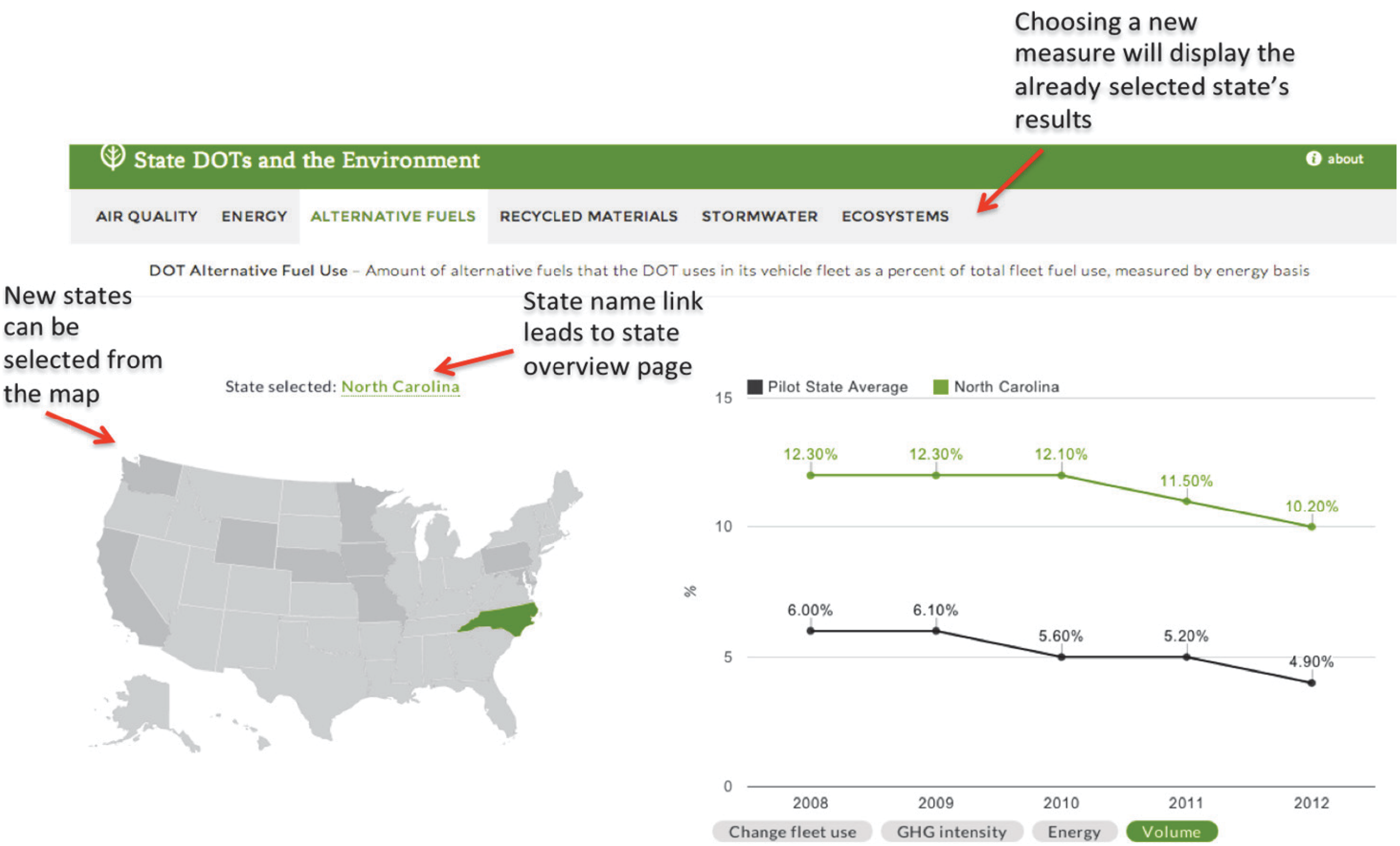


Figure 18. Website functionality.

Generally, the website template is easily navigated; any page is reachable with one click and no back clicking is required. Once on a focus area page displaying a single state's results, a new state can be added with one click. Likewise, a user can choose a different focus area with one click and see a chart displaying the previously selected state's results for the new focus area. A state's overview page can always be reached from any page by clicking the state name that displays above the map.

CHAPTER 7

Measure Calculation Guidance

In this chapter, step-by-step instructions for calculating each measure are described. In addition, a set of Excel® templates are included on TRB's website for this project that readers can use to assist in calculating measures efficiently.

7.1 Air Quality Measure Methodology

Data Summary	
Major Data Elements/Sources:	VMT by road type (FHWA's *Highway Statistics*)
	Other MOVES inputs, such as VMT distribution by month, day, and hour; inspection and maintenance program information; fuel information; meteorology; ramp fraction; vehicle speed distribution; and alternative fuel and vehicle technology information may be used, if available. (Many of these inputs are maintained by a state environmental agency.)
Known Data Limitations:	None

Data Elements and Sources

EPA's Office of Transportation and Air Quality (OTAQ) has developed the MOVES modeling system to estimate emissions for mobile sources covering a broad range of pollutants on multiple scales of analysis.

States are generally encouraged (see Step 1) to use a *national-scale* MOVES model run to calculate this performance measure because it requires less data and modeling resources than a *county-scale* MOVES analysis. In a national-scale approach, statewide emission rates generated by MOVES are post-processed with state-specific and year-specific VMT data from FHWA to estimate total annual emissions.

A national-scale MOVES approach for estimating this measure is consistent with EPA's guidance for creating a state-level GHG inventory (*15*). EPA generally cautions that the accuracy of the MOVES national-scale option is not acceptable for meeting Clean Air Act requirements because default data in MOVES is not always the most current information for any specific county or state, but EPA's GHG inventory guidance states the following:

"*The* [MOVES] *national scale may be helpful for a screening analysis designed to inform more detailed subsequent analyses, or for some types of comparative GHG analyses, where the relative* *difference in emissions between different scenarios is more important than the precision of the absolute level of emissions.*" (*15*)

Furthermore, EPA GHG inventory guidance encourages use of statewide VMT values from the FHWA's Highway Performance Monitoring System (HPMS), which improves the accuracy of emissions estimates produced via a national-scale MOVES run. HPMS is a national-level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways.

Step 1. Determine MOVES Analysis Scale

Two options are available in the MOVES mobile source emissions model for producing the emissions estimates required for this measure including a national-scale analysis, which relies on MOVES defaults, or a more complex, but more accurate county-scale analysis.

States may opt to conduct a county-scale MOVES analysis if they have sufficient technical capabilities and staff resources, and if, in addition to VMT, they possess county-specific MOVES input data for the years of analysis. Analysis at the county-scale should generally follow EPA guidance for Clean Air Act–mandated State Implementation Plan and Conformity analyses. At the county scale, MOVES requires the user to enter data to characterize local meteorology, fleet, and activity information through its *county data manager*. The individual county results can then be aggregated to statewide totals. This is a resource intensive method that requires detailed inputs for every county in a state over a period of years.

Step 2. Set MOVES Pollutants and Emissions Processes

Once the preferred scale for MOVES is chosen, the model should be set to report fine particulates, NO_X, and VOCs and to include on-network (running) emission processes and off-network processes, including starting and extended idling.

Evaporative emission processes, which include refueling vapor displacement loss, refueling spillage loss, evaporative fuel leaks, evaporative fuel venting, and evaporative permeation, can be excluded for the purposes of this performance measure, because they are unlikely to affect overall emissions; in addition, their calculation greatly increases model run times, because MOVES analyzes some evaporative process emissions for each hour in an entire year.

If the national-scale approach is being used, proceed to Step 3.

If the county-scale approach is being used, proceed to Step 3 (Alternative).

Step 3. Collect and Process Input Data—National-Scale MOVES Run

A national-scale MOVES run may be conducted for a given state and year without any inputs, relying solely on model defaults. EPA recommends, however, that local data be used in MOVES analyses where they are available, to enhance accuracy of emissions estimates. Table 15 shows all possible inputs for a national-scale MOVES run.

At a minimum, states should provide their own statewide VMT data to replace the MOVES defaults. Statewide values of VMT by roadway type and year are available from FHWA's *Highway Statistics* Table VM-2 (*16*). Other local input data may be more challenging to collect, but should be included if available.

In a national-scale run, VMT and vehicle population cannot be input directly for a state. (The MOVES field labeled "HPMSVtypeYear" is used to input total VMT by vehicle type, while the other VMT fraction fields shown in Table 15 provide the distribution of VMT by time periods [daily

Table 15. MOVES data inputs available at the national scale.

Input	Defaults Directly Available?
VMT inputs	
Monthly VMT fraction	Yes
Daily VMT fraction	Yes
Hourly VMT fraction	Yes
Inspection and maintenance program	Yes
Fuel inputs	
Fuel supply	Yes
Fuel formulation	Yes
Meteorology	Yes
Ramp fraction	Yes
Road type distribution	No
Vehicle age distribution	No
Vehicle speed distribution	Yes
Alternative fuel vehicle technology	Yes

and hourly].) If total VMT by vehicle type is imported for a national-scale simulation, the model assumes the values represent the entire nation. Instead, VMT values must be prepared to agree with the output resolution requested in the model's "*Runspec*" file (Step 4). Accordingly, the user is advised to wait on processing local VMT until Step 7 is complete. This method allows all other fields to be left as defaults at the national scale to optimize efficiency. If local data is included, it may be imported through the *data importer*. The *MOVES User's Guide* details the proper use and potential sources of these inputs (*17*).

Table 16 shows the required fields for the MOVES data inputs, in the order in which they would be imported into the model. (As discussed above, vehicle population and HPMS vehicle-type VMT are excluded from the list, because they cannot be specified for a single state when simulations are conducted at the national scale.) For each of the inputs listed in Table 16, the user should enter state-specific values, if available.

States typically do not maintain a central repository for this input data, but many states have these inputs available from their state air quality agency at the county scale for 2011, because that is the most recent year for which EPA collected data for the triennial *National Emission Inventory*. These same *National Emission Inventory* inputs are also available at the county level through EPA. A state may have some of these inputs for other years. Note that for a statewide analysis (i.e., MOVES national scale), statewide values are needed, so county-level data would need to be aggregated to the state level.

For other values, the MOVES defaults may be used if no better state-specific values are available. As noted in Table 15, the model has default data for many fields at the national scale. Much of this default data is already populated in the model in the national default database, derived from sources such as Census Vehicle Inventory and Use Survey, data from R. L. Polk, FHWA's *Highway Statistics*, FTA's *National Transit Database*, School Bus Fleet Fact Book, EPA's MOBILE6, DOE's *Annual Energy Outlook & National Energy Modeling System*, and the Oak Ridge National Laboratory's *Transportation Energy Data Book* and *Light-Duty Vehicle Database*. The contribution of each is discussed in EPA's technical documents, particularly, EPA's *Draft MOVES2009 Highway Vehicle Population and Activity Data* (*18*).

Table 16. MOVES data inputs at the national scale.

Input Type	Input Fields			
Monthly VMT Distribution	sourceTypeID	isLeapYear	monthID	monthVMT Fraction
Daily VMT Distribution	sourceTypeID	monthID	roadTypeID	dayID
	dayVMTFraction			
Hourly VMT Distribution	sourceTypeID	roadTypeID	dayID	hourID
	hourVMTFraction			
Inspection and Maintenance Program	polProcessID	stateID	countyID	yearID
	sourceTypeID	fuelTypeID	IMProgramID	inspectFreq
	testStandardsID	begModelYearID	endModelYearID	useIMyn
	complianceFactor			
Fuel Supply	countyID	fuelYearID	monthGroupID	Fuel FormulationID
	marketShare	marketShareCV		
Fuel Formulation	Fuel Formulation ID	Fuel Subtype ID	RVP	Sulfur Level
	ETOH Volume	MTBE Volume	ETBE Volume	TAME Volume
	Aromatic Content	Olefin Content	Benzene Content	E200
	E300	Bio Diesel Ester Volume	Cetane Index	PAH Content
	T50	T90		
Meteorology	monthID	zoneID	hourID	temperature
	relHumidity			
Ramp Fraction	roadTypeID	rampFraction		
Road Type Distribution	sourceTypeID	roadTypeID	roadTypeVMT Fraction	
Vehicle Age Distribution	sourceTypeID	YearID	ageID	ageFraction
Vehicle Speed Distribution	sourceTypeID	roadTypeID	hourDayID	avgSpeedBinID
	avgSpeedFraction			
Alternative Fuel Vehicle Technologies	sourceTypeID	modelYearID	fuelTypeID	engTechID
	fuelEngFraction			

Step 3 (Alternative). Collect and Process Input Data: County-Scale MOVES Run

If both county-scale inputs and sufficient staff resources are available, a county-scale analysis, consistent with EPA's State Implementation Plan and Conformity guidance (*19*), with all local inputs is preferred for its accuracy.

The level of input data and resources required for county-scale analysis may not be readily available for all the years of analysis needed for this performance measure since such an analysis is typically only performed for metropolitan planning agency regions or smaller regions where detailed conformity findings have been performed, or for all counties for submission to the EPA's periodic *National Emission Inventory*. Even in these cases, inputs may not be available for all years under consideration. At a minimum, the following values without defaults must be collected for every county under consideration for every year:

- Source (vehicle) type population
- Vehicle type VMT
- Road type distribution

Table 17. MOVES data inputs required at the county level.

Input	County-level defaults directly available
Source (vehicle) type population	No
Vehicle type VMT	No
Month, day, hour VMT fractions	Yes
Road type distribution	No
Meteorological data	Yes
Age distribution	Yes
Average speed distribution	Yes
Ramp fraction	Yes
Fuel supply/formulation	Yes
Inspection and maintenance program	Yes
Alternative fuel vehicle technology	Yes

An identical approach may be applied for multi-county simulations at the county scale with custom domains. This would reduce the total number of regions considered while increasing accuracy. See the *MOVES User's Guide* for more information (*17*).

At the county- or multi-county scale, emissions would be calculated for all counties in the state and aggregated. Input data would then be required for each individual county-year simulation. Table 17 shows the inputs that may be imported for each county of interest.

All fields from Table 17 should be populated in the correct format for input in the MOVES *data importer* and the source of each documented. Note that VMT is reported by HPMS class ("HPMSVtypeID"), as defined in Table 18.

Table 18. MOVES HPMS vehicle type classification.

sourceTypeID	sourceTypeName	HPMSVtypeID	HPMSVtypeName
11	Motorcycle	10	Motorcycles
21	Passenger Car	20	Passenger Cars
31	Passenger Truck	30	Other 2 axle-4 tire vehicles
32	Light Commercial Truck	30	Other 2 axle-4 tire vehicles
41	Intercity Bus	40	Buses
42	Transit Bus	40	Buses
43	School Bus	40	Buses
51	Refuse Truck	50	Single Unit Trucks
52	Single Unit Short-Haul Truck	50	Single Unit Trucks
53	Single Unit Long-Haul Truck	50	Single Unit Trucks
54	Motor Home	50	Single Unit Trucks
61	Combination Short-Haul Truck	60	Combination Trucks
62	Combination Long-Haul Truck	60	Combination Trucks

The user should follow the guidelines in each individual tab of the *county data manager* importers (discussed more fully in Step 5) to create an import template file with required data field names and required fields populated. The user will then edit these templates to add specific local data with a spreadsheet application or other tool. Importing the values is discussed in Step 5.

Step 4. Populate Model RunSpec File

A MOVES *RunSpec* control file (in XML format) must be created for the scenario of interest. The *RunSpec* XML file defines all simulation inputs, including the place and time period of the analysis, the vehicle, fuel, and road types, and which emissions processes and pollutants are included. This will most likely be done through use of the model's graphical user interface. This process is described fully in the *MOVES User's Guide* (*17*) and summarized here. Within the graphical user interface, the navigation panel should be used to access each tab specifying the various inputs:

- Description
  - Populate this tab with a text description of the simulation.
- Scale and Calculation Type (Inventory or Emissions Rate)
  - Select the analysis scale determined in Step 1, either the national or county scale. Also select the calculation type. For this approach, the inventory option will be used to determine emissions estimates.
- Time Spans
  - Select the time aggregation level and specific years, months, days, and hours to include in the analysis. To capture all emissions, all months, days, and hours of each year should be included. Annual aggregation is sufficient for this measure if evaporative processes are not included. Otherwise, hourly aggregation must be selected. See Step 1 for more information on pollutant processes to be included.
  - A single model run can be conducted for all years of interest if running at the national scale. If run at the county scale, a single run can represent only a single county/year combination.
- Geographic Bounds
  - If the modeling scale is national, select the state of interest. If the modeling scale is county, select each of the counties being modeled within the state. However, if the latter, only one county may be modeled per simulation, so multiple simulations will be required to cover the entire state. (Another option is to model a group of counties, using the option for a "custom domain." A custom domain could be appropriate if certain data is available and known to vary regionally.)
- Vehicles/Equipment
  - Select all vehicle/fuel combinations available in the model that are active in the state. For most cases, this will be all available combinations.
- Road Type
  - Select the road types present in the area being analyzed. Typically, all road types should be selected.
- Pollutants and Processes
  - Select all processes associated with each pollutant determined in Step 1. In cases where the model prompts for the addition of other pollutants, select all of the base pollutants that are required to determine the desired pollutant.
- Manage Input Data Sets
  - For analyses here, the *county data manager* at the county scale and the *data importer* at the national scale allow import of all required data. Accordingly, this tab is not necessary.
- Strategies
  - The Strategies option provides access to two additional panels: On-Road Retrofit and Rate of Progress, neither of which are relevant for this analysis. Accordingly, this tab is not necessary.

- Output
  - Use this panel to create or select an appropriate database for model output. Choose the correct output emissions and activity units. Also, select the activity parameters to output. EPA recommends selecting *Distance Traveled*, *Population*, and *Starts* in most cases. At a minimum, if the national-scale approach is used with HPMS VMT, *Distance Traveled* must be selected.
  - For a national-scale approach, the user should select output detail by *Road Type* at a minimum, because this level of detail will be needed for the post-processing of results discussed in Step 7. Other detail, such as for the *Source Type*, may also be useful. Under the *All/Vehicle Equipment Categories* section, it is not recommended to select *Model Year. Detailed Output by Fuel Type* is also not needed for this analysis.
  - Activity outputs should include at least *Distance Traveled.*
- Advanced Performance Features
  - This tab is not required for this analysis.

