Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments

September 26, 2011

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Acknowledgements

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Outline

Summary of recent work performed under NCHRP 25-25

Task 65: Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments.

• Learn about greenhouse gas (GHG) accounting basics
• Learn to identify emission sources relevant to state DOTs
• Develop knowledge of methods for completing GHG emission estimates
• Develop approaches for obtaining or approximating data
• Learn about other research, resources, and materials available to state DOTs to help them complete operational GHG inventories

Task 76: Synthesis of Climate Change and Transportation Research Efforts at State DOTs, State Universities, and the Federal Level.
GREENHOUSE GAS EMISSION INVENTORY METHODOLOGIES FOR STATE TRANSPORTATION DEPARTMENTS

Requested By:
American Association of State Highway and Transportation Officials (AASHTO)

Standing Committee on the Environment

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SPECIAL NOTE: This report is NOT an official publication of the National Cooperative Highway Research Program, Transportation Research Board, National Research Council, or the National Academies.
Task 65 Objective

Increasingly State DOTs, as part of state governments, are performing GHG emission inventories of their operations.

The Task 65 report, *Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments* provides GHG accounting procedures to:

1. Help state DOTs prepare a GHG emission inventory of their daily operations, or daily activities associated with running a state DOT as a governmental body, and

2. Increase GHG accounting consistency across state DOT inventories.
Greenhouse Gas Accounting Basics

A GHG emission inventory is the first step in accounting for, monitoring, and reducing GHG emissions.
Why prepare a GHG emission inventory?

A GHG inventory allows you to:

• Define, categorize, and quantify GHG emissions
• Develop informed strategies to manage and reduce GHG emissions
• Set achievable goals and targets for reducing emissions
• Track progress towards meeting goals
• Build support and empower staff
• Educate the public through informed leadership
• Plan long-term approaches to operational management in a carbon-constrained world
What is an Inventory: Elements of GHG Inventory

- **GHGs**: International guidelines require including six GHG emissions in a GHG emission inventory: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

- **Emission Sources**: The sources or activities that produce GHG emissions that are to be included in the GHG emission inventory.

- **Inventory Boundaries**: define the structure of the state DOT for the purposes of conducting the current and future GHG emission inventories.

- **Inventory Baseline Year**: Year against which all future GHG emission inventories will be compared.
A Note on the Inventory Baseline Year…

- Earliest relevant point in time for which DOT has complete and accurate data
- Representative of the general level of emissions over a surrounding period
- May be mandated externally through state or regional reporting requirements.

Calendar Year or Fiscal Year Reporting

The State DOT GHG Guidelines recommend that State DOTs choose a single baseline year using the earliest year for which the state DOT has relatively complete and reliable data. Where possible, these Guidelines recommend using calendar year 2010 as the baseline inventory year.
Additional Elements of GHG Inventory

- **Inventory Methods:** specify the approaches and calculations that should be used to estimate GHG emissions for emission sources included in the GHG inventory.

- **Activity Data:** data specified by the inventory methods that are needed to complete the emission estimates.

- **Inventory Reporting:** ensures that the inventory results are structured for the inventory audience.

- **Inventory Principles:** ensure that the inventory is of the highest quality possible, and that those factors that limit inventory quality are addressed.
A Note on Inventory Principles…

Five principles of GHG accounting ensure a high-quality emission inventory¹

1. **Relevance**: Include *all relevant emission sources* that reflect the emissions impact of a state DOT

2. **Completeness**: Include all GHG emission sources that are *within defined organizational and operational boundaries*.

3. **Consistency**: Use *consistent methodologies* to estimate emissions to enable a meaningful comparison of inventories over time

4. **Transparency**: *Disclose* all relevant assumptions, data sources, and calculation methodologies

5. **Accuracy**: Ensure that GHG emission estimates are *neither systematically underestimated nor overestimated*

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Identifying Emission Sources Relevant to State DOTs

GHG emission sources constitute the GHG emission inventory. Proper selection ensures an accurate portrayal of your state DOT’s emissions.
How to define you inventory boundaries

Boundaries establish the framework for structuring a GHG emission inventory and are used to determine the emission sources that should be included.

- **Organizational boundaries** define the operations, facilities, and sources that are to be included in a GHG emission inventory

- **Operational boundaries** categorize the emissions associated with the operations, facilities, and sources as resulting either directly or indirectly from the DOT’s activities
Organizational boundaries should follow your State DOT’s organizational structure

Typical DOT Structure

• Departments of planning (long-term),

• Project delivery (including construction, design, engineering, and environmental analysis)

• Operations and maintenance (including maintenance, equipment, and traffic operations)

• In addition, the majority of states are divided into 5 to 15 district or regional offices, each of which covers one or several counties.

Organizational boundaries are drawn using either an operational control approach or a financial control approach.

• The Public Sector Standard and Federal GHG Guidance encourage all agencies to use the operational control approach

It is good practice for state DOTs to adopt an operational control approach to set organizational boundaries for their GHG inventory, whereby state DOTs report emissions from sources for which the DOT holds an operating license.
The Operational Control approach is recommended for state DOTs to set organizational boundaries

- Includes all operations over which the DOT has the authority to introduce and implement operating policies—including facilities that are not owned, but for which the DOT maintains a capital, financial, or operating lease.²

² This includes facilities that are wholly owned, partially owned with financial and operational control, partially owned with operational control and no financial control, joint financial control with operational control, associated entity with operational control, and facilities not owned but with a capital, financial, or operating lease.
*Operational* boundaries categorize emissions as resulting either directly or indirectly from DOT activities.

Relevant DOT Activities to Include in an Inventory:

- Design, construction, operation, and maintenance of state highway system;
- Development of long-range, intermodal plans for statewide transportation;
- Promotion of transportation safety; management and reduction of the environmental impacts of transportation; and
- Coordination with local or regional transportation authorities

- **Direct** emissions are those that are emitted by sources owned or controlled by the DOT (e.g., fuel consumed in DOT-owned vehicles).

- **Indirect** emissions are those that are emitted by sources owned or controlled by another organization but result from the activities of the DOT (e.g., purchased electricity).
Defining a GHG Inventory Boundary: Operational Boundaries

- Direct and indirect emissions are further categorized into scopes
  - Scope 1 – direct emissions
  - Scope 2 – indirect emissions from purchased electricity and steam
  - Scope 3 – all other indirect emissions
Defining Operational Boundaries: Scopes

SCOPE 1
GHGs from sources owned or controlled by the DOT.

SCOPE 2
GHGs from electricity purchased by the DOT.

SCOPE 3
GHGs from the activities of the DOT that occur at sources owned or controlled by another organization.
# Emission Sources Relevant to State DOTs: Scope 1

<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Description</th>
<th>Data Source</th>
<th>Location of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stationary Fossil Fuel Combustion</strong></td>
<td>Emissions from fossil fuel combustion in stationary equipment for which DOTs pay energy bills</td>
<td>Individual equipment meters, Fuel purchase records, Fuel receipts</td>
<td>Accounts Payable, Dept. Records, Facility Engineers, Fuel Vendors or Suppliers, Utility Providers</td>
</tr>
<tr>
<td><strong>Mobile Fossil Fuel Consumption</strong></td>
<td>Emissions from fossil fuel combustion in vehicles and equipment for which DOTs purchase fuel</td>
<td>Fuel purchase receipts, mileage reimbursement records, Maintenance records</td>
<td>Accounts Payable, Dept. Records, Fleet Manager, Fuel Tracking System, Fuel Vendors or Suppliers, Contractor Records</td>
</tr>
<tr>
<td><strong>Refrigerants and Fluorinated GHGs</strong></td>
<td>Flourinated GHG emission primarily from the use of refrigerants in climate control systems and equipment</td>
<td>Purchase Records, Maintenance Records</td>
<td>Facility Managers, Contractor in charge of Maintaining Equipment, Accounts Payable</td>
</tr>
<tr>
<td><strong>On-Site Wastewater Treatment</strong></td>
<td>Emissions from decomposition of organics in wastewater treated within DOTs organizational boundaries</td>
<td>Personal records, Inventory of Septic Systems, water testing</td>
<td>Human Resources, Asset Management Database, Environmental Compliance Manager</td>
</tr>
</tbody>
</table>
## Emission Sources Relevant to State DOTs: Scope 2