Step 5. Populate Input Database

Once the *RunSpec* XML file has been created, the second part of preparing the MOVES simulation is inputting proper data. Following assembly and formatting of a set of input values (Step 4) for the state of interest, they are imported to the model.

This process is described fully in the *MOVES User's Guide* and summarized here. With the national scale, the *data importer* is used, if required (See Step 1.) When using the county scale, the *county data manager* is used. Both are discussed here, although most emphasis is on the national-scale process.

- **Data Importer.** At the national scale, local data (other than VMT and vehicle population) can be imported to an input database for a MOVES run using the *data importer*, which has the same set of importers as the *county data manager*, each on its own tab.

The approach for use of local VMT data is discussed in Step 7. Thus, the user should not use the *data importer* to import local VMT or vehicle population data when using the national scale for a smaller geographic area than the entire nation. Instead the user will run MOVES to calculate an emission inventory, have MOVES post-process the inventory to calculate average emissions rates (total emissions per total miles traveled), and then multiply those rates by the statewide VMT.

Emissions resulting from vehicle starts will be included in the estimated emissions rates, rather than calculated based on vehicle population. Therefore, with this method, the user cannot include local information about vehicle population. If the user has both state-specific VMT and vehicle population information, EPA encourages the use of the county scale rather than the national scale so this information can be used by the model for a more precise estimate of emissions. This is discussed further under Step 6.

The tabs under the *data importer* are as follows:

- Source Type Population
- Vehicle Type VMT
- Inspection and Maintenance Programs
- Fuels
- Meteorology
- Ramp Fraction
- Road Type Distribution
- Age Distribution
- Average Speed Distribution
- Fuel Type and Technology (in MOVES2010b only) (*17*)

The values for each of the fields were prepared under Step 3. If using the national scale, the user will import each data file into an input database for the run after creation of the *RunSpec* file. The *data importer* can be accessed from the *pre-processing* pull-down menu at the top of the MOVES graphical user interface. Details of the mechanics for using the *data importers* are provided in the *MOVES User Guide.*

- **County Data Manager.** The *county data manager* is the interface for importing specific local data for a single county or a user-defined custom domain. The *county data manager* includes multiple tabs, each one of which opens importers that are used to enter specific local data. Use of the *county data manager* is necessary for county-scale analyses. To complete a *RunSpec* at the county scale, the user must either import local data, or review and import default data for each tab in the *county data manager* except for *Ramp Fraction.* These tabs and importers include the following:
  - Source Type Population
  - Vehicle Type VMT
  - Inspection and Maintenance Programs
  - Fuels
  - Meteorology
  - Ramp Fraction
  - Road Type Distribution
  - Age Distribution
  - Average Speed Distribution
  - Zone (in MOVES2010b, used with Custom Domain only) (*17*)
  - Generic Importer
  - Fuel Type and Technology (in MOVES2010b only) (*17*)

The values for each of the fields were prepared under Step 3 (Alternative). If using the county scale, the user will import each data file into an input database for the run after creation of the *RunSpec* file. Details of the mechanics of using the *data importers* are provided in the *MOVES User's Guide*.

Step 6. Execute Model Runs

Once the *RunSpec* control file(s) and input and output databases are created and the input database populated, the user should execute the model runs for the state and years of interest. Follow the instructions in the *MOVES User's Guide*, summarized as follows:

1. Select **File, Open** on the Main Menu Bar.
2. Select the *RunSpec* file for the case being modeled.
3. Select **Action**, **Execute** on the Main Menu Bar to start the simulation. The graphical user interface will ask you if you want to save the *RunSpec* before executing. You may choose either Yes or No to execute the simulation.
4. Wait for the simulation to finish.
5. The output will be saved in the MySQL output database named in the *RunSpec* and may be viewed using MOVES' *Post-Processing* menu options or by viewing the database directly using MySQL commands, either through the command prompt or through MySQL Query Browser.

Step 7. Extract and Post-Process Model Results

If the runs were performed at the county level, the statewide emissions will be computed as the sum over all individual counties.

If a national-scale run was conducted with default (national-scale) VMT and population values, the emission inventory results will represent national default activity. In this case, the user should employ the method in Appendix B of EPA's GHG Guidance to determine state-level emissions. The Guidance states the following:

When the *RunSpec* has been completed, go to the *Action* pull-down menu at the top of the screen and select *Execute.* This will run MOVES and results will be included in the output database you specified.

Once the MOVES run has been successfully executed, go to the *Post-Processing* pull-down menu at the top of the screen, and select *Run MySQL Script on MOVES Output Database.*

From the list of scripts available in the pull-down menu, select the script called *EmissionRates.sql.*

After getting a message that the script has been successfully executed, open the MySQL Query Browser. In the output database created for the MOVES run, there will be a new data table produced by the script called *movesrates.* This table provides emission rates per unit of distance for the GHG emissions selected in the *Pollutants and Processes* panel of the *RunSpec.* The user can find emission rates in this data table according to what was selected in the *RunSpec*, and multiply these rates by the appropriate VMT. These rates will include emissions for all processes selected in the *Pollutants and Processes* panel in the *RunSpec*, expressed in units of mass per distance, regardless of whether some of these processes (e.g., starts and extended idle) are a function of distance.

The resulting emission rates should be multiplied by statewide VMT. If the user has selected output detail by *Road Type* (Step 4), then MOVES will report emissions and distance traveled by road type for the national-scale approach, and these can be used to calculate an emission rate for each road type. Statewide emissions can then be calculated as follows:

$$\boldsymbol{Emissions}_{State\ A,\ Road\ type\ A} = \left(\frac{\boldsymbol{Emissions}_{National\ Default}}{\boldsymbol{VMT}_{National\ Default}}\right) \times \boldsymbol{VMT}_{State\ A,\ Road\ type\ A}$$

This simplified approach allows a scaling of results to state-supplied values without requiring upscaling of statewide VMT (and population) to national values on import and circumvention of MOVES' default allocation factors. It also streamlines handling of the various emissions processes, requiring only VMT values. However, it will be less accurate than a county-level estimate based on extensive local data.

Data Limitations and Special Notes

The approach for calculating the air quality measure relies on MOVES defaults for most parameters and post-processing MOVES output to reflect state-specific VMT for each analysis year. This approach is consistent with EPA's guidance for conducting a state-level GHG emission inventory.

This special note examines how results would differ if the measure used only MOVES defaults in place of adjusting the results with state-specific VMT. Figure 19 shows this comparison for Vermont. The state-specific VMT adjustment results in a small difference in emissions. Default Vermont VMT in MOVES is higher for most years than reported in *Highway Statistics.* The reduction in emissions from 2005 through 2011 is 4 percentage points lower if the suggested approach is used to adjust VMT, as shown in Table 19. Other states could see a larger difference between the two approaches if the MOVES default VMT diverges more from *Highway Statistics* data.

The research team calculated the on-road vehicle emissions measure for California using both the suggested MOVES approach and the state's currently approved emissions model, EMFAC 2011. Figure 20 compares the results for the two modeling approaches. The MOVES

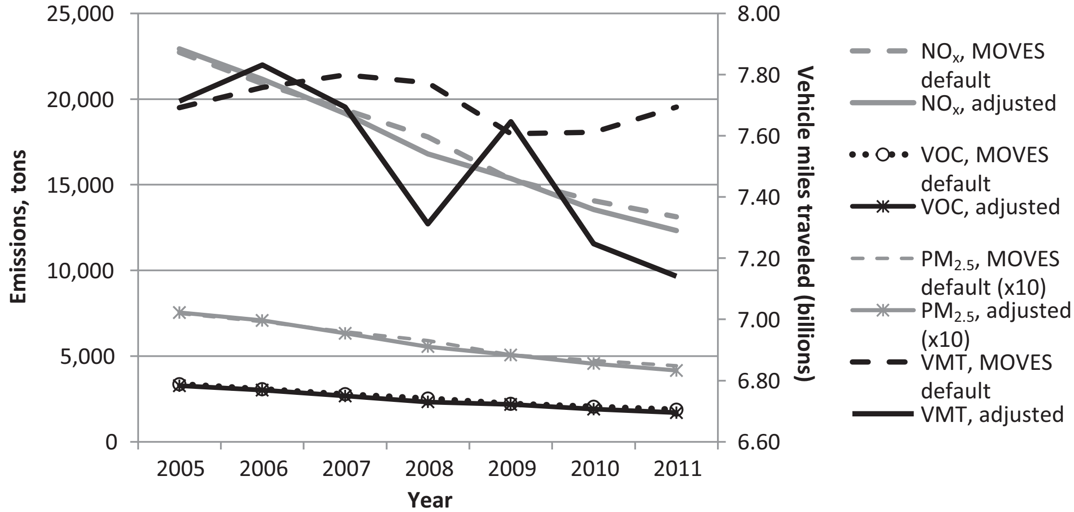


Figure 19. Comparison of emissions results for two methodological approaches, Vermont.

Table 19. Comparison of emissions changes for two methodological approaches, Vermont.

	Emissions Change 2005–2011		
	NO_x	$PM_{2.5}$	VOC
All MOVES Defaults	-42%	-41%	-44%
MOVES Defaults with State VMT	-46%	-45%	-48%

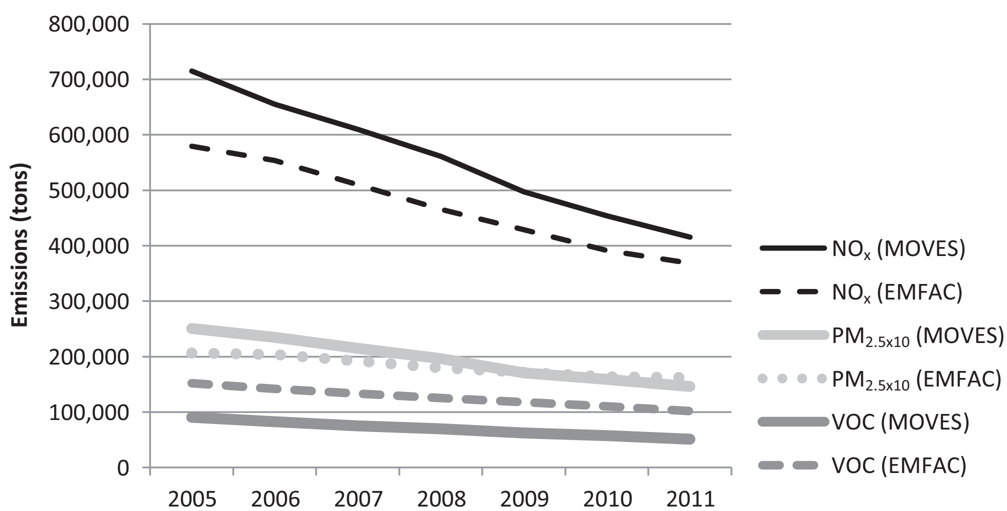


Figure 20. Comparison of MOVES versus EMFAC approach, California.

approach produces higher NO_x emissions, lower VOC emissions, and similar $PM_{2.5}$ emissions. One reason for these differences is the model VMT assumptions. EMFAC 2011 does not reflect the impacts of the 2008–2009 recession on light-duty vehicle travel, so automobile and light-truck emissions from EMFAC are likely overestimated. The two models also use different emission factors.

7.2 Alternative Fuels Use Measure Methodology

Data Summary	
Major Data Elements/Sources:	State DOT fleet annual alternative fuel consumption by fuel type (from DOT internal records).
Known Data Limitations:	In some states, a state DOT's records may not capture all or any fuel use by the state DOT fleet.

Data Elements and Sources

State DOTs maintain detailed records on fuel consumption for the centrally fueled vehicle fleets they oversee. Data over time is readily obtained from the state DOT's fleet manager and can be broken out by the alternative fuels of interest, e.g., E-85, biodiesel (by blend level), natural gas, propane, and electricity.

Measure Methodology

Step 1: Gather Fuel Consumption Data

Contact the state DOT's fleet manager for data on the fleet's alternative fuel use. Most, if not all, state DOTs will have this data available for multiple years. Data requests to the state DOT should specify the following alternative fuels of interest:

- E-85
- Biodiesel (by blend level)
- Natural gas
- Propane
- Electricity

Step 2: For Biofuels, Calculate Volume of Biofuel versus Gasoline Based on Blend Ratio

Biofuels such as biodiesel and ethanol are typically blended with conventional fuel for use in motor vehicles. Only the biofuel portion of these blends should be counted as an alternative fuel for the purposes of this performance measure.

States using biodiesel typically purchase a blended fuel and will report annual consumption by blend level (e.g., B-5, B-10, B-20). Some states may purchase pure biodiesel (B-100) and blend the fuel themselves.

The blend volume reported by the state DOT should be multiplied by the biofuel fraction to determine the volume of pure biofuel consumed. For example, if the state DOT reports using 200,000 gallons of B-10, this equates to 20,000 gallons of pure biodiesel and 180,000 gallons of conventional diesel.

Step 3: Convert All Fuels to a Gallon-Equivalent Basis

Natural gas volumes are typically reported in units of gasoline gallon equivalent (GGE), even when used in applications that normally run on diesel. If natural gas volumes are not reported in GGE, convert to GGE using the following standard conversion factors:

- 1 therm CNG = 0.832 GGE
- 1 gallon LNG = 0.636 GGE

If a state DOT operates PEVs, gasoline gallon-equivalent fuel use can be estimated based on the vehicle's annual mileage. For BEVs, a vehicle's EPA fuel economy rating in miles per gallon equivalent can be multiplied by annual mileage to estimate total energy use in GGE. For most PHEVs, the state DOT should estimate the portion of miles driven in all-electric mode versus gasoline mode, and estimate gasoline-equivalent use for these vehicles by applying the vehicle's two EPA fuel economy ratings.

Step 4: Sum Totals

Sum all alternative fuels and all conventional fuels for each year of data provided.

Step 5: Calculate Percentage

Divide the alternative fuels volume by the total fuel volume of alternative fuels plus conventional fuels for each year of data provided.

Data Limitations and Special Notes

- **Lack of Data for Commercial Fuel Station Purchases.** State DOTs may not have records if alternative fuel is purchased at commercial stations (i.e., stations other than the state DOT's own facilities) or may have information only on commercial station fuel expenditures and not fuel type. For example, a state DOT may not be able to determine if a flexible fuel vehicle has purchased gasoline or E-85 at a commercial station. Discussion with the DOT fleet manager should determine the extent of this practice. If commercial station fueling accounts for a small fraction of total DOT fuel use, it can be ignored for the purposes of this measure. If commercial station fueling is widespread, the state DOT can often estimate the types of fuel purchased.
- **Lack of Data for Light-Duty Fleet Vehicles.** In some states, the state DOT maintains records only for heavy-duty vehicles because light-duty vehicles used by the state DOT are managed by a state motor fleet department or general services administration. In these cases, the state DOT may not have easy access to fuel records for the light-duty vehicles it uses. Ideally, fuel use data for these vehicles should be obtained from the appropriate state agency; otherwise, these vehicles can be ignored for the purposes of this measure.
- **Ethanol in Gasoline.** Virtually all gasoline sold in the United States contains 10 percent ethanol. Ethanol is added to gasoline to boost octane levels, meet air quality requirements, or satisfy mandates such as the EPA's Renewable Fuel Standard. This ethanol fraction should not be considered an alternative fuel for the purposes of this performance measure, because it is considered the conventional and default gasoline blend for all fleets.
- **Reformulated Gasoline.** Some states may report separate volumes for reformulated gasoline and conventional unleaded gasoline; the former may be mandated for ozone nonattainment areas to reduce smog-forming emissions. Both fuels should be considered conventional fuels and combined for the purposes of this measure. Similarly, some state DOTs may separately report #1 and #2 diesel; both should be considered conventional diesel for the purposes of this measure.

7.3 Gasoline Consumption Measure Methodology

Data Summary	
Major Data Elements/Sources:	Statewide gallons of gasoline consumed for highway use (from FHWA *Highway Statistics*); statewide population (from U.S. Census Bureau data).
Known Data Limitations:	Gasoline data is based on gasoline sales within a state, which may differ from gasoline use.

Data Elements and Sources

The *Highway Statistics* series is available by year for every state at www.fhwa.dot.gov/policy information/statistics.cfm. The most recent year reported is 2012. For its *Highway Statistics* table, FHWA obtains data on statewide purchases of gasoline from state motor-fuel tax agencies that collect taxes at the point of sale. Because there are differences between states in how they assess fuel taxes, FHWA makes adjustments so that the data is uniform and complete for all states. FHWA's data for on-road motor fuels is used to allocate highway funding and is generally considered more accurate than other sources. In FHWA's data, sales of pure gasoline are combined with sales of gasohol (low-level blends of ethanol with gasoline). State population data by year is available for download at http://www.census.gov/popest/data/historical/index.html.

Measure Methodology

Step 1: Collect State Highway Gasoline Use Data and State Population Data for Years of Interest

Step 2: Divide Highway Gasoline Use by Population for Each State and Year

7.4 Materials Recycling Measure Methodology

Data Summary	
Major Data Elements/Sources:	Annual amount of reclaimed asphalt pavement used (DOT internal records).
	Annual amount of asphalt pavement used (DOT internal records).
Alternative Data Sources:	Contractors (RAP use)/National Asphalt Pavement Association (total asphalt use).
Known Data Limitations:	Some DOTs do not maintain data on the amount of RAP used in their highway projects.

Data Elements and Sources

Many states collect and compile information on the pavement mix and total pavement used for individual highway projects, and thus can calculate the mass of RAP used for each project. These states often sum annual RAP use, sometimes for purposes of an annual performance report. If this information is not available from a state DOT, paving associations, such as the National Asphalt Pavement Association, gather estimates for each state from their members, who are generally state DOT contractors.

Measure Methodology

Step 1: Collect Data on RAP Use per Year, in Tons

A state DOT's pavement engineer should be contacted to inquire about data on RAP use.

Step 2: Collect Data on Total Asphalt Use per Year, in Tons

Similar to RAP, a state DOT's pavement engineer should be contacted to provide information on total asphalt pavement used per year. If reported separately, hot mix and warm mix asphalt should be combined.