<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Description</th>
<th>Data Source</th>
<th>Location of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased Electricity</td>
<td>Emissions from purchased electricity for which DOT pays the utility bills</td>
<td>Electricity Meters, Utility Bills</td>
<td>Accounts Payable, Energy Office, Facility Managers, Utility Providers</td>
</tr>
<tr>
<td>Purchased Steam, Hot Water, and Chilled Water</td>
<td>Emissions from steam, water, or chilled water purchased by DOT from a provider</td>
<td>Metered energy use records, Utility/supplier energy bills</td>
<td>Accounts Payable, Utility or Supplier Records, Energy Provider, Federal GHG Guidance</td>
</tr>
</tbody>
</table>
Emission Sources Relevant to State DOTs: Scope 3

Reasons to include scope 3 sources:

• Often a significant source of emissions for an organization
• Often have significant GHG reduction potential
• Inclusion is often encouraged by state mandates or regional reporting programs
• Present an opportunity to engage suppliers and enable supply chain GHG management

The recently released Federal Greenhouse Gas Accounting and Reporting Guidance requires that Federal agencies include select scope 3 emission sources in their GHG inventories.
There are Many Scope 3 Emission Sources: How to prioritize what to include

Under Task 65, Scope 3 sources were prioritized using an Evaluation Approach:

1. Establish a list of evaluation criteria:
   - Magnitude of emissions,
   - Level of effort (LOE) required to estimate emissions,
   - GHG mitigation potential,
   - Importance to stakeholders, and
   - Consistency with other inventories and programs

2. Assign weights to each criterion based on relative importance

3. Rank the evaluation criteria for each scope 3 emission source

4. Prioritize including the sources with the highest scores
# Recommended Scope 3 Sources to include in State DOT Inventories

<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Description</th>
<th>Data Source</th>
<th>Location of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vendor and Contractor Emissions</strong></td>
<td>Emissions from the operations of a state DOT's vendors and contractors including the contractor's scope 1 and 2 emissions attributable to state DOT. Emissions from the operations of a state DOT's vendors and contractors including the contractor's scope 1 and 2 emissions attributable to state DOT.</td>
<td>Construction and maintenance contracts</td>
<td>Accounts payable, Contract records</td>
</tr>
<tr>
<td><strong>Contracted Solid Waste</strong></td>
<td>Emissions from decomposition of waste in municipal landfills. Emissions from decomposition of waste in municipal landfills. Emissions from decomposition of waste in municipal landfills.</td>
<td>Waste Manager</td>
<td>Human Resources</td>
</tr>
<tr>
<td><strong>T&amp;D of Purchased Electricity</strong></td>
<td>Energy losses associated with the transmission and distribution of electricity. Energy losses associated with the transmission and distribution of electricity. Energy losses associated with the transmission and distribution of electricity.</td>
<td>Electricity Meters, Utility Bills</td>
<td>Accounts payable, Energy Office, Facility Managers, Utility Providers</td>
</tr>
<tr>
<td><strong>Employee Commuting</strong></td>
<td>Emissions from fossil fuel combustion resulting from employees commuting to and from work. Emissions from fossil fuel combustion resulting from employees commuting to and from work.</td>
<td>Employee commuter survey, personnel records, parking permits, regional/national transportation surveys</td>
<td>Human Resources, MPO or Regional Transportation Organization, Census Bureau</td>
</tr>
<tr>
<td><strong>Employee Business Travel</strong></td>
<td>Emissions from fossil fuel combustion in vehicles rented by DOT employees for business travel and business air travel. Emissions from fossil fuel combustion in vehicles rented by DOT employees for business travel and business air travel.</td>
<td>Travel reimbursements forms, rental agency forms, employee receipts, state DOT travel agencies records, expense forms</td>
<td>Car rental agencies, travel agencies, Default average factor 419 miles traveled per rental; Travel Agency Budget Office</td>
</tr>
</tbody>
</table>
A note on vendor and contractor emissions

- Emissions from the operations of a state DOT’s vendors and contractors…
  - Include scope 1 and 2 emissions from the state DOT’s Tier 1 suppliers—those with whom the state DOT has purchased goods or services.
  - Exclude Tier 2 suppliers—those with whom the Tier 1 supplier has purchased goods or services.

- Considerations for when to include vendor and contractor emissions
  - Is the contracted service a service that is normally provided by state DOTs, and therefore included in other state DOT GHG inventories?
  - Was the contracted service previously provided by the state DOT and would thus be included in previous GHG emission inventories?
  - Does the state DOT exert significant influence over the contractor’s emission sources?
Methods for estimating GHG emissions

The quality of an inventory depends on the quality of the data and methods used to produce it.
Overall approach for estimating GHG emissions

Emissions are estimated using activity data, emission factors and global warming potentials (GWPs).

\[
\text{GHG Emissions} = \text{Activity Data} \times \text{Emission Factor} \times \text{GWP}
\]

- **Activity Data**
  - a measurement of the activities that generate GHG emissions

- **Emission Factors**
  - ratios of the GHGs emitted per unit of activity data
  - i.e., metric tons of \( \text{CO}_2 \) emitted per kilowatt hour of generated electricity

- **Global Warming Potential**
  - a factor that describes the atmospheric heat-trapping impact of one mass unit of a GHG relative to one mass unit of \( \text{CO}_2 \)
Calculation steps to estimate GHG emissions

- **Step 1.** Determine the needed activity data (e.g., fuel consumption) for each emission source

- **Step 2.** Collect the activity data

- **Step 3.** Select appropriate emission factors based on the activity data

- **Step 4.** Calculate GHG emissions by gas (i.e., CO$_2$, CH$_4$, N$_2$O, HFCs, PFCs, and SF$_6$) by multiplying activity data by the appropriate emission factors

- **Step 5.** Convert emissions to metric tons CO$_2$-equivalent (MTCO$_2$e) using each GHG’s GWP and sum to obtain total emissions
The Guidelines specify data needs by source…

The *Identifying and Calculating GHG Emissions* section of the State DOT GHG Guidelines specify the data needs, where to get the data, what methods to use, and where the methods originate by emission source.

**Example: Scope 1 ➔ Stationary Combustion Activity Data**

<table>
<thead>
<tr>
<th>Activity Data Description</th>
<th>Data Sources</th>
<th>Location of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility Fuel Use: Amount of fossil fuel, such natural gas, fuel oil, coal, etc., in physical units (e.g., gallons or cubic feet) combusted on-site stationary equipment such as generators</td>
<td>Individual equipment meters</td>
<td>Accounts Payable</td>
</tr>
<tr>
<td></td>
<td>Fuel purchase records</td>
<td>Department records</td>
</tr>
<tr>
<td></td>
<td>Fuel receipts</td>
<td>Facility Engineers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fuel Vendors or Suppliers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Utility Providers</td>
</tr>
</tbody>
</table>

**Example: Scope 1 ➔ Stationary combustion Emission Factors**

<table>
<thead>
<tr>
<th>Description</th>
<th>Type of Emission Factor</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Emission Factors: Unique to each type of fuel (Metric tons CO₂/Unit of fuel use)</td>
<td>Default national emissions factors</td>
<td>LGO Protocol Appendix G.1; Appendix A of this memo for converted emission factors in units of activity data</td>
</tr>
<tr>
<td>CH₄ and N₂O Emission Factors: Unique to each type of fuel (metric tons CH₄ or N₂О/unit of fuel use)</td>
<td>Default national emissions factors; varies by type of technology, combustion characteristics, and other factors</td>
<td>LGO Protocol Appendix G.1</td>
</tr>
</tbody>
</table>
Approaches for obtaining or approximating data

The *Identifying and Calculating GHG Emissions* section of the State DOT GHG Guidelines also provides methods for approximating activity data when measured data is unavailable.