Note that only asphalt pavement is included in the denominator of this measure, because RAP would only be used in asphalt pavements. While this excludes some portion of DOT roads, for example those paved with Portland cement concrete, more than 90 percent of all pavement in the United States is paved with asphalt. This measure therefore includes the vast majority of roadways.

Step 3: Divide RAP Use by Total Asphalt Use

Statewide annual total weight (tons) of RAP used on state highway projects ÷
Statewide annual total weight of all asphalt pavement used on state highway projects

Data Limitations and Special Notes

Not all state DOTs keep track of RAP usage at the statewide level. If usage is not tracked, a new workflow must be established to collect the data. Records on roadway material usage must be collected from state DOT contractors. The collection process can be a big hurdle given the decentralized nature of pavement contracting, which usually involves many contractors across a state. If data collection is an issue, task an engineer at the district level to collect the information for their district, and then report it to the central office. If possible, the contractor reporting mechanism should be attached to an already established process in which contractors are supplying information to the district to minimize the new work introduced.

7.5 Stormwater Measure Methodology

Data Summary	
Major Data Elements/Sources:	DOT-owned impervious area DOT-owned BMPs from field surveys BMP drainage areas from GIS or field surveys
Data Sources:	DOT system records and HPMS
Known Data Limitations:	Some DOT estimates of impervious area may not include maintenance facilities and rest areas; estimates based on total lane/center miles may be inaccurate.

Measure Methodology Options

Step 1: Calculate State DOT-Owned Impervious Area

This calculation represents the amount of impervious area a state DOT should be accountable for treating and serves as the denominator for the measure calculation.

- **Detailed Road Inventory Method.** State DOTs often have exact road and shoulder width documentation for each road segment in either a spreadsheet or, more likely, in the attribute table of a GIS layer. Ohio, for example, has a GIS file for the state road system with columns for travel lane width, number of travel lanes, and shoulder width. Using this data, the impervious area for all of the network's segments can be totaled to obtain the impervious area of the state DOT's network:
  1. *Obtain Road Inventory.* Each road segment must have data on its length, travel area width (or number of lanes and lane width), and the width for each shoulder.
  2. *Calculate Paved Area.* In either the GIS attribute table or in spreadsheet software, multiply each segment length by the corresponding total road width, which includes the travel area and all shoulders. Sum the resulting area for all segments.
  3. *Add Other Impervious Area.* State DOTs also own impervious areas outside of the roadway, for example in rest areas, maintenance facilities, or storage areas. The approximate impervious areas of these facilities should be added to the figure for increased accuracy.
- **Imagery Analysis Method.** Not all state DOTs have detailed road inventory data. In these cases or for DOTs wishing to conduct a more thorough analysis, high-quality lidar maps or ortho-imagery in combination with GIS can be used to estimate impervious area. A spatial analysis tool is required with the ability to differentiate impervious from pervious surface. The tool scans each image and groups similar pixels together and categorizes the groupings. Initial automated assignments can be manually adjusted to better "train" the program, and an iterative process of automated runs and manual adjustments creates evermore accurate results. Maryland, for example, has successfully used this approach.
  1. *Obtain Imagery.* Aerial images of a state or area of interest, such as high-resolution ortho-imagery or lidar maps, are required. States often have their own images to use, or these can be obtained from national sources, such as the United States Geological Survey (USGS) or the National Oceanic and Atmospheric Administration (NOAA).
  2. *Run Spatial Analysis Tool.* Tools that can automatically classify image elements into pervious or impervious surfaces can be custom designed, or some are available for free or for purchase. NOAA, for example, has such a tool available in a free download on its website. Within a GIS environment, the tool can be applied to the imagery obtained above for estimates of impervious area.
  3. *Manually Adjust Impervious Assignment.* These tools will not result in 100 percent accuracy after one run, but they can often be trained to better identify impervious area after manual adjustments to one section. The tool can be run again for an improved outcome. This process may take several iterations for an acceptable outcome.
  4. *Identify State DOT Right of Way.* The next step is to delineate the impervious area that is within the DOT's right of way, since the aerial imagery will include all impervious area. This can be accomplished with a separate GIS layer that outlines the right of way an overlay. Using standard GIS tools, such as the "intersect" function, DOT-owned impervious area can be isolated and exported as a new layer.
  5. *Calculate the Area of State DOT-Owned Impervious Area.* Sum the area column in the new state DOT-owned impervious surface layer to get the total area.

Step 2: Locate Structural BMPs

For decades, state DOTs have installed retention ponds, swales, culverts, and other structures meant to improve water flow or water quality. Yet only a few states have an accurate location inventory for these structures. Before any work can be done to determine how much impervious area is treated in a road system, a state DOT must create an inventory of its treatment facilities, usually via fieldwork:

1. *Determine Database Schema.* Before any fieldwork is done, data elements should be defined, including at least: *latitude and longitude coordinates*, *type of BMP*, *structure capacity*, and other identifying information to make groupings of structures possible later, such as road served, road category, county, or watershed. Other data elements that support additional state DOT goals should also be considered.
2. *Fieldwork.* According to practitioners who have already undertaken a stormwater inventory, actually locating each structure involves driving along roads to visually locate each structure. While documentation may generally exist for structures at the state DOT, this information may not be centralized, and for older structures it may be unavailable. Field surveys therefore provide the most reliable means to inventory all state DOT structures. Many state DOTs deploy a combination of engineers to lead these efforts, with interns and students providing additional staffing. Completing this step for a large state DOT's entire state network can take several years.

Step 3: Delineate BMP Drainage Areas

The most accurate and consistent means to estimate treatment area is to have each BMP's drainage area surveyed and determined by a certified engineer. Once the drainage area is determined, it should be digitized and stored in a GIS environment. The drainage area layer should be a vector polygon with area as one of the attributes.

A shortcut method can be used in cases where a rough estimate is desired before drainage areas can be surveyed. This method uses GIS hydrology tools in conjunction with digital elevation models to simulate the drainage areas. The point locations of BMPs are required.

- **Survey Method**
  1. *Survey BMPs.* This step should be completed concurrent with locating BMPs, but it requires steps and expertise beyond those needed to record more basic structure information. A hydraulic engineer should perform the initial delineation for each BMP located, with precise geographic references for future digitization.
  2. *Digitize into GIS.* GIS analytical tools provide the most options for assessing where roads are served by a BMP. Getting the drainage areas into a GIS format can most likely be done through heads up digitizing, where maps are scanned into special digitizing software and finalized by GIS technicians tracing over the lines and polygons. In cases where the maps with the drainage areas are of low quality, such as on older plans, manual digitizing, where technicians draw in drainage areas to the software program by hand, may be required.

Step 4: Estimate the Impervious Area Treated by Each BMP

At this point, all the GIS inputs are available and only simple GIS and arithmetic operations remain. With a polygon layer for impervious surface combined with the drainage area polygons, a simple intersect tool yields the numerator of the measure: impervious area treated by state DOT-owned structural BMPs. Note that this does not necessarily have to be state DOT-owned impervious area. If a policy decision is made that treatment of any impervious area is equivalent to treating state DOT-owned impervious area, all impervious surface can be included:

1. Import BMP drainage area and impervious surface GIS layers, making sure they are in the same coordinate or projection system

2. Find where impervious surface and BMP drainage areas overlap using the GIS software's "intersect" tool
3. Sum treated impervious area using the software's summary statistics

Step 5: Calculate the Percentage of the State DOT-Owned Impervious Area That Is Treated by all BMPs

With the denominator and the numerator now in hand, the measure can be calculated. Divide the amount of treated impervious area (the output of Step 4) by the total amount of impervious area.

7.6 Wildlife and Ecosystems Measure Methodology

Data Summary	
Major Data Elements/Sources:	Ecosystems Self-Assessment Tool and knowledge of state DOT administrator(s) and other staff, as required.
Known Data Limitations:	Response data is primarily qualitative and subject to interpretation of respondent

Measure Methodology

Designated state DOT administrators, with input from other staff, can apply the ESAT to evaluate the performance of their respective transportation programs in incorporating ecological considerations into planning, operations, and project implementation activities. Completion of the ESAT questionnaire requires institutional knowledge of state DOT practices, and in some cases, specific data that is thought to be available to most state DOTs. The results are intended to give practitioners an at-a-glance assessment of which aspects of their program could be improved and which areas already benefit from best practices.

Step 1: Identify an ESAT Administrator

Each state DOT should identify one or more staff members to complete the ESAT within its program. In proof of concept testing, ESAT administrators were typically directors of environmental services or senior biology staff. The selected person or persons should have extensive institutional knowledge of the program's environmental policies and practices and must be able to allocate 1 to 2 hours, at minimum, to complete the ESAT.

Step 2: Review Questions to Determine Level of Coordination Required to Complete

The ESAT administrator should review the content of the ESAT to determine which questions can be answered immediately and which will require additional research or coordination with other staff. The spreadsheet ESAT's filtering functions, located in the *Question Categories* section, may be helpful in identifying groups of questions relevant to specific function areas or resource specialties within the state DOT.

Step 3: Gather Required Information

The ESAT administrator should request any information/data for questions that cannot be easily answered from the appropriate party. Table 20 contains the following specific information relevant to completion of the ESAT:

Table 20. ESAT questions grouped by data type.

Data Type	Relevant ESAT Question(s)
Budget and Staffing	
• Budget allocated to ecosystem-focused research	*37*
• Staff receiving biological resource conservation/mitigation training	*04*
Geospatial Data	
• Threatened and endangered species habitat information (e.g., National Heritage Program)	*17, 19*
• Wetlands (e.g., National Wetland Inventory; other statewide, regional, or site-specific high-resolution wetland data)	*18, 19*
• Streams	*19*
• Public lands (e.g., parks, wildlife refuges)	*19*
• Wildlife corridors/crossings and collision mitigation sites	*19, 30, 32*
• Priority wildlife habitats	*19*
• Stream and wetland mitigation areas and status	*25, 26*
• DOT-owned land maintained as native vegetation	*41*
Monitoring Data	
• Wildlife crossing structures or barriers	*34*
Plans	
• Long-Range Transportation Plan	*19*
• State Wildlife Action Plan	*05*
• Regional conservation strategies (e.g., programmatic biological opinions, critical habitat designations, species recovery plans, regional habitat conservation plans)	*19*

Table 20. (Continued).

Data Type	Relevant ESAT Question(s)
Policies/Manuals	
• Construction guidance and manuals	*01*
• Operations and maintenance guidance and manuals	*02*
• Stormwater management guidance and manuals	*03*
• Memoranda of Agreement with state or federal resource agencies	*09*
• Asset management/data sharing agreements related to biological resources	*10*
Project Statistics	
• Impacts of noise and vibration quantitatively assessed	*21, 22*
• Compliance inspections for biological resource commitments	*07, 16*
• Work periods set to minimize disruption of fish and wildlife	*08*
• Wetland and mitigation site monitoring extends beyond federal regulatory requirements	*24, 29*
• Functional assessments are used to determine wetland mitigation requirements	*23*
• Water crossings designed to improve habitat continuity	*06*
• Invasive species monitoring and integrated pest management	*38, 39*

Step 4: Complete the Ecosystems Self-Assessment Tool

The ESAT administrator should respond to the questions to the best of their knowledge and try to answer all questions. Unanswered questions are scored as zero points, so every question must be answered to maximize the score. Refer to Chapter 4 for a detailed explanation of each component of the ESAT and its purpose.

Step 5: Evaluate Performance and Identify Areas for Improvement

The results of the ESAT should be used to evaluate the state DOT's performance within specific ecological focus areas, as well as to compare practices with other state DOT's and with national best practices. Each state should identify priority areas of improvement and develop specific strategies to improve performance. Consult the sources listed in the ESAT that provide examples of best practices for the areas where improvement is desired.

Data Limitations and Special Notes

For the reasons summarized below, we suggest that future iterations of the ESAT be adapted from a spreadsheet-based tool to a web-based format to improve accessibility, ease of use, and standardization:

Microsoft Excel

- Requires specialized desktop software to access
- Some users may be unfamiliar with Microsoft Excel functionalities
- Results not readily comparable with scores from other states

Web-Based Format

- Accessible to anyone with an internet connection
- Requires only basic computer skills to operate
- Can be designed to generate score comparison with other states at time of answer submittal
- Can more easily include links to sources provided by respondents

CHAPTER 8

Conclusions and Research Next Steps

8.1 Suggested Measures

Performance measurement is best described as a continual journey. When research for this work began, the state of the practice for environmental performance measures could fairly be described as a scattered assortment of hundreds of measures with each state left to reinvent its own wheel. No guidance existed for practitioners on what measures might be most useful, or how to use them.

This report's purpose is to start a conversation among practitioners about the kind of environmental performance measures that might complement national-level transportation measures now emerging for safety, infrastructure condition, and system performance. The following are key themes the conversation should include:

- **Environmental Focus Areas.** Transportation policy makers sometimes speak of the environment as a single strategic priority, alongside other priorities such as safety, infrastructure preservation, and congestion. In reality, however, the environment is a complex and multifaceted topic for which performance cannot easily be captured by a single metric. As a result, the measures proposed in this report are based around a set of five major focus areas within the broad universe of the biophysical environment:
  - Air Quality
  - Energy and Climate
  - Materials Recycling
  - Stormwater
  - Wildlife and Ecosystems

These five focus areas were chosen because they are indisputably national-scale environmental concerns where transportation is generally accepted to make a meaningful contribution.

- **Environmental Measures.** The report suggests a core set of environmental performance measures:
  - **Air Quality.** Change in statewide motor vehicle emissions for NO_x, VOC, and fine $PM_{2.5}$
  - **Energy and Climate (Measure 1).** State DOT fleet alternative fuel use as a percentage of total fuel use by volume
  - **Energy and Climate (Measure 2).** Statewide on-road gasoline consumption per capita
  - **Materials Recycling.** Annual percentage by mass of all roadway pavement materials composed of recycled asphalt pavement used by state DOT
  - **Stormwater.** Percentage of state DOT-owned impervious surface for which stormwater treatment is provided
  - **Wildlife and Ecosystems.** Ecosystems Self-Assessment Tool

Together, this is the set of environmental measures that the research team believes comes closest to meeting desired measure selection criteria given today's environmental and technological know-how and political constraints. None of the measures, however, is perfect; they should be treated as a step forward in providing DOTs with a practical, yet valuable set of environmental performance measures to be improved over time. In particular, the stormwater and wildlife and ecosystems measures will benefit from additional development.

- **Implementation Readiness.** None of the 27 states involved in proof of concept testing for the above measures could easily provide all data for all measures. Clearly, all 50 states are not immediately ready to implement a complete set of environmental measures, but the testing conducted as part of the research for this report suggests that the measures are broadly within reach.

  For the measures of air quality, energy and climate change, and recycling, testing validated the immediate availability of data and viability of measure calculation methods, suggesting these measures can be adopted by several to many state DOTs in the near term. For these measures, comprehensive statewide data was obtained for multiple states.

  The stormwater and wildlife and ecosystems core measures are clearly more experimental in nature, with the performance measurement capabilities of most state DOTs in these two areas nascent and pilot testing confined to a handful of states. While the measures in these two areas should not be considered immediately "implementation ready," testing suggests they show strong promise and continued efforts to expand on their potential are encouraged with phased adoption over time.

As in other areas where state DOTs are attempting to measure their performance, the search for the ideal measure is best characterized as a continual journey whose path is regularly redirected by shifts in industry practices, technology, or politics, among many other factors. Nonetheless, the measures proposed here should be considered a useful map for the path ahead in developing more robust state DOT environmental performance measures.

8.2 Research Next Steps

Additional research is a logical next step for strengthening the environmental performance measures suggested in this report. Ideas for future research include the following:

- **State DOT Environmental Performance Measures Workshop.** This report's purpose is to start a conversation among practitioners about the kind of environmental performance measures that might complement the national-level transportation measures now emerging for safety, infrastructure condition, and system performance. A workshop with invited DOTs to discuss environmental performance research findings and encourage adoption of measures by states would be a good start to take this conversation further.
- **Full-Scale or Partial Data Collection.** Given that the research for this project largely demonstrated that collection of data for the suggested measures is practical in the near term, all or some states could be encouraged to begin attempting to collect and report data for all or some of the measures as part of a collective effort. This could be an outgrowth of the workshop idea described above and might involve a regular meeting of states to share lessons learned as data is collected.
- **Explore Trends and Map Target Setting Opportunities.** While targets are largely premature at this stage, examination of trends and concerns as data is collected will provide a firmer basis for developing robust target setting approaches.
- **Performance Reporting Website.** This report provides the foundation for creating a public or password protected website that provides centralized tracking and reporting of state DOT performance on the core environmental performance measures.

- **Enhance Performance Measure Methodologies.** There is room within the performance measures to take the essential ideas slightly further, whether through resolving methodological details or making the calculations more precise.
  - **Air Quality.** The methodology suggested for calculating the air quality measure involves a state-level analysis of vehicle emissions using the MOVES model. The methodology uses MOVES default values for most parameters, combined with state-specific data on VMT by highway functional class reported in *Highway Statistics.* This approach is more simplistic than that employed by states for air quality planning or conformity analysis, which involves county-level analysis. Most states that develop emissions estimates for the EPA's triennial National Emission Inventory also use a county-level approach.

    Further research is needed to understand the differences in results between a state-level and county-level approach to estimate statewide emissions, and the reasons for any major differences. Ideally, an emissions performance measure used by a DOT would be consistent with emissions estimates developed in that state for air quality planning purposes and for the National Emission Inventory. However, using MOVES to estimate emissions for every county in a state for multiple years is time consuming and likely beyond the capabilities and/or resources of many states. It may be possible for a state to develop this performance measure by starting with an existing emissions analysis for a base year (e.g., 2011) and then scaling the results to estimate other years and thereby quantify the percentage change in emissions.
  - **Energy.** Further research is needed to explore the potential for a performance measure that captures state DOT fleet fuel efficiency. While many DOTs use alternative fuels in their fleets to achieve energy and environmental objectives, DOTs also take steps to reduce their overall fuel consumption. These steps can include purchasing more fuel efficient vehicles, avoiding use of vehicles and equipment that are larger or more powerful than needed for a job, and reducing employee travel through video-conferencing and webinars.