### Example: Proxy Data → Stationary Fuel Consumption

<table>
<thead>
<tr>
<th>Proxy Data Source</th>
<th>Alternative Activity Data</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method 1: Proxy Year Data</strong></td>
<td>Alternate year’s fuel consumption by type of fuel</td>
<td>Equipment meters, Fuel purchase records, Fuel receipts</td>
</tr>
<tr>
<td></td>
<td>Percentage of fuel used for heating and cooling</td>
<td>Facility manager, Department Records</td>
</tr>
<tr>
<td></td>
<td>Heating and cooling degree days in proxy and inventory year</td>
<td>NOAA</td>
</tr>
<tr>
<td><strong>Method 2: Proxy Building Data</strong></td>
<td>Square footage of building</td>
<td>Facility manager</td>
</tr>
<tr>
<td></td>
<td>Energy use of buildings with comparable size</td>
<td>Equipment meters, Fuel purchase records, Fuel receipts, EIA’s Commercial Building Energy Consumption Survey (Consumption and Expenditures Tables, C1-C38)</td>
</tr>
<tr>
<td></td>
<td>Energy use per square foot of comparable buildings</td>
<td>Calculation</td>
</tr>
</tbody>
</table>
The Guidelines reference GHG protocols...

<table>
<thead>
<tr>
<th>Guidance Document</th>
<th>Target Audience</th>
<th>Type</th>
<th>Scope 3 Reporting?</th>
<th>Organization of Emission Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRI/WBCSD Corporate Standard</td>
<td>Corporations</td>
<td>Protocol</td>
<td>Optional</td>
<td>Scope</td>
</tr>
<tr>
<td>WRI Public Sector Standard</td>
<td>U.S. Public Sector</td>
<td>Protocol</td>
<td>Optional</td>
<td>Scope</td>
</tr>
<tr>
<td>Local Government Operations Protocol</td>
<td>Local government,</td>
<td>Combined Protocol and</td>
<td>Optional</td>
<td>Scope and Sector</td>
</tr>
<tr>
<td></td>
<td>municipalities</td>
<td>Methodology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Climate Registry General Reporting</td>
<td>North American</td>
<td>Combined Protocol and</td>
<td>Optional</td>
<td>Scope</td>
</tr>
<tr>
<td>Protocol</td>
<td>organizations</td>
<td>Methodology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>California Climate Action Registry</td>
<td>California organizations</td>
<td>Combined Protocol and</td>
<td>Optional</td>
<td>Scope</td>
</tr>
<tr>
<td>General Reporting Protocol</td>
<td>(implications for other</td>
<td>Methodology</td>
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<td></td>
<td>states as well)</td>
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<tr>
<td>Federal GHG Guidance</td>
<td>Federal Agencies</td>
<td>Methodology</td>
<td>Required</td>
<td>Scope</td>
</tr>
<tr>
<td>IPCC Guidelines for National Inventories</td>
<td>Nations</td>
<td>Methodology</td>
<td>NA</td>
<td>Sector</td>
</tr>
<tr>
<td>U.S. EPA Inventory of U.S. GHG Emissions</td>
<td>Nations</td>
<td>Methodology</td>
<td>NA</td>
<td>Sector</td>
</tr>
</tbody>
</table>

Other research, resources, and materials available to state DOTs to complete operational GHG inventories

Good management begins with good measurement
GHG Inventory Approach

- There are three possible approaches for a state DOT to prepare a GHG emission inventory
  - Centralized Approach: Top-down
  - Decentralized Approach: Bottom-up
  - Hybrid Approach

The most appropriate GHG inventory approach for a state DOT will depend on the current data management systems the state DOT has in place, the ability of those systems to inform the GHG inventory, the resources available to modify or supplement those systems, and the staff time available to support the inventory at all levels of the DOT.
GHG Inventory Approach: Centralized

- Centralized control of data analysis
- Ability to roll out department- or portfolio-wide best practices and mitigation actions
- Limited buy-in at the facility level
GHG Inventory Approach: Decentralized

- Potential for reduced inventory transparency
- Limits department-wide analysis
- GHG inventory and mitigation actions are prepared at the site-level, which increases buy-in, relevance, and ownership
GHG Inventory Approach: Hybrid

- Centralized control of data analysis
- Ability to roll out department- or portfolio-wide best practices and mitigation actions
- Inventory information rolls down to the site-level increasing understanding, which demonstrates relevance and encourages ownership
Determining the best approach for your DOT

- The type of approach that is most appropriate for your DOT will, in part, depend on the systems you have in place.

- The approach you select will also help to determine the type of GHG accounting tool or system you need.

- A state DOT will have many requirements when selecting a GHG accounting tool. These needs should be compared against costs and feasibility to determine a state DOT’s best fit for GHG management.

- Common considerations when selecting a GHG accounting tool are:
  - System Compatibility and Integration, Dashboard Capabilities, Data Resolution, Analytics and Planning Capabilities, GHG Reporting Requirements

- The general types of tools available include
  - Internal systems and tools, publicly available tools, and commercially available tools
Selecting the tools and resources to help you: Internal Tools

- **Internal Tools** – Many state DOTs already have existing systems in place to manage their energy or financial information. In some cases, these systems can be modified to include the factors needed to estimate GHG emissions from some emission sources. In other cases, state DOTs may choose to develop their own calculators or tools.

Based on a survey of state DOTs conducted in October 2010, state DOTs are using the following data collection systems for tracking utility data:

- Microsoft Excel- or Access-based system (15%)
- Database Management Software (20%)
- Varies (20%)
- Do Not Track Data (10%)
- Other (35%)
Selecting the tools and resources to help you: Publicly Available Tools

- **Publicly Available Tools** – Several non-profits and government agencies have developed GHG accounting tools that are freely available to the public. These tools are often designed to accommodate specific agencies, industries, or organizations, but with an understanding of their capabilities, structure, and purpose can be used by state DOTs.

  - **Federal Energy Management Program (FEMP) GHG and Sustainability Workbook**: Excel-based calculator released by FEMP to help federal agencies prepare GHG emission in response to Executive Order 13514.

  - **Greenhouse Gas Calculator for State Departments of Transportation (GreenDOT)**: GreenDOT is a spreadsheet-based calculator tool, available through NCHRP that calculates CO₂ emissions from the operations, construction, and maintenance activities of state DOTs.

  - **World Resources Institute Greenhouse Gas Protocol Initiative Cross Sector Tools**: The WRI provides several GHG accounting tools that support their GHG inventory protocols. These GHG accounting tools are simple Excel-based tools and are both sector specific (e.g., cement industry) as well as cross-sectoral (e.g., mobile combustion).

  - **CARROT**: The Climate Action Registry Reporting Online Tool (CARROT) is the California Registry’s GHG accounting tool and reporting software. CARROT follows the Climate Action Registry’s protocols and comes pre-loaded with GHG emission factors and calculations.
Selecting the tools and resources to help you: Commercially Available Tools

- **Commercially Available Tools** – many firms and software companies sell GHG accounting tools. These commercially-available options vary in costs, features, and capabilities, but typically offer a more robust suite of applications than publicly available tools.
There are also transportation-specific tools

These tools may assist state DOTs in developing tailored GHG emission factors or conversion factors and may also support state DOTs as they consider GHG mitigation opportunities.

- **EPA’s Motor Vehicle Emissions Simulator (MOVES) 2010**: An emissions model that can be used for, including emissions inventories of different geographic scales, as well as the modeling of a specific roadway segment. The primary application of MOVES is calculation of specific emission factors (including GHG emissions) by mile for different vehicle and fuel combinations.

- **EPA’s NONROAD Model**: The NONROAD model estimates emissions of CO2 from more than 80 basic types of off-road equipment including recreational vehicles, logging equipment, agricultural equipment, construction equipment, industrial equipment, and lawn and garden equipment.

- **The Pavement Lifecycle Assessment Tool for Environmental and Economic Effects (PaLATE)**: PaLATE is a spreadsheet tool designed for life-cycle assessment (LCA) of environmental and economic effects of pavements and roads. PaLATE is setup to calculate emissions associated with construction and maintenance of roadways including extraction, processing, and transportation of raw materials and the use of some equipment on the construction site.

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7 [http://www.epa.gov/otaq/models/moves/index.htm](http://www.epa.gov/otaq/models/moves/index.htm)
8 [http://www.epa.gov/otaq/nonrdmdl.htm](http://www.epa.gov/otaq/nonrdmdl.htm)
9 [http://www.ce.berkeley.edu/~horvath/palate.html](http://www.ce.berkeley.edu/~horvath/palate.html)
How to ensure a high-quality inventory.