    A performance measure based on fleet aggregate fuel efficiency (miles per gallon) could facilitate comparison among states and allow a single DOT to track changes over time. To develop this measure, DOTs would need both annual fuel consumption and miles of travel for their fleet. It may be necessary to limit the measure to on-road vehicles, because miles traveled for off-road equipment would not be available or relevant.
  - **Alternative Energy.** Some state DOTs report that they have limited ability to use alternative fuels in their fleets due to fuel supply constraints or vehicle purchasing restrictions. At least one DOT reported a reduction in alternative fuel use because of price concerns. And other DOTs were not able to report complete information on their fleet fuel use because of incomplete data. Further research is needed to better understand the constraints and opportunities for using alternative fuels in DOT fleets, as well as the potential to collect and report complete fuel use data. This information will help in understanding the potential for widespread adoption of this measure among DOTs and the suitability of targets.
  - **Materials Recycling.** While RAP is the most extensively recycled material used in road construction on a tonnage basis, some state DOTs also make extensive use of other recycled products with environmental benefits. For example, adding fly ash to concrete mixtures can reduce use of Portland cement, which is highly GHG-intensive to produce. Some DOTs also use crumb rubber from recycled tires or recycled asphalt shingles in asphalt, reducing the need for virgin materials and also eliminating landfill waste. Additional research could determine the extent of these practices and the suitability of additional recycling performance measures.
  - **Stormwater.** Being one of the more experimental measures, there are a number of future research directions for the stormwater performance measure.
    - **Simpler Form of the Measure.** The suggested form of the measure requires a system-wide assessment of stormwater control structures. An alternative would include only

newly constructed or reconstructed roads—in essence, measuring the DOT's current practices rather than how all roads ever built perform. More research into this option for the measure could explore how much simpler the process becomes, and the tradeoffs involved.

- **Setting Measure Parameters.** Discussion with states revealed a common belief among practitioners that not all roads should be treated for runoff equally. Higher traffic volumes, an urban environment, amount of rainfall, or the sensitivity of the surrounding waterbodies were all discussed as possible parameters to place on the measure to exclude some roadways in less need of treatment from the measure. Further discussion by more practitioners on these ideas could help reach a consensus on what matters the most in roadway runoff treatment.
- **Agreeing on What Counts as "Treatment."** From non-engineered grassy swales to non-structural BMPs like tree planting to designing roads to be lower impact from the start, there are a number of DOT actions and roadway elements to improve stormwater runoff that are not captured in the current version of the measure. Agreeing on which of these should be captured and developing ways to integrate them are the next steps desired by many of the participating DOTs.
- **Enhancing Estimation Techniques for Drainage Areas.** DOTs must know the drainage area for each BMP to calculate the stormwater measure, but this is the piece of information that can take the longest to acquire. It is worth exploring if efficiencies can be made in the process, whether in current surveying practices, through reviewing original engineering documents, or confirming whether GIS-generated results are sufficiently accurate.
- **Best Practices for BMP Inventorying.** With more DOTs beginning to develop BMP inventories, it is a good time to examine and share best practices, from initially locating each structure, integrating engineering information, deciding on the most important elements of a database schema, acquiring tools for housing and accessing the information, and updating the inventory on a regular basis.
- **Incorporation with the NPDES Process.** For most states, BMP tracking is very closely aligned with the EPA's NPDES stormwater permitting process. For example, most states are starting BMP inventories in response to tightening NPDES requirements. There may be ways to integrate capturing measure information with activities already underway for this important water quality-related work.
- **Direct Measurement of Runoff Quality.** The ideal form of any measure would directly measure the outcome of interest, that is, roadway runoff water quality. As technologies evolve and state DOTs do more work in this area, it may one day be possible to examine realistic options for this.

– **Ecosystems.** Due to profound regional differences in species and habitats, an appropriate measure for nationwide comparison of wildlife and ecosystem performance may not exist with the constraints of existing data and technology. However, the ESAT provides a general template that may be improved through internal analysis and improvement by individual DOTs and the development of regional and resource-specific measures (e.g., coastal wetland conservation in the Gulf of Mexico, water quality in the Chesapeake Bay watershed, or anadromous salmonid passage in the Pacific Northwest).

In addition, work can be conducted to explore the potential application of remote sensing and GIS technologies to assess habitat quality and connectivity of DOT-maintained land. Incorporating this into DOT operations could open up new possibilities for a more focused and concrete wildlife and ecosystems performance measure.

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Acronyms

AASHTO	American Association of State Highway and Transportation Officials
DOT	Department of Transportation
BEV	Battery Electric Vehicle
BMP	Best Management Practice
CNG	Compressed Natural Gas
EMFAC	EMissions FACtors model
EPIC	Environmental Permits, Issues, and Commitments
ESA	Endangered Species Act
ESAT	Ecosystems Self-Assessment Tool
FHWA	Federal Highway Administration
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gases
GIS	Geographic Information Systems
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model
HPMS	Highway Performance Monitoring System
IVM	Integrated Vegetation Management
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MOVES	Motor Vehicle Emissions Simulator
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NO_x	Nitrogen Oxides
MPO	Metropolitan Planning Organization
LRTP	Long-Range Transportation Plan
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
$PM_{2.5}$	Fine Particulate Matter
RAP	Reclaimed Asphalt Pavement
ROW	Right of Way
SHA	Maryland's State Highway Administration
T&E	Threatened and Endangered
TRB	Transportation Research Board
U.S. DOT	United States Department of Transportation
USGS	United States Geological Survey
U.S. EPA	United States Environmental Protection Agency (referred to as EPA in this report)
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compounds

APPENDIX A

Initial Measure Screening Results

This appendix presents the project research team's findings from Tasks 2 and 3 of the NCHRP Project 25-39 research project. Based on interviews with practitioners and the research team's staff expertise, an initial laundry list of 190 measures was identified in Task 2. In Task 3, this laundry list was pared down to a core set of environmental performance measures. For each of the project's five environmental goal areas, several measures were considered in detail and the reasons for rejecting them are described in this appendix.

Special Note about Wildlife and Ecosystems Measures: Considerable effort was expended by the research team on developing the proof of concept for a wildlife and ecosystems measure, "Percent of wetland and stream mitigation that achieves regulatory approval on, or ahead of schedule based on the permitted monitoring period." Ultimately, this measure was not chosen for inclusion in the report's set of core measures and was replaced with the ESAT. The reasoning behind this decision is explained in this appendix.

Air Quality

Initial Comprehensive List of Air Quality Measures

Early in the research for this report, a long list of air quality measures was compiled from individual DOTs, research reports, and other sources. The following measures did not meet most or all criteria for measure effectiveness laid out in Chapter 3 of this report and thus were discarded from the research:

Air Quality and Health Risk-Related Measures

- Percentage of state population in air quality nonattainment area for $PM_{2.5}$
- Percentage of state population in air quality nonattainment area for ozone
- Number of violations/days exceeding National Ambient Air Quality Standards for $PM_{2.5}$
- Number of violations/days exceeding National Ambient Air Quality Standards for ozone
- Trend in average $PM_{2.5}$ concentration as a percentage of the National Ambient Air Quality Standards (regionally or in major highway corridors)
- Trend in average ozone concentration as a percentage of the National Ambient Air Quality Standards (regionally)
- Average incremental cancer risk caused by motor vehicle emissions (regional or corridor scale)
- Population living in areas with $PM_{2.5}$ concentration greater than 15 micrograms/meter (or other threshold)
- Cases of chronic respiratory illness, cancer, respiratory restricted activity days, and/or premature deaths due to motor vehicle air pollution (regional scale)
- Number of sensitive receptors within close proximity (e.g., 100 meters) of highway corridor

Statewide Vehicle Fleet-Related Measures

- Statewide percentage of total gasoline usage substituted with alternative fuels
- Statewide percentage of total diesel usage substituted with alternative fuels
- Electric vehicles as percentage of total light-duty vehicles registered in state
- Percentage of statewide heavy-duty vehicle fleet that meets EPA standards

Emissions-Related Measures

- Change (trends) in statewide motor vehicle emissions, relative to base year ($PM_{2.5}$, NO_x, VOC)
- Change (trends) in statewide light-duty vehicle emissions, relative to base year ($PM_{2.5}$, NO_x, VOC)
- Change in metropolitan scale vehicle emissions ($PM_{2.5}$, NO_x, VOC)
- Statewide motor vehicle emissions per VMT ($PM_{2.5}$, NO_x, VOC)
- Statewide light-duty vehicle emissions per VMT ($PM_{2.5}$, NO_x, VOC)
- Metropolitan scale vehicle emissions per VMT
- Statewide motor vehicle emissions per capita ($PM_{2.5}$, NO_x, VOC)
- Statewide light-duty vehicle emissions per capita ($PM_{2.5}$, NO_x, VOC)
- Metropolitan scale vehicle emissions per capita
- Quantity of chlorofluorocarbons (CFCs) consumed in autos in state

State DOT Fleet-Related Measures

- Annual emissions from state DOT vehicles (normalized by annual fuel use or highway miles)
- Percentage of state DOT on-road heavy-duty vehicle fleet meeting PM standards
- Percentage of state DOT off-road diesel fleet meeting Tier 3 or 4 standards
- Percentage of state DOT light-duty vehicle fleet using alternative/cleaner fuels (E-85, CNG, electric, etc.)
- Percentage of state DOT heavy-duty vehicle fleet using alternative/cleaner fuels (biodiesel, CNG, etc.)
- Percentage of state DOT fuel consumption defined as cleaner fuels
- Tons of emissions due to DOT construction projects
- Engine idling hours due to DOT construction projects
- Emission reduction strategies-related measures
- Statewide travel delay per capita or per VMT
- Metropolitan travel delay per capita or per VMT
- Number of Transportation Control Measures funded
- Statewide transit mode share (or regional scale)
- Statewide bicycle/pedestrian mode share (or regional scale), work trips
- Statewide carpool mode share (or regional scale), work trips
- Percentage of urban state highway/roadway miles with bikes lanes and/or sidewalks
- Statewide mode share for non-single occupant vehicle trips
- Non-single occupant vehicle mode share in air quality nonattainment areas

Air Quality Measures Subjected to Scrutiny

Before selecting a suggested measure, the research team considered several air quality-related measures in detail because they appeared to meet some or many of the criteria for measure effectiveness laid out in Chapter 3 of this report. After further research and discussion with state DOT practitioners, however, the following measures were excluded from further development:

- **Change in Metropolitan Motor Vehicle Emissions, Relative to Base Year.** The proposed measure can be adjusted to look only at the metropolitan areas within a state, rather than at the state as a whole. This measurement option explicitly acknowledges that air pollution is primarily a regional problem that is greatest in areas with heavy concentrations of vehicle travel.

Most major metropolitan areas maintain fine-grained network-based travel models, so the methodology for calculating this measure option would be the same as that described in Chapter 6, but on a regional versus statewide scale. For nonattainment areas, this type of calculation is regularly performed as part of the air quality planning process. Typically, regional emissions are calculated by an MPO, although the state DOT or state environmental agency may take the lead in some states. Calculation of this performance measure should seek to use existing emissions calculations to the extent possible. In states without nonattainment areas, calculations of regional emissions may or may not be performed by the MPO or state. If not, it is possible to estimate emissions using travel demand model output.

- **Direct Measures of Air Quality.** The research team considered direct measures of air quality, such as the number of days in violation of ambient air quality standards, or the population living in air quality nonattainment areas. A principal drawback of this kind of measure, however, is that DOTs have less control over measure results because sources of emissions other than motor vehicles can also contribute to air pollution. In the Los Angeles region, for example, on-road motor vehicles are currently responsible for about 61 percent of NO_x emissions and 23 percent of $PM_{2.5}$ emissions.
- **Emissions Control Strategy-Related Measures.** DOTs can most directly influence emissions by implementing strategies to improve traffic flow (e.g., ramp metering, incident management, signal timing, capacity additions) and reduce automobile travel (e.g., transit programs, bicycle, and pedestrian programs). These types of strategies, however, are virtually impossible to standardize and quantify consistently. While transportation agencies, and particularly MPOs, do quantify the effects of their plans and programs on vehicle delay, this is typically done as a forecasting exercise, not through historic tracking. Quantifying the emissions impacts of highway operations strategies is particularly challenging, even for a single corridor. The team, however, considers simpler measures that merely count the number of implemented emission control strategies as too far removed from the ultimate outcome of interest to provide meaningful value to decision makers or the public.

Energy and Climate Change

Initial Comprehensive List of Energy and Climate Change Measures

Early in the research for this report, a "laundry list" of energy and climate change measures was compiled from individual DOTs, research reports, and other sources. The following measures did not meet most or all criteria for measure effectiveness laid out in Chapter 3 of this report and thus were discarded from the research:

Statewide Fuel/Energy Use-Related Measures

- Change in annual statewide transportation energy use
- Statewide transportation energy use per capita
- Transportation energy use per person mile of travel
- Transportation energy use per amount of freight transported
- Change in statewide gasoline consumption
- Statewide gasoline consumption per capita
- Transportation share of statewide total energy use

GHG Emissions-Related Measures

- Change in transportation GHG emissions, statewide
- Transportation GHG emissions per capita, statewide
- Change in motor vehicle GHG emissions, statewide

- Motor vehicle GHG emissions per capita, statewide
- Change in light-duty vehicle GHG emissions, statewide
- Light-duty vehicle GHG emissions per capita, statewide
- Metropolitan scale GHG emissions (total or per capita; all vehicles or light-duty vehicles only)
- Statewide share of GHG emissions from on-road transportation

Vehicle Miles Traveled-Related Measures

- Change in statewide VMT
- Change in statewide light-duty vehicle VMT
- Statewide VMT per capita
- Statewide light-duty vehicle VMT per capita
- Metropolitan level VMT or VMT per capita (total or light-duty only)

GHG Mitigation: Vehicles and Fuels-Related Measures

- Statewide alternative fuel use as percentage of gasoline use
- Change in annual statewide use of alternative vehicle fuels
- Electric vehicles as percentage of total light-duty vehicles registered in state
- Percentage of truck stops with electrification
- Percentage of toll lanes with electronic toll collection
- GHG Mitigation: Transportation Demand Management-Related Measures
- Transit passenger miles per total person miles of travel
- Transit mode share (statewide or metropolitan scale)
- Carpool mode share, work trips
- Average vehicle occupancy
- Percentage of population or jobs within 0.5 mile of transit
- Bicycle/pedestrian mode share, work trips
- Percentage of person miles traveled by non-motorized modes
- Percentage of urban state highway/roadway miles with bikes lanes and/or sidewalks
- Ratio of bikeway miles to arterial and collector miles

DOT Fleet-Related Measures

- Percentage of state DOT light-duty vehicle fleet using alternative fuels (E-85, CNG, electric, etc.)
- Percentage of state DOT heavy-duty vehicle fleet using alternative fuels (biodiesel, CNG, etc.)
- Percentage of state DOT fuel consumption defined as cleaner fuels
- Number of electric vehicle charging points for state DOT vehicles

DOT Operations and Facilities-Related Measures

- Kilowatt hours of electricity used per total energy consumption in state DOT offices per square meter of occupied floor space or per employee
- Change in the amount and percentage of renewable energy purchased by DOT
- Renewable energy generated at state DOT facilities
- Change in the number and percentage of DOT projects/facilities/fixtures that have lighting meeting Energy Star requirements
- Percentage of state DOT's roadway lights with light-emitting diode (LED) lamps
- Percentage of state DOT traffic signals with LED lamps
- Number of DOT contracts incorporating energy efficiency practices
- Percentage of state DOT employees commuting by non-single occupant vehicle mode
- Number of state DOT buildings that are Leadership in Energy & Environmental Design (LEED) certified

Energy and Climate Change Measures Subjected to Scrutiny

Before selecting a suggested measure, the research team considered several energy and climate change-related measures in detail because they appeared to meet some or many of the criteria for measure effectiveness laid out in Chapter 3 of this report. After further research and discussion with state DOT practitioners, however, the following measures were excluded from further development:

- **GHG Emissions Measures.** The team considered measures of GHG emissions from transportation, such as carbon dioxide emitted by on-road transportation or total GHG emissions from the transportation sector. These measures generally require more steps to estimate and would not substantially increase the amount of information provided to states about their performance.
- **Per Capita Carbon Dioxide Emissions from On-Road Transportation.** This measure requires some additional calculation steps relative to the measure selected. States would need to measure use of non-gasoline fuels including diesel and biofuels and estimate CO_2 emissions using standard factors.
- **Per Capita Transportation Energy Use.** This measure would require substantially more calculation steps relative to the measure selected because of the need to include rail, air, and marine travel, and multiple fuel types within each mode. A high proportion of cross-state and even international travel by these modes complicates the attribution of transportation energy to individual states.
- **Measures of VMT.** While VMT is proportional to fuel consumption in the near term, without changes in vehicle technologies and fuels, it is less closely related to fuel consumption and GHG emissions in the long term. VMT is also generally less well understood as a performance measure than fuel consumption.

Materials Recycling

Comprehensive List of Additional Materials Recycling Measures

Early in the research for this report, a "laundry list" of materials recycling measures was compiled from individual DOTs, research reports, and other sources. The following measures did not meet most or all criteria for measure effectiveness laid out in Chapter 3 of this report and thus were discarded from the research:

Transportation System-Focused Waste Management/Recycling Measures

- Quantity of hazardous waste generated and managed
- Quantity of municipal solid waste generated and managed
- Number of motor vehicles scrapped annually
- Annual volume of trash collected by Adopt-a-Highway program volunteers
- Change in the quantity of total litter collected annually (weight, volume, etc.)
- Percentage of state DOT projects that have a waste diversion or recycling plan
- Change in the quantity of hazardous waste cleaned up compared with waste generated (e.g., acres of brownfield, gallons of waste, amount of treated groundwater)
- Change in total weight/volume composted annually

Agency-Focused Waste Management/Recycling Measures

- Share of post-consumer recycled products for janitorial paper products
- Recycling rate for office paper
- Change in the amount of waste generated by type, weight, and/or volume
- Change in the amount of waste diverted (from landfill) by type, weight, and/or volume

Construction Materials-Related Measures

- Average percent of recycled material used in pavements
- Tons of reclaimed concrete aggregate used annually on paving projects to replace virgin graded aggregate base
- Amount of RAP in asphalt
- Tons of fly ash used annually in concrete pavement applications
- Amount of asphalt shingles in asphalt
- Tons of blast furnace slag used annually as aggregate in concrete pavement applications
- Amount of crushed glass used annually as aggregate in pavement
- Amount of crumb rubber material used in asphalt
- Amount of steel slag used in asphalt
- Percentage of construction waste diverted from landfills
- Percentage of pavement area recycled
- Percentage by which the expected life of infrastructure increases over baseline

Materials Recycling Measures Subjected to Scrutiny

Before selecting a suggested measure, the research team considered several materials recycling-related measures in detail because they appeared to meet some or many of the criteria for measure effectiveness laid out in Chapter 3 of this report. After further research and discussion with state DOT practitioners, however, the following measures were excluded from further development:

- **Percentage by Mass of All Recycled Materials Used.** It would be desirable to acknowledge all recycled materials a DOT is using in its operations because they are all contributing to using fewer virgin resources. But discussions with federal and state practitioners confirmed that it would be difficult to fairly quantify crumb rubber tires in the same metric as a very heavy concrete. The differences in density make measurement by weight difficult, and different materials can have different uses and benefits, such as use of shingles for replacing petroleum-based asphalt binder and use of concrete solely as an aggregate. States like North Carolina and Illinois acknowledged that they sometimes calculate a measure that combines all materials by weight, but they stated it would not be ideal for a comparative performance measure.
- **Percentage of DOT Projects That Have a Waste Diversion or Recycling Plan.** This measure is further removed from the outcome of interest and is a less reliable measure of calculating the decreased use of virgin materials than measuring the actual amounts of recycled materials used.
- **Measures Aimed at Increasing Infrastructure Life.** Actual measures of increases in infrastructure life would take too long to manifest—generally several decades. Estimates of improvements to infrastructure life through new technology are uncertain. Best management practices to extend the life of pavement and other infrastructure has merit, but because of variation in the types of practices and the intensity of their application, a performance measure on this topic would be more difficult to quantify and measure.

Stormwater/Water Quality

Comprehensive List of Additional Water Quality Measures

Early in the research for this report, a "laundry list" of water quality/stormwater measures was compiled from individual DOTs, research reports, and other sources. The following measures did not meet most or all criteria for measure effectiveness laid out in Chapter 3 of this report and thus were discarded from the research:

Water Quality-Based Measures

- Percentage of monitored water bodies classified as impaired for aquatic life
- Reduction in total number of sensitive receiving environments adversely affected by state highway runoff
- Population served by community water systems with no reported violations of health-based standards
- Average pollutant concentrations of various metals, suspended solids, and toxic organics in road runoff
- Quality of stormwater discharge from construction sites
- Acreage of riparian areas or areas providing water quality functions that are disturbed, degraded, or eliminated
- River miles, lakes, and ocean shore miles impaired by urban runoff (not just highways)

Pollutant-Based Measures

- Quantity per year of nitrogen pollution abated
- Quantity per year of phosphorus pollution abated
- Quantity per year of sediment abated
- Quantity of road salt used
- Quantity of deicing chemicals used per inch of snowfall
- Per capita vehicle fluid losses
- Change in the amount of net impervious surface area (acres) due to program of projects
- Per capita impervious surface area
- BMP installation/effectiveness-based measures
- Number of BMPs incorporated annually
- Amount of untreated pavement retrofitted for stormwater management controls each year
- Number of stormwater management facilities built annually
- Percentage of stormwater management facilities rated as functionally adequate
- Number of stormwater management facilities requiring remediation, retrofit, and/or maintenance
- Percentage of impervious surface owned by DOT for which water quality treatment is provided
- Amount of runoff treated for new and retrofit projects (percentage of total volume)
- Amount of runoff managed for new and retrofit projects (percentage of total volume)
- Number of projects programmed to maintain or improve water quantity or quality
- Change in the number of retrofitted drainage and crossing structures
- Change in the number of water detention facilities in operation
- Number of water quality-related watershed restoration projects
- Miles of streams restored
- Percentage of state highway impacting sensitive receiving environments that have designed road runoff treatment mechanisms in place
- Change in the percentage of system impervious surfaces receiving water quality treatment
- Use of low impact development (LID) measures

Regulatory Compliance-Based Measures

- Percentage of NPDES permit conditions met annually
- NPDES stormwater permit compliance
- Comparison of enforcement actions to active construction projects
- Percentage of water samples that exceed × concentration of pollutants
- Percentage of water measurements where the high flow is 30 percent or more above baseline/reference

Stormwater/Water Quality Measures Subjected to Scrutiny

Before selecting a suggested measure, the research team considered several stormwater/water quality-related measures in detail because they appeared to meet some or many of the criteria for measure effectiveness laid out in Chapter 3 of this report. After further research and discussion with state DOT practitioners, however, the following measures were excluded from further development:

- **Direct Water Quality Measurement.** Many factors outside of DOT actions or vehicle activity impact water quality, so directly measuring water bodies does not give meaningful information on what changes in water quality are attributable to DOT management practices. DOT water monitoring efforts are also not consistent and widespread enough to make comparable data available in the near future.
- **Number of NPDES Permit Violations.** In many cases, NPDES permits are overseen by state entities, such as a department of environmental protection. States vary widely in how rigorous permit requirements are and in how closely the requirements are monitored. This variation has a high risk of rewarding states with low environmental oversight and penalizing those with the most stringent, and therefore beneficial, requirements.
- **Compliance with TMDL Implementation Plans.** EPA's Total Maximum Daily Load (TMDL) program assesses impaired water bodies and has an accompanying implementation plan with actions required for DOTs. As with NPDES permits, there is too much variation in the kind of actions required for compliance to make comparisons between states meaningful. It would also be time consuming to research and track every action outlined in the plans.
- **Number of BMPs Incorporated Annually.** BMPs can vary widely in scope and effectiveness, so looking only at the quantity of different BMPs may not be very telling of a DOT's progress on stormwater management.

Wildlife and Ecosystems

Comprehensive List of Additional Wildlife and Ecosystems Measures

Early in the research for this report, a "laundry list" of wildlife and ecosystems measures was compiled from individual DOTs, research reports, and other sources. The following measures did not meet most or all criteria for measure effectiveness laid out in Chapter 3 of this report and thus were discarded from the research:

Process-Based Measures

- Number of design policies and specifications for preserving or restoring streams and wetlands
- Number of bid items that emphasize habitat friendly options
- Number of Memoranda of Agreement executed with resource agencies for conservation
- Policies in place to encourage redevelopment versus greenfield development
- Policy/specification for setting construction periods to minimize wildlife disruption
- Policy/specification exists for selecting mitigation sites to maximize their value, minimize invasive species, roadway interference, road kills
- Number of projects that are consistent with/designed to meet statewide environmental plan goals
- A cross agency system for biodiversity/planning exists
- A cross agency asset management system exists
- Number of staff/consultants receiving biodiversity training
- Number of guidance/policy manuals relevant to biodiversity
- Investment in research of transportation impacts to habitat/biodiversity

- Investment in outreach to county/local transportation officials (dollars)
- Investment in programs to involve the general public in mitigating roadway ecosystem impacts (dollars)

Planning/Project Development-Related Measures

- Total number of wetlands impacted (acres)
- Ratio of acres replaced by state DOT to acres of wetland affected
- Wetland mitigation acres achieved
- Number of fish barrier removal projects
- Change in net area of undeveloped land converted to transportation uses (acres) due to projects/program
- Area of right-of-way acquisition per year, per mile/VMT
- Investment in avoidance of habitat fragmentation, and possibly tracking
- Number of takings of threatened/endangered species per VMT/miles of roadway constructed compared with baseline
- Investment in habitat surveys during planning (dollars spent per new roadway mile constructed)
- Number of projects that select the minimal ecosystem degradation option
- Number of retrofitted water crossings that improve biological/physical habitat continuity

Operations and Maintenance-Related Measures

- Units of native plant materials installed per mile/VMT per year
- Acres of wetlands mitigated per area of wetland impact
- Length of streams mitigated per length of impact area
- Total area of compensation for habitat fragmentation
- Number of sites meeting mitigation goal within monitoring period
- Number of wildlife crossings implemented or reduction in animal strikes at high activity locations
- Wildlife strikes recorded in crash data per mile of roadway/VMT
- Innovations in habitat/biodiversity preservation/impact minimization
- Area of invasive species monitoring/eradication
- Percentage of construction projects completing pre-construction inspections
- System for communicating environmental site concerns between planners, maintenance/ construction crews
- Quantity of right of way managed as native plant communities
- Area wetland/other mitigation sites monitored/controlled for invasive species and wildlife usage
- Procedure/dollars allocated for integrated pest management
- Quantity of hazardous materials spills
- Percentage of mitigation sites that are monitored and found to be meeting permit conditions
- Number of high priority culverts remaining to be retrofitted or replaced to improve fish passage
- Change in the number of animal kills
- Number of acres replanted with native species
- Total amount spent on Endangered Species Act (per unit)

Wildlife and Ecosystems Measures Subjected to Scrutiny

Before selecting a suggested measure, the research team considered several wildlife- and ecosystems-related measures in detail because they appeared to meet some or many of the criteria for measure effectiveness laid out in Chapter 3 of this report. After further research and discussion with state DOT practitioners, however, the following measures were excluded from further development:

- **Programmatic Agreement/Conservation Policy-Related Measures.** These measures would credit DOTs that have made programmatic agreements with natural resource agencies. These policies/programmatic agreements could address project impacts to protected species, streams, wetlands, or other habitats. They could establish goals for avoiding/minimizing impacts to streamline project review; reduce the level of coordination required based on project type, size, and context; and benefit both the resources and the project development process. The difficulty of using such policies/agreements as a measure is that they are finite in number—there are a limited number of coordination processes or resources that may be covered by such agreements. Once they are established, the measure will plateau, and additional "improvement" or continued performance would not be measured. Also, the development of policies and programmatic agreements does not necessarily gauge their effectiveness.
- **Establishing Systems for Communicating Environmental Concerns.** Creating a system to communicate among transportation planners, resource agencies, and contractors could help to ensure consistency of highway planning with statewide conservation goals and environmental compliance during construction. However, once established, there is no measure of improvement or continued performance. Assuming that it is implemented as a routine procedure, then all projects would be included in the system.
- **Investment in Training, Outreach, Habitat Surveys, and Invasive Species Management.** Investment of funds toward conservation goals is commendable; however, it has the following issues: (1) it is not in itself a good measure of performance or benefit to the ecosystem, (2) it depends largely upon legislation and available funding, and (3) it is not comparable from state to state.
- **Number of Threatened and Endangered Species Takings.** The diversity of habitats and rare species across the nation makes this measure unreliable. Rare species are not evenly distributed state to state, and their numbers are not necessarily proportional to the area of a state.
- **Proportion of New Right of Way from Greenfields versus Redevelopment.** The measurement of the area of right of way over land use depends on the availability of accurate and current land use mapping. Additionally, it was thought that this information would not be readily available and that deriving this data from individual projects may be a burden on DOT staff.
- **Number of Projects That Select the Minimum Ecological Degradation Alternative.** This measure could reflect the efforts of the DOT toward avoidance and minimization of ecosystem impacts. However, assembling the data to compare all the alternatives project by project would require a considerable effort by the DOT. Also, projects of different type, size, and context will vary in complexity and consideration of other legitimate environmental issues (such as socioeconomics, cultural resources, etc.) that also drive the selection of the preferred alternative.
- **Number of Wildlife Crossings or Stream Crossings That Improve Aquatic Life Passage.** The absolute number of wildlife/aquatic life crossings that are implemented does not necessarily indicate their value, and crossings are difficult to normalize across states. Also, the value of these crossings is not a given on a site-by-site basis. Crash data only includes large animal strikes, and does not reflect the effectiveness of wildlife crossings, particularly if the target species is a smaller animal. Measurement of the effectiveness of these crossings will require a substantial investment of time and funds by the DOT, and therefore this measure would not likely be embraced.
- **Proportion of Right of Way Managed as Natural Area/Replanted with Native Vegetation.** Some states, such as Washington, already manage the majority of their right of way in this manner, and so improvement could not be gauged. Other more densely populated states may have less opportunity to manage right of way in this manner. There may be conflicts between managing narrow right of way in native vegetation and highway safety, such as maintaining clear zones and risk of animal crashes.

Wildlife and Ecosystems Proof of Concept Results for "Percentage of wetland and stream mitigation that achieves regulatory approval on, or ahead of, schedule based on the permitted monitoring period"

Note: This measure was not selected for inclusion as a core measure following the proof of concept phase. Results are summarized here as a record of the decision to reject this measure.

Pilot States: Ohio, Georgia, Iowa

Proof of Concept Validation		Implementation Readiness
Does Measure Support Consistent State-to-State Application?	◑	☐ Ready for Use by Many DOTs Today
Do DOTs Have Easy Access to Data/ Is Measure Easily Calculated?	●	☐ Suitable for Use by DOTs in Longer Term
Is Data Quality Credible and Defensible?	◑	☑ Not Suitable for Use by Most DOTs

Key
● Measure is fully consistent with criteria
◕ Measure is mostly consistent with criteria
◑ Measure is somewhat consistent with criteria
◔ Measure lacks consistency with criteria

Overview

State DOTs' construction projects have the potential to affect wetlands and streams either through direct losses or via indirect fragmentation. Typically, habitats may include wetlands and streams, which are routinely mitigated pursuant to the Clean Water Act Section 404 and Section 401 permit requirements, but also could include rare species habitat, which is regulated under the Endangered Species Act.

The "mitigation success" measure uses state DOTs records to track whether environmental mitigation commitments made to regulators to compensate for impacts are successfully completed in a timely manner. "Success" is defined as an outside regulatory agency's final approval of mitigation, which offers a common means of comparison among states. (Habitat assessment methods that categorize the level of functionality achieved by mitigation based on physical characteristics vary too widely among states to make "habitat function" possible as a comparative measure.)

DOTs generally maintain detailed records of their mitigation efforts as part of project cost tracking and for regulatory compliance. Some states (e.g., Ohio, Montana, Illinois, Washington, and Florida) keep centralized databases of their wetland and stream mitigation efforts online that contain documentation of wetland mitigation accounting and mitigation site descriptions/ monitoring reports on their websites.

Data was gathered for mitigation projects at Ohio, Iowa, and Georgia state DOTs, however, mitigation by the state DOTs in Iowa and Georgia was found to be conducted mostly via banking, therefore the proposed measure could not be calculated.

Ultimately, the research team was only able to make meaningful use of Ohio data for this study. All results shown are for Ohio only. In Ohio, most projects are permitted contingent on 5 years of monitoring. Few, if any projects, are approved prior to the date, even if they meet mitigation goals earlier. So, rather than report a gradient of success based on time-to-agency-approval, the vast majority of projects are given "pass/fail" grades.

Wildlife and Ecosystems Performance Results

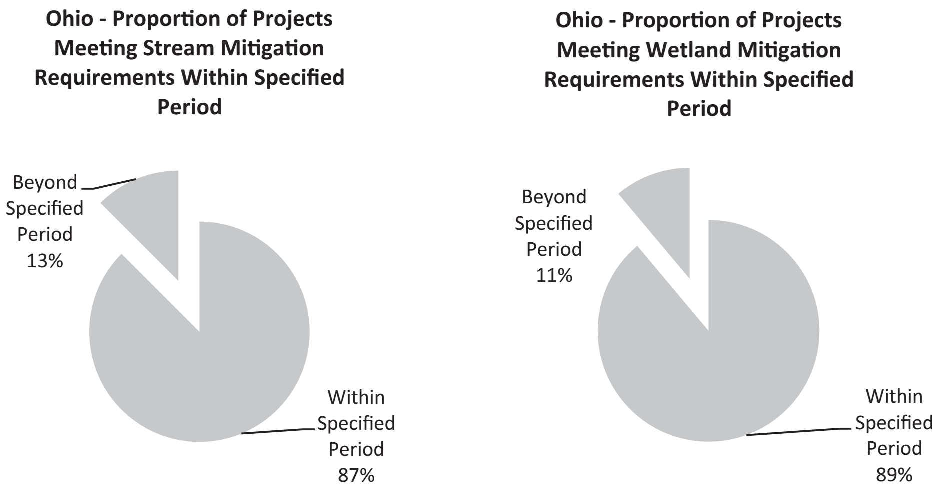

Figure A-1. Share of Ohio DOT's onsite stream and wetland mitigation sites meeting approval on schedule, 2005–2013.

Wildlife and Ecosystems Measure: Criteria Assessment

Does Measure Support State-to-State Comparisons?

- **Varied Use of Mitigation Banks across States Makes Comparisons Difficult.** Because mitigation banking activity cannot be addressed via this measure (banks are already "approved" by resource agencies before mitigation begins), this measure gives a skewed perspective on a DOT's ability to meet mitigation goals when comparing states that rely to greater or lesser degrees on banking.

Do DOTs have Easy Access to Data/Is Measure Easily Calculated?

- **Data on Mitigation Approvals Is not Readily Available.** Ohio DOT, Georgia DOT, and Iowa DOT all agreed to be pilot states for the "mitigation success" measure. The Ohio DOT maintains an online record of all its current and most of its past wetland and stream mitigation sites (http://www.dot.state.oh.us/Divisions/Planning/Environment/Ecological_Resources_Permits/MitigationInventory/Pages/default.aspx). The Georgia and Iowa DOTs, however, spent considerable time collating data manually for the research team.
- **Bank-Based Mitigation Efforts Cannot Be Used in Measure.** The greatest problem encountered in testing this measure is that of the three pilot states, only Ohio was able to provide data that was directly applicable for the measure. The reason for the unsuitability of data provided by Georgia and Iowa is their high or exclusive usage of mitigation banks, or third parties from whom the DOT can purchase mitigation credits to avoid having to perform mitigation activities themselves.

Many states use "wetland banks" (and occasionally stream mitigation banks) to compensate for some or much of their project-level losses incurred. In the case of Georgia DOT, for example, mitigation banks are available over most of the state and are cost-effective. Consequently, Georgia DOT relies primarily on banking for stream and wetland restoration and reports only two project-specific mitigation sites that are "in progress." Therefore, performance results could not be generated for Georgia. A similar situation was found by the team upon reviewing Iowa's data.