- GHG emission estimates, by the nature of being emission *estimates* and not *measured* data, are inaccurate to a certain degree. The accuracy of an emission estimate is determined by the quality of the data used to produce it.

- *Quality control* is a system of routine technical activities to measure and control the quality of the inventory as it is being developed. These QC activities include:
  
  - Performing consistent checks to ensure data integrity, correctness, and completeness,
  
  - Identifying and addressing errors and omissions, and
  
  - Documenting and archiving inventory material including inventory methods, roles and responsibilities, and data sources in an Inventory Management Plan.
How to ensure a high-quality inventory.

- **Quality assurance** consists of a series of procedures performed after completing an inventory to ensure that the inventory receives a thorough review and that it adheres to the GHG accounting principles of relevance, completeness, consistency, transparency, and accuracy.
  
  • Address quality assurance in an Inventory Management Plan
  
  • Address uncertainty

- Decide on the level of review required
  
  • Conduct *internal* verification through a second party not affiliated with the inventory
  
  • Conduct *external* verification by a party outside the agency that is not affiliated with the inventory
Reporting GHG Emissions

- Many organizations voluntarily report their GHG emissions to GHG registries. Recently, other organizations and facilities are being required, either by the US EPA or state governments, to report their GHG emissions directly to the state or federal government.

- Unless required to report as part of state government requirements, state DOTs are not required to report their GHG emissions.

- GHG Reporting Programs include
  - EPA’s Greenhouse Gas Reporting Program
  - California Air Resources Board (CARB) California Global Warming Solutions Act
  - The Climate Registry
  - Regional Greenhouse Gas Initiative (RGGI)
  - Western Climate Initiative (WCI)
  - Midwest Regional Greenhouse Gas Reduction Accord
  - EPA’s State Climate and Energy Program
Summary Recommendations

Recommendations presented in the following section are intended to simplify state DOT’s decision-making when preparing a GHG inventory and to increase consistency across state DOT GHG inventories.
Summary of Recommendations

- It is good practice for state DOTs to apply the five principles of GHG accounting when preparing a GHG emission inventory. These are relevance, consistency, completeness, transparency, and accuracy.

- It is good practice for state DOTs to choose a single baseline year using the earliest year for which the state DOT has relatively complete and reliable data. Where possible and for consistency, it is recommended that state DOTs use calendar year 2010 as the baseline inventory year.

- It is good practice for state DOTs to adopt an operational control approach to set organizational boundaries for their GHG inventory, whereby state DOTs report emissions from sources for which the DOT holds an operating license.

- It is good practice for state DOTs to include GHGs associated with space they lease in their GHG emission inventories.
Summary of Recommendations

- It is good practice for state DOTs to include all scope 1 (direct) and scope 2 (indirect) emission sources in their GHG emission inventory.

- It is good practice for state DOTs to consider including the following 5 scope 3 emission sources in their inventory: Vendor and Contractor Emissions, Contracted Solid Waste, Transmission and Distribution Losses, Employee Commuting, and Business Travel.

- It is good practice for state DOTs to include procedures for continual improvement and refinement in their GHG inventory and recognize that finer detailed data will improve the state DOTs ability to make informed GHG management decisions.

- It is good practice for state DOTs to put Quality Assurance and Quality Control procedures in place to ensure that the inventory receives a thorough review and that it adheres to the GHG accounting principles.
Task 76: Synthesis of Climate Change and Transportation Research Efforts at State DOTs, State Universities, and the Federal Level
Task 76 Objective

- Provides a synthesis of climate change and transportation research efforts at state DOTs, state universities, and the Federal government

- Supplements *Special Report 299: A Transportation Research Program for Mitigating and Adapting to Climate Change and Conserving Energy (SR 299)* by providing an overview of state DOT and university-led research efforts related to climate change and transportation in recent years.

- Provides an update on federal research initiatives conducted since the release of *SR 299* in October of 2009.
Mitigation Research Categories

1. Measuring or estimating GHG emissions from transportation;
2. Vehicle technology,
3. Fuel technology;
4. Construction, maintenance, and operations;
5. Land use, planning and multimodal transportation;
6. Regulatory instruments and pricing strategies; and
7. Vehicle/highway system operations.