Projects relying on banking-based mitigation have the advantage that as soon as bank credits are purchased and verified, mitigation is considered "successful." On the other hand, successful onsite mitigation has the value of preserving functions at the location of the impact, some of which may be particularly important to retain at that location rather than offsite, such as restoration of a unique or high-quality habitat. This is part of the basis for using site-specific mitigation in the measure. Site-specific mitigation (and consolidated mitigation sites) can also reflect the greater effort required by the DOT to meet permit requirements.

While some state DOTs develop and manage their own banks, and are therefore responsible for ensuring monitoring periods and performance goals are met, many use commercial banks or banks developed by other governmental bodies. The team believes that use of commercial mitigation bank credits does not indicate the same level of commitment by a DOT that is required for site-specific mitigation. Therefore, the measure was designed to exclude projects that use only mitigation bank credits.

- **The Use of Mitigation Banks Is High, and Possibly Increasing.** As indicated by this project's pilot states, many DOTs prefer to use mitigation banks rather than perform mitigation in house. Further, it is preferred by regulatory agencies (e.g., U.S. Army Corps of Engineers' 2008 mitigation guidelines). The process is simpler, requires less personnel and expertise, fulfills the requirement immediately, can be more cost-effective (depending on the bank credit market), and carries a lower risk of regulatory failure. For these reasons, and based on conversations the research team has had with states, it is likely that use of banks will continue to be high, which would exclude from this measure large portions of the mitigation work occurring in response to DOT activity. This situation therefore lowers the impact of the measure to a degree that it is not suitable for national implementation.

Is Data Quality Credible and Defensible?

- **Data Quality, When Available, Is Credible.** Because the data for this measure is based on third-party regulator records, the expectation is that data would be consistent and reliable. Regulators are generally state environmental compliance departments, whose credibility is strong.

APPENDIX B

Wildlife and Ecosystems Self-Assessment Tool (ESAT)

Table B-1. Final Ecosystems Self-Assessment Tool—assessment questions and scoring.

Question ID	Question	0 Points	1 Point	2 Points	3 Points	Examples of Best Practice
01	Construction guidance and manuals include specific biological resource conservation/mitigation practices?	None	1 practice	2 practices	3 or more practices	Ohio DOT, "Construction Administration Manual of Procedures" 2013: contains criteria for screening borrow and waste sites for environmental resources
02	Operations and maintenance guidance and manuals include specific biological resource conservation/mitigation practices?	None	1 practice	2 practices	3 or more practices	Ohio DOT, Highway Operations Environmental Checklist
03	Manuals and guidance include specific practices for minimizing impacts to biological resources from stormwater runoff?	None	1 practice	2 practices	3 or more practices	NY DOT Highway Design Manual, Chapter 8—Highway Drainage discusses specific site considerations for the protection of fish and wildlife resources
04	Percentage of environmental staff and construction contractors receiving biological resource conservation/mitigation training?	None	1-33%	34-66%	Greater than 66%	Illinois DOT INVEST v1.0: Construction environmental training requirements
05	Programmatic guidance and planning documents from state wildlife agencies (e.g., Wildlife Action Plans) are used in DOT projects and planning decisions?	Not utilized, or not available	Somewhat	Modestly	Extensively	Texas DOT uses Species of Greatest Conservation Need, which are part of the State Wildlife Action Plan, and species listed on county lists as triggers for coordination with Texas Parks and Wildlife Department

Question ID	Question	0 Points	1 Point	2 Points	3 Points	Examples of Best Practice
06	Culvert designs that mitigate impacts to aquatic species are used during new construction or retrofits?	Rarely or never	As required on a project-specific basis	Frequently (i.e., more than half of projects)	Routinely (i.e., nearly all projects)	State laws in Oregon and Washington require culvert designs that allow for passage of all native and migratory fish and access to historic habitat
07	Inspections occur before and during construction to determine compliance with biological resource commitments?	Rarely or never	As required on a project-specific basis	Frequently (i.e., more than half of projects)	Routinely (i.e., nearly all projects)	Caltrans Environmental Commitments Record
08	Work periods are set to minimize disruption to fish and wildlife?	Rarely or never	As required on a project-specific basis	Frequently (i.e., more than half of projects)	Routinely (i.e., nearly all projects)	Nebraska DOT (GAO-04-563): Nebraska DOT is working with the state resource agency to identify preferred times for construction in order to reduce impacts on the breeding of certain species
09	Number of Memoranda of Agreement with state or federal resource agencies to improve biological resource impact analyses, mitigation, conservation actions?	None	MOA in place with one or more agencies	Routinely coordinate with one agency in accordance with MOA	Routinely coordinate with multiple agencies in accordance with MOAs	Illinois DOT uses Illinois National Heritage Program staff to perform ecological surveys
10	Extent of asset management/data sharing related to biological resources?	None	Agreement in place with one or more agencies	Data sharing system implemented with one agency	Data sharing system implemented with multiple agencies	Illinois DOT has a data license agreement with the Illinois Department of Natural Resources for the Illinois Natural Heritage Database

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Table B-1. (Continued).

11	A system exists for planners, maintenance crews, and construction crews to communicate regarding environmental sensitivities? (e.g., restricted activity zone mapping, standardized data sheets)	No	As required on a project-specific basis	Frequently (i.e., more than half of projects)	Routinely (i.e., nearly all projects)	Texas DOT uses Environmental Permits, Issues, and Commitments (EPIC) Sheet used for communicating environmental constraints including permits and/or ESA consultation commitments
12	Conduct planning to reduce abundance, distribution, and/or dispersal of invasive species with partner agencies?	None	As required on a project-specific basis	Frequently (i.e., more than half of projects), as part of pre-project planning	Mitigation coordinated with agencies on a system-wide/statewide basis	New York DOT follows a six-step approach for Integrated Vegetation Management (IVM) that includes plant selection to resist invasive woody plants
13	Stream and wetland mitigation planning conducted with partner agencies?	None	As required on a project-specific basis	Frequently (i.e., more than half of projects), as part of pre-project planning	Mitigation coordinated with agencies on a system-wide/statewide basis	Illinois DOT: Wetlands Action Plan with the Illinois Department of Natural Resources
14	Threatened and endangered species mitigation planning conducted with partner agencies?	None	As required on a project-specific basis	Frequently (i.e., more than half of projects), as part of pre-project planning	Mitigation coordinated with agencies on a system-wide/statewide basis	As part of Texas DOT/Texas Parks and Wildlife Department (TWPD) Memorandum of Understanding, a Conservation Coordinator position at TPWD is funded to assist in enhancing the effectiveness of project-specific mitigation efforts

Question ID	Question	0 Points	1 Point	2 Points	3 Points	Examples of Best Practice
15	Wildlife corridor mitigation planning conducted with partner agencies at state level?	None	As required on a project-specific basis	Frequently (i.e., more than half of projects), as part of pre-project planning	Mitigation coordinated with agencies on a system-wide/statewide basis	Georgia DOT coordinated with the Georgia Department of Natural Resources when developing plans for bear crossings along SR 96
16	System is in place to track biological resource commitments compliance?	None	1 resource	2 resources	3 or more resources	Various states have or are developing Environmental Commitments Tracking Systems
17	Department mapping system is updated with threatened and endangered species occurrence and/or habitat information?	Less often than 3 years	Every 2 to 3 years	Annually	Biannually or more often	Ohio DOT has access to the Ohio Department of Natural Resources' continuously updated Ohio Biodiversity Database
18	Department mapping system is updated with wetland information?	None	National Wetland Inventory or National Hydrography Database only	Plus other statewide or regional data	Plus other higher resolution data	Ohio DOT annual data sharing contract with the Ohio Department of Natural Resources allows access to any new wetland locations, including beyond National Wetlands Inventory resolution
19	Elements of statewide ecological mapping incorporated in Long-Range Transportation Plan: -Regional conservation strategies (e.g., programmatic biological opinions, critical habitat designations, species recovery plans, regional habitat conservation plans) -Federal/state listed and rare species records -Mapping of priority waterways/streams -Public lands (e.g., parks, wildlife refuges) mapping -Wildlife corridors/crossings -Priority wildlife habitats -Wetlands	None currently available or available but not used	1-3 elements	4-6 elements	7 or more elements	Michigan DOT: 2035 Transportation Plan, Environmental White Paper

(continued on next page)

Table B-1. (Continued).

20	DOT guidelines in place for noise/vibrations effects on aquatic life?	No	In process	Yes		California DOT aquatic noise guidelines
21	Percentage of projects that quantitatively assessed the impacts of noise or vibration on adjacent wildlife habitats in the last 5 years?	0%	1-10%	11-50%	More than 50%	Texas DOT: Noise research was funded to assess impact of noise on endangered birds as part of two biological opinions from U.S. Fish and Wildlife Service
22	Percentage of projects that quantitatively assessed the impacts of noise or vibration on aquatic life in last 5 years?	0%	1-10%	11-50%	More than 50%	Caltrans "Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish" 2009
23	Functional assessments are used to determine wetland mitigation requirements?	None	As required on a project-specific basis	Frequently (i.e., more than half of projects), as part of pre-project planning	Mitigation coordinated with agencies on a system-wide/statewide basis	Oregon DOT uses the Oregon Department of State Lands Oregon Rapid Wetland Assessment Protocol to assess impacts and proposed mitigation for projects impacting greater than 0.20 acres of wetland.
24	Duration of wetland and other mitigation site monitoring and maintenance activities extends beyond federal regulatory requirements?	No	As required on a project-specific basis	Frequently (i.e., more than half of projects)	Routinely (i.e., nearly all projects)	Ohio DOT: monitoring of sites with pooled credits often extends beyond the 5-year permit requirement
25	Average statewide ratio of streams mitigated per length of stream impact over the last 5 years?	Less than 1:1	1.1 to 1.5:1	1.5 to 3:1	Greater than 3:1	Georgia DOT performs stream mitigation at an approximately 6:1 ratio

Question ID	Question	0 Points	1 Point	2 Points	3 Points	Examples of Best Practice
26	Average statewide ratio of acres of wetlands mitigated per area of wetland impact over the last 5 years?	Less than 1:1	1.1 to 1.5:1	1.5 to 3:1	Greater than 3:1	Oregon state law requires 3:1
27	Conservation/mitigation banks have been proactively established in advance of foreseen impacts to streams and wetlands?	None	Sometimes participate in other programs	Often participate in other programs	DOT-sponsored program	Oregon DOT has a wetland banking program with 130 total established acres
28	Conservation/mitigation banks have been proactively established in advance of foreseen impacts to threatened and endangered species?	None	Sometimes participate in other programs	Often participate in other programs	DOT-sponsored program	Oregon DOT implemented a conservation bank for federal owl habitat and developing a similar bank for streaked horned lark
29	Proportion of sites meeting mitigation goal in time period determined in the mitigation and monitoring plan? **Note:** *For the purposes of this assessment, mitigation credits purchased from other entities may be assumed to have met mitigation goal*	Less than 50%	51-75%	76-99%	100%	Oregon DOT hired a consultant to evaluate their approved mitigation and monitoring plans and the result was within the 76-99% score range
30	Wildlife collision hazard sites are prioritized for mitigation?	None	1-25% of state highway network	25-50% of state highway network	Greater than 50% of state highway network	Oregon DOT: "wildlife collision hot spots map"
31	Statewide guidance or tool kit available to determine appropriate wildlife collision mitigation methods/structures?	No	One design available	Two designs available	More than two designs available	Utah DOT: "Collaborative Research Effort Identifies Effective Wildlife Crossing Practices in Utah" 2014

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Table B-1. (Continued).

32	Percentage of wildlife collision hazard sites with crossing structures or other mitigation?	None	1-50%	50-75%	75-100%	Planners in New Mexico, with data from their Department of Game and Fish, used corridor studies to identify areas of high potential for animal-vehicle crashes. The studies led to the construction of underpasses that allow bear and deer to pass beneath highways
33	Identified crossings are monitored for wildlife use?	No locations	Few locations	Some locations	Many locations	Utah DOT: "Determining Wildlife Use of Wildlife Crossing Structures under Different Scenarios" 2012
34	After installation of wildlife crossing structures or barriers, there was a documented and maintained reduction in animal strikes at priority crossings?	Not monitored or no detectable reduction	Measurable but small reduction	Modest reduction	Substantial reduction	Ohio DOT: "Effectiveness of the TRU-88 Wildlife Roadway Crossing Culverts and Exclusion Fencing" 2014
35	Percentage of water crossings affected by DOT road construction or improvement projects within the last 5 years that were installed or retrofitted to improve biological/physical habitat continuity?	None	1-5%	6-25%	Greater than 25%	The Ohio Environmental Protection Agency has a Nationwide Permit certification condition that includes burying the bottom of culverts (greater than 36 inches) to allow for natural substrate

Question ID	Question	0 Points	1 Point	2 Points	3 Points	Examples of Best Practice
36	New methods for biological resource conservation and mitigation deployed in last 5 years?	No examples	Few examples	Some examples	Many examples	Ohio DOT: full delivery, in-lieu fee program, pooled sites, conservation areas, installation of bat houses
37	Average share of annual research budget allocated to ecosystem-focused research over the last 5 years?	None	Less than 0.5%	0.5-1.0%	More than 1%	Florida DOT: "Economic Impact of Ecosystem Services Provided by Ecologically Sustainable Roadside Right-of-Way Vegetation Management Practices, Final Report"
38	Invasive species monitoring and control efforts are implemented on projects?	Not done	As required on a project-specific basis	Frequently (i.e., more than half of projects)	Routinely (i.e., nearly all projects)	Georgia DOT includes invasive species control in every construction contract
39	Use of integrated pest management in operations and maintenance activities?	No	Rarely	Sometimes	Often or always	Ohio DOT standard operating procedure
40	Emphasize use of native seed mixes or native plants for revegetation?	Rarely or never	Some examples	Many examples	Statewide policy or guidance in place	Minnesota DOT: "Native Seed Mix Design for Roadsides" 2010
41	Percentage of DOT-owned land, excluding areas of long-term disturbance from roads and other permanent infrastructures, that is maintained as native vegetation? (Can be mowed or otherwise managed)	None	1-5%	6-25%	Greater than 25%	Oregon DOT maintains approximately 50,000 acres of property, of which around 50% is currently native vegetation, especially in the rural eastern part of the state

Table B-2. Final Ecosystems Self-Assessment Tool—question categorization.

Question ID	Question	DOT Functional Area	DOT Planning Level	Ecological Focus Area					
				Wetlands	*Aquatic, Streams*	*Wildlife Movement/ Corridors*	*Invasive Species*	*T&E/ Sensitive Species*	*Data and Research*
01	Construction guidance and manuals include specific biological resource conservation/mitigation practices?	Manuals	Policy	X	X	X		X	
02	Operations and maintenance guidance and manuals include specific biological resource conservation/mitigation practices?	Manuals	Policy	X	X	X		X	
03	Manuals and guidance include specific practices for minimizing impacts to biological resources from stormwater runoff?	Manuals	Policy	X	X				
04	Percentage of environmental staff and construction contractors receiving biological resource conservation/mitigation training?	Training	Policy	X	X	X		X	
05	Programmatic guidance and planning documents from state wildlife agencies (e.g., Wildlife Action Plans) are used in DOT projects and planning decisions?	Planning and Construction	Statewide Data/Strategy			X		X	
06	Culvert designs that mitigate impacts to aquatic species are used during new construction or retrofits?	Planning and Construction	Statewide Data/Strategy	X	X	X		X	
07	Inspections occur before and during construction to determine compliance with biological resource commitments?	Planning and Construction	Policy	X	X	X		X	

Question ID	Question	DOT Functional Area	DOT Planning Level	Ecological Focus Area					
				Wetlands	***Aquatic, Streams***	***Wildlife Movement/ Corridors***	***Invasive Species***	***T&E/ Sensitive Species***	***Data and Research***
08	Work periods are set to minimize disruption to fish and wildlife?	Planning and Construction	Policy		X	X		X	
09	Number of Memoranda of Agreement with state or federal resource agencies to improve biological resource impact analyses, mitigation, conservation actions?	Partnerships and Coordination	Policy	X	X	X		X	
10	Extent of asset management/data sharing related to biological resources?	Partnerships and Coordination	Statewide Data/Strategy						X
11	A system exists for planners, maintenance crews, and construction crews to communicate regarding environmental sensitivities? (e.g., restricted activity zone mapping, standardized data sheets)	Partnerships and Coordination	Project Implementation	X	X	X		X	
12	Conduct planning to reduce abundance, distribution, and/or dispersal of invasive species with partner agencies?	Partnerships and Coordination	Statewide Data/Strategy				X		
13	Stream and wetland mitigation planning conducted with partner agencies?	Partnerships and Coordination	Statewide Data/Strategy		X				
14	Threatened and endangered species mitigation planning conducted with partner agencies?	Partnerships and Coordination	Statewide Data/Strategy					X	
15	Wildlife corridor mitigation planning conducted with partner agencies at state level?	Partnerships and Coordination	Statewide Data/Strategy			X			

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Table B-2. (Continued).

16	System is in place to track biological resource commitments compliance?	Information Tracking	Statewide Data/Strategy	X	X	X		X	
17	Department mapping system is updated with threatened and endangered species occurrence and/or habitat information?	Information Tracking	Statewide Data/Strategy			X		X	
18	Department mapping system is updated with wetland information?	Information Tracking	Statewide Data/Strategy	X	X				
19	Elements of statewide ecological mapping incorporated in Long-Range Transportation Plan: -Regional conservation strategies (e.g., programmatic biological opinions, critical habitat designations, species recovery plans, regional habitat conservation plans) -Federal/state listed and rare species records -Mapping of priority waterways/streams -Public lands (e.g., parks, wildlife refuges) mapping -Wildlife corridors/crossings -Priority wildlife habitats -Wetlands	Long-Range Plan Coordination	Statewide Data/Strategy	X	X	X		X	
20	Statewide guidelines in place for noise/vibrations effects on aquatic life?	Noise Mitigation	Policy	X	X			X	

Question ID	Question	DOT Functional Area	DOT Planning Level	Ecological Focus Area					
				Wetlands	***Aquatic, Streams***	***Wildlife Movement/ Corridors***	***Invasive Species***	***T&E/ Sensitive Species***	***Data and Research***
21	Percentage of projects that quantitatively assessed the impacts of noise or vibration on adjacent wildlife habitats in the last 5 years?	Noise Mitigation	Project Implementation			X		X	
22	Percentage of projects that quantitatively assessed the impacts of noise or vibration on aquatic life in last 5 years?	Noise Mitigation	Project Implementation			X		X	
23	Functional assessments are used to determine wetland mitigation requirements?	Habitat Mitigation	Statewide Data/Strategy	X					
24	Duration of wetland and other mitigation site monitoring and maintenance activities extends beyond federal regulatory requirements?	Habitat Mitigation	Policy	X	X			X	
25	Average statewide ratio of streams mitigated per length of stream impact over the last 5 years?	Habitat Mitigation	Project Implementation		X				
26	Average statewide ratio of acres of wetlands mitigated per area of wetland impact over the last 5 years?	Habitat Mitigation	Project Implementation	X					
27	Conservation/mitigation banks have been proactively established in advance of foreseen impacts to streams and wetlands?	Habitat Mitigation	Project Implementation	X	X				

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Table B-2. (Continued).

28	Conservation/mitigation banks have been proactively established in advance of foreseen impacts to threatened and endangered species?	Habitat Mitigation	Project Implementation					X	
29	Proportion of sites meeting mitigation goal in time period determined in the mitigation and monitoring plan? **Note:** *For the purposes of this assessment, mitigation credits purchased from other entities may be assumed to have met mitigation goal*	Habitat Mitigation	Project Implementation	X	X			X	
30	Wildlife collision hazard sites are prioritized for mitigation?	Wildlife Movement Planning	Statewide Data/Strategy			X			
31	Statewide guidance or tool kit available to determine appropriate wildlife collision mitigation methods/structures?	Wildlife Movement Planning	Statewide Data/Strategy			X			
32	Percentage of wildlife collision hazard sites with crossing structures or other mitigation?	Wildlife Movement Planning	Project Implementation			X			
33	Identified crossings are monitored for wildlife use?	Wildlife Movement Planning	Project Implementation			X			
34	After installation of wildlife crossing structures or barriers, there was a documented and maintained reduction in animal strikes at priority crossings?	Wildlife Movement Planning	Project Implementation			X			

Question ID	Question	DOT Functional Area	DOT Planning Level	Ecological Focus Area					
				Wetlands	*Aquatic, Streams*	*Wildlife Movement/ Corridors*	*Invasive Species*	*T&E/ Sensitive Species*	*Data and Research*
35	Percentage of water crossings affected by DOT road construction or improvement projects within the last 5 years that were installed or retrofitted to improve biological/physical habitat continuity?	Wildlife Movement Planning	Project Implementation		X				
36	New methods for biological resource conservation and mitigation deployed in last 5 years?	Research and Communication	Statewide Data/Strategy						X
37	Average share of annual research budget allocated to ecosystem-focused research over the last 5 years?	Research and Communication	Statewide Data/Strategy	X	X	X	X	X	X
38	Invasive species monitoring and control efforts are implemented on projects?	Maintenance and Procurement	Project Implementation				X		
39	Use of integrated pest management in operations and maintenance activities?	Maintenance and Procurement	Project Implementation				X		
40	Emphasize use of native seed mixes or native plants for revegetation?	Maintenance and Procurement	Statewide Data/Strategy	X	X	X	X	X	
41	Percentage of DOT-owned land, excluding areas of long-term disturbance from roads and other permanent infrastructures, that is maintained as native vegetation? (Can be mowed or otherwise managed)	Maintenance and Procurement	Project Implementation			X			

Table B-3. Results of proof of concept testing for six pilot states by overall scores.

		Ecological Focus Area					
State	**Score Measures**	***General***	***Wetlands***	***Aquatic, Streams***	***Wildlife Movement/ Corridors***	***Invasive Species***	***T&E/ Sensitive Species***
Illinois	*Points Scored*	3	15	16	18	1	17
	Percentage Scored	21%	31%	29%	25%	7%	26%
	Score Category	needs improvement	needs improvement	needs improvement	needs improvement	needs improvement	needs improvement
Georgia	*Points Scored*	4	23	25	28	5	25
	Percentage Scored	29%	48%	45%	39%	36%	38%
	Score Category	needs improvement	good	good	good	good	good
Maryland	*Points Scored*	11	36	39	37	9	36
	Percentage Scored	79%	75%	70%	52%	64%	55%
	Score Category	outstanding	outstanding	outstanding	good	good	good
Ohio	*Points Scored*	12	33	38	40	7	40
	Percentage Scored	86%	69%	68%	56%	50%	62%
	Score Category	outstanding	outstanding	outstanding	good	good	good
Oregon	*Points Scored*	11	35	41	47	14	42
	Percentage Scored	79%	73%	73%	66%	100%	65%
	Score Category	outstanding	outstanding	outstanding	good	outstanding	good
Texas	*Points Scored*	8	13	13	22	1	23
	Percentage Scored	57%	27%	23%	31%	7%	35%
	Percentage of Questions Answered[1]	79%	94%	95%	97%	86%	100%
	Score Category	good	needs improvement	needs improvement	needs improvement	needs improvement	good
Totals	*Score Range*	3 - 12	13 - 36	13 - 41	18 - 47	1 - 14	17 - 42
	Mean Score	8.2	25.8	28.7	32.0	6.2	30.5
	Mean Percentage Scored	58%	54%	51%	45%	44%	47%
	Mean Score Category	good	good	good	good	good	good

[1] All other states completed all questions.

Note: The maximum possible points, both overall and within each category, vary from the current version of the ESAT because of revisions in questions and scoring.

APPENDIX C

States' Performance Data

Air Quality Data by State

Nitrogen Oxides Emissions (Tons per Year)

Year	CA	VT	WA	PA	VA	WY	SD	ND	NC	NJ	MO	MD	IL	FL	DE	CO
2005	714,712	22,935	255,658	279,829	209,649	31,361	27,397	24,133	248,307	161,692	183,778	129,530	269,780	471,765	21,762	127,526
2006	654,873	21,152	241,920	257,313	194,251	29,594	26,904	22,742	228,042	152,224	168,763	122,642	242,775	442,237	19,878	118,591
2007	609,501	19,155	227,552	237,824	181,234	27,338	24,374	21,104	213,917	142,294	153,699	114,172	225,901	413,975	18,476	109,939
2008	561,268	16,792	206,155	217,207	165,662	25,197	22,358	19,226	191,834	126,983	139,805	102,665	205,153	368,808	16,005	99,331
2009	497,180	15,371	188,020	186,708	144,770	22,291	19,447	17,663	171,687	111,822	124,471	91,373	180,917	325,919	14,365	84,446
2010	453,950	13,557	176,963	166,890	134,851	20,007	17,928	16,468	156,710	102,632	117,911	85,179	166,311	300,298	13,042	78,606
2011	415,170	12,329	164,130	152,621	122,530	18,339	16,696	16,656	146,002	94,268	105,347	78,719	149,505	271,901	12,183	72,385
Change 2005-11	-41.9%	-46.2%	-35.8%	-45.5%	-41.6%	-41.5%	-39.1%	-31.0%	-41.2%	-41.7%	-42.7%	-39.2%	-44.6%	-42.4%	-44.0%	-43.2%

Volatile Organic Compounds Emissions (Tons per Year)

Year	CA	VT	WA	PA	VA	WY	SD	ND	NC	NJ	MO	MD	IL	FL	DE	CO
2005	90,493	3,268	116,229	48,417	36,096	3,029	3,045	2,807	36,662	23,533	25,136	16,835	37,204	80,556	3,287	16,097
2006	82,533	3,011	110,568	43,824	32,911	2,858	2,997	2,652	33,661	21,567	22,513	16,072	34,049	72,810	2,915	14,690
2007	75,222	2,670	103,669	39,587	30,112	2,548	2,628	2,341	30,744	19,513	20,291	14,283	31,161	65,406	2,614	13,060
2008	69,558	2,317	94,947	35,773	27,543	2,342	2,374	2,123	27,371	17,110	18,025	12,565	28,469	57,051	2,225	11,581
2009	62,512	2,171	90,022	30,873	24,345	2,099	2,069	1,961	24,454	15,098	16,106	11,149	25,821	50,106	2,005	9,901
2010	57,271	1,905	85,339	27,606	22,827	1,909	1,903	1,834	22,412	13,825	15,211	10,402	24,223	45,846	1,815	9,274
2011	51,251	1,700	78,180	24,588	20,250	1,705	1,732	1,815	20,584	12,429	13,267	9,395	21,884	40,214	1,637	8,300
Change 2005-11	-43.4%	-48.0%	-32.7%	-49.2%	-43.9%	-43.7%	-43.1%	-35.3%	-43.9%	-47.2%	-47.2%	-44.2%	-41.2%	-50.1%	-50.2%	-48.4%

Fine Particulate Matter Emissions (Tons per Year)

Year	CA	VT	WA	PA	VA	WY	SD	ND	NC	NJ	MO	MD	IL	FL	DE	CO
2005	25,094	754	8,230	9,241	6,835	1,018	861	759	7,943	5,622	5,893	4,586	9,066	14,400	690	4,175
2006	23,454	708	7,846	8,633	6,414	971	857	726	7,404	5,370	5,484	4,271	8,261	13,567	641	3,912
2007	21,510	632	7,269	7,868	5,885	880	766	665	6,854	4,952	4,913	3,894	7,573	12,432	589	3,572
2008	19,633	555	6,587	7,209	5,401	812	704	608	6,168	4,431	4,472	3,499	6,892	11,016	516	3,237
2009	17,057	506	6,001	6,178	4,688	720	613	560	5,494	3,879	3,958	3,094	6,056	9,513	458	2,757
2010	15,909	456	5,727	5,630	4,447	658	577	533	5,117	3,639	3,813	2,936	5,684	8,868	423	2,613
2011	14,616	415	5,328	5,171	4,053	602	540	542	4,797	3,365	3,420	2,720	5,137	8,057	398	2,416
Change 2005-11	-41.8%	-44.9%	-35.3%	-44.0%	-40.7%	-40.8%	-37.3%	-28.7%	-39.6%	-40.2%	-42.0%	-40.7%	-43.3%	-44.1%	-42.3%	-42.1%

Energy Data by State

California

Caltrans Annual Fuel Use by Fuel Type (Gallons)

Fiscal Year (July-June)	Unleaded Gasoline	Diesel (ULSD)	Biodiesel (B5)	E85	LPG	CNG (GGE)	Total
2008-2009	7,688,847	4,407,558	1,214,042	197,859	35,492	114,561	13,658,359
2009-2010	6,737,860	1,945,943	3,314,060	197,810	31,991	123,566	12,351,230
2010-2011	7,191,462	3,005,892	3,223,614	179,129	29,534	140,657	13,770,288
2011-2012	6,725,111	2,810,836	2,218,246	153,834	29,178	138,209	12,075,414
2012-2013	6,678,560	2,229,866	3,343,720	108,402	21,429	152,622	12,534,599

Caltrans Alternative Fuel Percentage (Volume Basis)

Fiscal Year (July-June)	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2008-2009	13,279,424	378,935	2.8%
2009-2010	11,861,832	489,399	4.0%
2010-2011	13,286,657	483,631	3.5%
2011-2012	11,666,356	409,058	3.4%
2012-2013	12,101,220	433,379	3.5%

Caltrans Alternative Fuel Percentage (Energy Basis)

Fiscal Year (July-June)	Conventional Fuel (MU)	Alternative Fuel (MU)	Alternative Fuel Percentage
2008-2009	1,640,382,832	38,577,357	2.3%
2009-2010	1,467,675,907	52,606,887	3.5%
2010-2011	1,650,768,148	52,615,320	3.1%
2011-2012	1,441,729,031	44,190,699	3.0%
2012-2013	1,501,184,094	49,211,618	3.2%

Caltrans CO_2-Equivalent Emissions (Metric Tons)

Fiscal Year	Unleaded Gasoline	Diesel (ULSD)	Biodiesel (B5)	E85	LPG	CNG (GGE)	Total
2008-2009	66,101	46,117	11,988	601	260	906	125,972
2009-2010	57,925	20,361	32,724	601	234	977	112,821
2010-2011	61,825	31,451	31,831	544	216	1,112	126,979
2011-2012	57,816	29,410	21,903	467	213	1,093	110,903
2012-2013	57,415	23,331	33,017	329	157	1,207	115,456

Caltrans Composite Carbon Intensity (g CO_2e/MJ)

Fiscal Year	Carbon Intensity
2008-2009	72.7
2009-2010	72.0
2010-2011	72.4
2011-2012	72.4
2012-2013	72.3

Iowa

Iowa DOT Fuel Use by Fuel Type (Gallons)

Year	Gasoline	Diesel	Neat Methyl Esthers (for B20)	Total
2012	1,993,234	1,946,908	76,673	4,016,815
2013	1,991,352	2,139,273	66,816	4,197,442

Iowa DOT Alternative Fuel Percentage (Volume Basis)

Year	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2012	3,940,142	76,673	1.91%
2013	4,130,626	66,816	1.59%

Iowa DOT Alternative Fuel Percentage (Energy Basis)

Year	Conventional Fuel (MJ)	Alternative Fuel (MJ)	Alternative Fuel Percentage
2012	505,934,881	9,670,765	1.88%
2013	531,571,798	8,427,502	1.56%

Iowa DOT CO_2-Equivalent Emissions (Metric Tons)

Year	Gasoline	Diesel	Neat Methyl Esthers (for B20)	Total
2012	17,136	20,371	110	37,617
2013	17,120	22,384	96	39,599

Iowa DOT Composite Carbon Intensity (g CO_2e/MJ)

Year	Carbon Intensity
2012	73.0
2013	73.3

Maryland

Maryland DOT Annual Fuel Use by Type (Gallons)

Year	Gasoline	Diesel	B5	E85	CNG (GGE)	Total
2008	842,378	27,273	1,637,229	5,443	129	2,512,452
2009	772,950	462	1,685,263	8,502	202	2,467,379
2010	707,594	5,595	1,715,251	6,217	138	2,434,794
2011	711,812	13,261	1,621,120	4,739	54	2,350,985
2012	743,712	9,579	1,493,117	4,668	22	2,251,098
2013	763,161	28,740	1,302,454	10,447	0	2,104,802

Maryland DOT Alternative Fuel Percentage (Volume Basis)

Year	Conventional Fuel	Alternative Fuel	Alternative Fuel Percentage
2008	2,425,835	86,617	3.4%
2009	2,375,688	91,692	3.7%
2010	2,343,609	91,185	3.7%
2011	2,265,847	85,138	3.6%
2012	2,172,452	78,645	3.5%
2013	2,030,800	74,003	3.5%

Maryland DOT Alternative Fuel Percentage (Energy Basis)

Year	Conventional Fuel (MJ)	Alternative Fuel (MJ)	Alternative Fuel Percentage
2008	316,093,383	10,718,062	3.3%
2009	310,176,867	11,241,872	3.5%
2010	306,650,905	11,264,900	3.5%
2011	296,146,322	10,558,506	3.4%
2012	283,205,254	9,742,433	3.3%
2013	263,913,618	8,937,749	3.3%

Maryland DOT CO_2-Equivalent Emissions (Metric Tons)

Year	Gasoline	Diesel	B5	E85	CNG (GGE)	Total
2008	7,242	285	16,166	17	1	23,711
2009	6,645	5	16,641	26	2	23,318
2010	6,083	59	16,937	19	1	23,098
2011	6,119	139	16,007	14	0	22,280
2012	6,394	100	14,743	14	0	21,252
2013	6,561	301	12,861	32	0	19,754

Maryland DOT Composite Carbon Intensity (g CO_2e/MJ)

Year	Carbon Intensity
2008	72.6
2009	72.5
2010	72.7
2011	72.6
2012	72.5
2013	72.4

Minnesota

Minnesota DOT Annual Fuel Use by Fuel Type (Gallons)

Year	Gasoline	Diesel (B5)	E85	Biodiesel (B20)	Total
2002	1,581,511	2,007,853	29		3,589,393
2003	1,381,603	2,233,999	800		3,616,402
2004	1,451,481	2,158,977	319		3,610,778
2005	1,410,453	2,318,932	5,369		3,734,754
2006	1,444,447	2,006,782	18,150		3,469,379
2007	1,339,422	2,445,758	134,400	1,266	3,920,845
2008	1,204,243	2,563,495	238,194	9,487	4,015,418
2009	1,395,231	2,654,379	200,510	70,883	4,321,004
2010	1,270,475	2,794,558	406,068	183,653	4,654,754
2011	1,128,594	2,453,393	404,011	169,979	4,155,977
2012	1,258,717	2,186,104	431,466	284,261	4,160,548

Minnesota DOT Alternative Fuel Percentage (Volume Basis)

Year	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2002	3,549,212	40,181	1.1%
2003	3,571,042	45,360	1.3%
2004	3,567,327	43,451	1.2%
2005	3,614,244	120,510	3.2%
2006	3,353,613	115,767	3.3%
2007	3,684,065	236,781	6.0%
2008	3,682,881	332,537	8.3%
2009	4,003,675	317,330	7.3%
2010	4,133,137	521,616	11.2%
2011	3,655,902	500,075	12.0%
2012	3,627,645	532,903	12.8%

Minnesota DOT Alternative Fuel Percentage (Energy Basis)

Year	Conventional Fuel (MU)	Alternative Fuel (MU)	Alternative Fuel Percentage
2002	458,302,402	5,066,999	1.1%
2003	463,633,095	5,690,920	1.2%
2004	462,296,698	5,468,353	1.2%
2005	469,088,413	14,996,323	3.1%
2006	433,610,782	13,913,286	3.1%
2007	479,096,746	24,767,780	4.9%
2008	480,371,515	32,908,888	6.4%
2009	521,286,734	32,420,018	5.9%
2010	539,821,597	50,390,510	8.5%
2011	477,352,425	47,751,517	9.1%
2012	471,943,267	50,850,879	9.7%

Minnesota DOT CO_2-Equivalent Emissions (Metric Tons)

Year	Gasoline	Diesel (B2)	Diesel (B5)	Biodiesel (B20)	E85	Total
2002	13,596	20,535	0	0	0	34,131
2003	11,878	22,847	0	0	2	34,727
2004	12,478	22,080	0	0	1	34,560
2005	12,126	0	22,898	0	16	35,039
2006	12,418	0	19,815	0	55	32,288
2007	11,515	0	24,150	10	408	36,083
2008	10,353	0	25,312	77	724	36,466
2009	11,995	0	26,210	576	609	39,390
2010	10,922	0	27,594	1,493	1,234	41,242
2011	9,702	0	24,225	1,382	1,227	36,537
2012	10,821	0	21,586	2,310	1,311	36,028

Minnesota DOT Composite Carbon Intensity (g CO_2e/MJ)

Year	Carbon Intensity
2002	73.7
2003	74.0
2004	73.9
2005	72.4
2006	72.1
2007	71.6
2008	71.0
2009	71.1
2010	69.9
2011	69.6
2012	68.9

Missouri

Missouri DOT Annual Fuel Use by Fuel Type (Gallons)

Fiscal Year	Gasoline	Diesel	E85	B20	Total
2011-2012	2,061,007	1,590,929	35,500	1,450,225	5,137,661
2012-2013	1,728,978	2,236,380	18,720	1,296,090	5,280,168
2013-2014	1,812,875	3,177,631	16,475	1,128,735	6,135,716

Missouri DOT Alternative Fuel Percentage (Volume Basis)

Fiscal Year	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2011-2012	4,817,441	320,220	6.2%
2012-2013	5,005,038	275,130	5.2%
2013-2014	5,895,965	239,751	3.9%

Missouri DOT Alternative Fuel Percentage (Energy Basis)

Fiscal Year	Conventional Fuel (MJ)	Alternative Fuel (MJ)	Alternative Fuel Percentage
2011-2012	623,028,934	39,042,940	5.9%
2012-2013	652,265,829	33,992,153	5.0%
2013-2014	771,067,049	29,614,915	3.7%

Missouri DOT CO_2-Equivalent Emissions (Metric Tons)

Fiscal Year	Gasoline	Diesel	E85	B20	Total
2011-2012	17,718	16,646	108	11,787	46,260
2012-2013	14,864	23,400	57	10,535	48,855
2013-2014	15,585	33,248	50	9,174	58,058

Missouri DOT Composite Carbon Intensity (g CO_2e/MJ)

Fiscal Year	Carbon Intensity
2011-2012	69.9
2012-2013	71.2
2013-2014	72.5

North Carolina

North Carolina DOT Annual Fuel Use by Fuel Type (Gallons)

Fiscal Year	Gasoline	E85	Diesel	B20	CNG (GGE)	Propane	Total
2005-2006	3,585,464		6,028,016	1,542,194	1,450	15,647	11,172,771
2006-2007	3,768,705		6,290,322	1,867,056	953	16,491	11,943,527
2007-2008	3,801,701		5,181,019	3,033,955	384	8,473	12,025,532
2008-2009	3,380,383		737,362	6,572,243			10,689,988
2009-2010	3,418,403	4,440	1,064,797	7,048,310		5,060	11,541,010
2010-2011	3,534,254	13,206	1,281,640	7,213,635		5,813	12,048,548
2011-2012	3,571,256	31,301	1,375,819	6,365,372		4,998	11,348,746
2012-2013	4,443,695	42,658	1,908,702	6,230,866			12,625,921

North Carolina DOT Alternative Fuel Percentage (Volume Basis)

Fiscal Year	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2005-2006	10,847,235	325,536	2.9%
2006-2007	11,552,672	390,855	3.3%
2007-2008	11,409,884	615,648	5.1%
2008-2009	9,375,539	1,314,449	12.3%
2009-2010	10,122,514	1,418,496	12.3%
2010-2011	10,588,783	1,459,765	12.1%
2011-2012	10,044,068	1,304,678	11.5%
2012-2013	11,343,489	1,282,433	10.2%

North Carolina DOT Alternative Fuel Percentage (Energy Basis)

Fiscal Year	Conventional Fuel (MJ)	Alternative Fuel (MJ)	Alternative Fuel Percentage
2005-2006	1,415,643,146	40,483,378	2.8%
2006-2007	1,508,306,408	48,693,118	3.1%
2007-2008	1,488,710,158	77,340,991	4.9%
2008-2009	1,220,202,838	165,791,402	12.0%
2009-2010	1,320,184,723	178,561,799	11.9%
2010-2011	1,381,479,251	183,407,116	11.7%
2011-2012	1,307,755,264	163,189,473	11.1%
2012-2013	1,472,008,657	160,135,321	9.8%

North Carolina DOT CO_2-Equivalent Emissions (Metric Tons)

Fiscal Year	Gasoline	E85	Diesel	B20	CNG	Propane	Total
2005-2006	30,824	0	63,072	12,535	11	114	106,557
2006-2007	32,399	0	65,817	15,175	8	121	113,520
2007-2008	32,683	0	54,210	24,660	3	62	111,618
2008-2009	29,061	0	7,715	53,419	0	0	90,196
2009-2010	29,388	13	11,141	57,289	0	37	97,868
2010-2011	30,384	40	13,410	58,633	0	43	102,509
2011-2012	30,702	95	14,395	51,738	0	37	96,967
2012-2013	38,202	130	19,971	50,645	0	0	108,948

North Carolina DOT Composite Carbon Intensity (g CO_2e/MJ)

Fiscal Year	Carbon Intensity
2005-2006	73.2
2006-2007	72.9
2007-2008	71.3
2008-2009	65.1
2009-2010	65.3
2010-2011	65.5
2011-2012	65.9
2012-2013	66.8

Nebraska

Nebraska DOT Annual Fuel Use by Fuel Type (Gallons)

Fiscal Year	Gasoline	Diesel	E85	Total
2010-2011	292,701	1,799,971	7,096	2,099,768
2011-2012	276,412	1,590,931	8,596	1,875,939
2012-2013	282,948	1,710,653	8,648	2,002,249
2013-2014	291,382	1,599,107	8,320	1,898,809

Nebraska DOT Alternative Fuel Percentage (Volume Basis)

Fiscal Year	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2010-2011	2,093,736	6,032	0.29%
2011-2012	1,868,632	7,307	0.39%
2012-2013	1,994,898	7,351	0.37%
2013-2014	1,891,737	7,072	0.37%

Nebraska DOT Alternative Fuel Percentage (Energy Basis)

Fiscal Year	Conventional Fuel (MJ)	Alternative Fuel (MJ)	Alternative Fuel Percentage
2010-2011	278,022,908	491,636	0.18%
2011-2012	247,945,757	595,561	0.24%
2012-2013	264,846,269	599,164	0.23%
2013-2014	250,873,660	576,439	0.23%

Nebraska DOT CO_2-Equivalent Emissions (Metric Tons)

Fiscal Year	Gasoline	Diesel	E85	Total
2010-2011	2,516	18,833	22	21,371
2011-2012	2,376	16,646	26	19,049
2012-2013	2,432	17,899	26	20,358
2013-2014	2,505	16,732	25	19,262

Nebraska DOT Composite Carbon Intensity (g CO_2e/MJ)

Fiscal Year	Carbon Intensity
2010-2011	76.7
2011-2012	76.6
2012-2013	76.7
2013-2014	76.6

Pennsylvania

PennDOT Annual Fuel Use by Fuel Type (Gallons)

Fiscal Year (July-June)	Gasoline	B5 Diesel	B2 Diesel	Total
2008-2009	1,217,753	5,295,811	4,696,285	11,209,849
2009-2010	1,399,982	5,456,092	4,838,422	11,694,496
2010-2011	1,878,628	5,232,430	4,640,079	11,751,137
2011-2012	1,968,796	4,453,191	3,949,057	10,371,044
2012-2013	2,357,273	5,152,135	4,568,874	12,078,282

PennDOT Alternative Fuel Percentage (Volume Basis)

Fiscal Year (July-June)	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2008-2009	10,851,132	358,716	3.2%
2009-2010	11,324,923	369,573	3.2%
2010-2011	11,396,714	354,423	3.0%
2011-2012	10,069,404	301,641	2.9%
2012-2013	11,729,298	348,984	2.9%

PennDOT Alternative Fuel Percentage (Energy Basis)

Fiscal Year (July-June)	Conventional Fuel (MU)	Alternative Fuel (MU)	Alternative Fuel Percentage
2008-2009	1,444,552,660	45,244,880	3.0%
2009-2010	1,506,078,612	46,614,249	3.0%
2010-2011	1,509,994,115	44,703,382	2.9%
2011-2012	1,330,429,657	38,045,942	2.8%
2012-2013	1,548,978,386	44,017,380	2.8%

PennDOT CO_2-Equivalent Emissions (Metric Tons)

Fiscal Year	Gasoline	B5 Diesel	B2 Diesel	Total
2008-2009	10,469	52,292	48,030	110,790
2009-2010	12,036	53,875	49,483	115,393
2010-2011	16,150	51,666	47,455	115,271
2011-2012	16,926	43,972	40,388	101,285
2012-2013	20,265	50,873	46,727	117,865

PennDOT Composite Carbon Intensity (g CO_2e/MJ)

Fiscal Year	Carbon Intensity
2008-2009	74.4
2009-2010	74.3
2010-2011	74.1
2011-2012	74.0
2012-2013	74.0

Washington State

Washington State DOT Annual Fuel Use by Fuel Type (Gallons)

Year	Gasoline	Diesel	Biodiesel (B100)	Propane	Total
2011	1,425,222	1,934,717	356,790	7,566	3,724,295
2012	1,348,781	2,259,469	330,684	11,544	3,950,478

Washington State DOT Alternative Fuel Percentage (Volume Basis)

Fiscal Year (July-June)	Conventional Fuel (gal)	Alternative Fuel (gal)	Alternative Fuel Percentage
2011	3,359,939	364,356	9.8%
2012	3,608,250	342,228	8.7%

Washington State DOT Alternative Fuel Percentage (Energy Basis)

Fiscal Year (July-June)	Conventional Fuel (MU)	Alternative Fuel (MU)	Alternative Fuel Percentage
2011	434,724,629	45,680,041	9.5%
2012	469,031,441	42,743,814	8.4%

Washington State DOT CO_2-Equivalent Emissions (Metric Tons)

Year	Gasoline	Diesel	Biodiesel (B100)	Propane	Total
2011	12,253	20,243	512	55	33,064
2012	11,595	23,641	475	84	35,796

Washington State DOT Composite Carbon Intensity (g CO_2e/MJ)

Year	Carbon Intensity
2011	68.8
2012	69.9

Wyoming

Wyoming DOT Annual Fuel Use by Fuel Type (Gallons)

Year	Gasoline	Diesel	CNG (gge)	Total
2012	834,000	987,337	4,100	1,825,437

Wyoming DOT Alternative Fuel Percentage (Volume Basis)

Year	Conventional Fuel (gal)	Alternative Fuel (gal)	CNG (gge)	Alternative Fuel Percentage
2012	834,000	987,337	4,100	0.23%

Wyoming DOT Alternative Fuel Percentage (Energy Basis)

Year	Conventional Fuel (MU)	Alternative Fuel (MU)	Alternative Fuel Percentage
2012	234,916,722	502,174	0.2%

Wyoming DOT CO_2-Equivalent Emissions (Metric Tons)

Year	Gasoline	Diesel	CNG	Total
2012	7,170	10,331	32	17,533

Wyoming DOT Composite Carbon Intensity (g CO_2e/MJ)

Year	Carbon Intensity
2012	74.5

Change in Gasoline Use per Capita, 2005–2011 by State

Alabama	-5.1%	Montana	-2.4%
Alaska	-10.5%	Nebraska	-2.7%
Arizona	-16.3%	Nevada	-13.9%
Arkansas	-6.0%	New Hampshire	-0.8%
California	-13.1%	New Jersey	-5.6%
Colorado	-10.3%	New Mexico	-6.9%
Connecticut	-10.5%	New York	-4.8%
Delaware	-10.8%	North Carolina	-10.4%
District of Columbia	-23.1%	North Dakota	11.4%
Florida	-12.3%	Ohio	-5.6%
Georgia	-15.2%	Oklahoma	-8.2%
Hawaii	-4.6%	Oregon	-11.3%
Idaho	-1.2%	Pennsylvania	-4.5%
Illinois	-11.1%	Rhode Island	-6.7%
Indiana	-10.8%	South Carolina	-3.9%
Iowa	-0.6%	South Dakota	3.1%
Kansas	-5.6%	Tennessee	-4.3%
Kentucky	-5.5%	Texas	-6.6%
Louisiana	-0.7%	Utah	-8.7%
Maine	-8.0%	Vermont	-8.3%
Maryland	-5.1%	Virginia	-9.7%
Massachusetts	-4.8%	Washington	-10.1%
Michigan	-7.9%	West Virginia	-3.6%
Minnesota	-12.8%	Wisconsin	-4.9%
Mississippi	-3.8%	Wyoming	-8.2%
Missouri	-5.8%	United States Average	-8.2%

RAP Data by State

HMA = Hot Mix Asphalt **WMA = Warm Mix Asphalt**

Colorado DOT Annual RAP Use

Year	RAP Allowed/Total Mix	RAP Used/Allowed	RAP Used/Total Mix
2005	11%	3%	<0.5%
2006	6%	26%	1.6%
2007	10%	14%	1.4%
2008	10%	55%	5.4%
2009	12%	66%	8.3%
2010	17%	63%	10.7%
2011	17%	71%	11.8%
2012	17%	92%	15.7%

Delaware DOT Annual RAP Use

Year	Total Asphalt (tons)	RAP (tons)	Percentage of RAP
2003	880,695	92,612	10.5%
2004	897,982	97,838	10.9%
2005	884,708	91,512	10.3%
2006	969,356	108,590	11.2%
2007	724,544	77,729	10.7%
2008	1,080,963	171,080	15.8%
2009	793,634	142,540	18.0%
2010	651,660	142,798	21.9%
2011	732,748	146,193	20.0%
2012	932,600	202,416	21.7%
2013	572,620	128,729	22.5%

Florida DOT Annual RAP Use

Fiscal Year	Asphalt, all FL (tons)	FDOT Asphalt (tons)	FDOT RAP (tons)	Percentage of RAP (FDOT Projects)
2005/2006	20,977,552	5,724,071	833,672	14.6%
2006/2007	20,532,519	6,376,198	890,371	14.0%
2007/2008	17,423,741	6,219,199	807,374	13.0%
2008/2009	14,834,418	5,089,733	699,925	13.8%
2009/2010	13,737,570	4,891,638	684,969	14.0%
2010/2011	13,569,053	4,383,485	765,307	17.5%
2011/2012	12,653,603	4,641,854	834,772	18.0%
2012/2013	12,378,311	4,850,291	940,357	19.4%

Illinois DOT Annual RAP Use

Year	HMA (tons)	RAP (tons)	RAP used in HMA (tons)	RAP used as Aggregate (tons)	Percentage of RAP
2008	6,164,792	739,265	657,074	82,191	10.7%
2009	9,385,624	1,277,513	1,069,479	208,034	11.4%
2010	10,127,156	1,370,909	1,108,169	262,740	10.9%
2011	5,382,886	974,051	740,396	233,655	13.8%
2012	4,673,543	1,023,771	725,255	298,515	15.5%

Missouri DOT Annual RAP Use

Year	Total Asphalt	Tons of RAP	Percentage of RAP
2004	3,384,284	14,500	0.4%
2005	5,502,816	115,100	2.1%
2006	7,250,257	444,800	6.1%
2007	4,384,102	428,700	9.8%
2008	3,494,261	335,000	9.6%
2009	4,540,786	499,400	11.0%
2010	3,399,225	441,600	13.0%
2011	4,075,577	708,900	17.4%
2012	3,578,391	598,600	16.7%
2013	3,322,966	628,150	18.9%

New Jersey DOT Annual RAP Use

Year	HMA (tons)	RAP (tons)	Percentage of RAP
1992	1,561,913	188,808	12.1%
1993	2,128,916	156,815	7.4%
1994	2,018,739	135,299	6.7%
1995	1,706,307	136,369	8.0%
1996	2,321,791	171,512	7.4%
1997	2,500,301	175,657	7.0%
1998		no data	
1999		no data	
2000	1,190,785	88,657	7.4%
2001	1,046,038	60,678	5.8%
2002	1,262,237	63,008	5.0%
2003	1,595,376	104,647	6.6%
2004	1,218,636	136,258	11.2%
2005	1,490,833	135,426	9.1%
2006		no data	
2007	2,256,031	310,665	13.8%
2008	2,557,266	380,689	14.9%
2009	2,393,010	337,022	14.1%
2010	2,145,827	313,586	14.6%
2011	2,017,372	278,836	13.8%
2012	1,725,732	247,579	14.3%

North Carolina DOT Annual RAP Use

Fiscal Year (July-June)	Total Asphalt (tons)	RAP (tons)	RAS (tons)	Percentage of RAP
2011-2012	6,751,701	1,381,135	105,767	20.5%
2012-2013	6,651,695	1,449,226	119,779	21.8%

North Dakota DOT Annual RAP Use

Year	Tons of Hot Bituminous Pavement	Tons of RAP	Percentage of RAP
2011	1,895,000	100,000	5.3%
2012	2,035,000	310,000	15.2%
2013	3,500,000	590,000	16.9%

Pennsylvania DOT Annual RAP Use

Year	HMA (tons)	RAP (tons)	Percentage of RAP
2012	5,814,230	925,930	15.9%

South Dakota DOT Annual RAP Use

Year	# of Projects	Asphalt Concrete Quantity (tons)	RAP Quantity (tons)	Asphalt Binder Quantity (tons)	Percentage of RAP
2007	36	783,413	26,604	45,438	3.1%
2008	42	1,040,962	83,856	60,376	7.1%
2009	48	1,514,054	168,300	44,544	9.7%
2010	88	2,073,298	197,045	107,812	8.3%
2011	69	1,612,074	131,796	83,828	7.2%
2012	72	1,509,394	136,951	78,488	7.9%
2013*	53	1,015,375	88,255	52,800	7.6%

Utah DOT Annual RAP Use

Year	HMA (tons)	WMA (tons)	RAP (tons)	Percentage of RAP
2011	1,052,181	335,242	220,958	15.9%
2012	1,361,482	525,126	342,311	18.1%
2013*	1,276,752	173,524	172,123	11.9%

* Note: 2013 only includes information through September, although the bulk of pavement projects were completed for the year.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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