<table>
<thead>
<tr>
<th>Mitigation Topic</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring or estimating GHG</td>
<td>Research that quantifies emissions of CO$_2$, CH$_4$, or N$_2$O from</td>
<td>Emissions models; vehicle performance testing</td>
</tr>
<tr>
<td>Estimating GHG Emissions from</td>
<td>transportation</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Technology</td>
<td>Strategies that reduce the fuel consumption of internal combustion</td>
<td>Fuel efficiency improvements, hybrid internal</td>
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<td></td>
<td>engine gasoline or diesel vehicles</td>
<td>combustion engine technologies</td>
</tr>
<tr>
<td>Fuel Technology</td>
<td>Initiatives that involve less carbon-intensive alternative transportation</td>
<td>Biodiesel, compressed natural gas (CNG), electric</td>
</tr>
<tr>
<td></td>
<td>fuels to replace gasoline or diesel fuels.</td>
<td>vehicles, hydrogen/fuel cell vehicles.</td>
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</tbody>
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Federal Mitigation Research

- Federal research initiatives are increasingly focusing on climate change and greenhouse gas mitigation.
  - Since the release of *SR 299*, more federal resources have been directed towards climate change mitigation research.
  - Department of Energy provides the largest amount of federal funding for climate change research
  - US DOT, EPA, DOE perform the bulk of federal research

- The concept of *sustainable communities* and “livability” is a prominent theme in current federal transportation research, and these initiatives often incorporate climate change within their goals.
  - Example - Housing and Urban Development (HUD)-U.S. DOT-EPA Partnership for Sustainable Communities
Federal Mitigation Research Gaps

- Additional research could focus on ways to better disseminate existing research findings to the public and to policy-makers at the state level through educational campaigns, case studies, and synthesis materials and resources.

- Research needs at the federal level have been well-defined for the near future through TRB research gap analysis, including:
  - Measuring or Estimating GHG Emissions from Transportation:
    - Life cycle analysis of materials and construction, cost-effectiveness of strategies
    - Integration of climate change considerations into transportation models
    - Evaluation tools and guidance for applying GHG mitigation strategies
  - Fuel Technology: infrastructure needs, social costs and benefits, life-cycle GHG impacts, policy options
  - Land Use, Planning and Multimodal Transportation:
    - Potential for alternative energy generation in ROWs
    - Incorporating climate change considerations into planning processes
State DOT Mitigation Research

Percent of State DOT Studies that Address Each Mitigation Topic

- Construction/Maintenance/Operations: 44%
- Vehicle Operations/Highway System: 28%
- Land Use/Planning/Multimodal: 19%
- Measuring/Estimating GHG Emissions: 17%
- Fuel Technology: 17%
- Vehicle Technology: 14%
- Regulatory Instruments/Pricing: 8%
- Environmental: 8%
- Regulatory Instruments/Pricing: 8%
- Measuring/Estimating GHG Emissions: 17%
- Fuel Technology: 17%
- Vehicle Technology: 14%
- Land Use/Planning/Multimodal: 19%
- Construction/Maintenance/Operations: 44%
- Vehicle Operations/Highway System: 28%
University Mitigation Research

Percent of University Studies that Address Each Mitigation Topic

- Measuring/Estimating GHG Emissions: 37%
- Fuel Technology: 34%
- Vehicle Operations/Highway System: 18%
- Vehicle Technology: 17%
- Land Use/Planning/Multimodal: 16%
- Regulatory Instruments/Pricing: 15%
- Construction/Maintenance/Operations: 12%
State DOT and University Mitigation Research Gaps

- Each of the mitigation topics identified is being researched.

- Most research focused on highway (light duty) vehicles, with fewer studies found on freight/rail or heavy duty vehicles.

- Increased attention to the energy and emissions of construction and maintenance materials over their full life cycle is needed.

- Research would benefit from a synthesis of best practices and results for evaluating the emissions, energy saving potential, and other environmental benefits from alternative construction materials.

- Coordination of land use and transportation planning scenarios between local communities and regional land use models is important.

- Need to scale national models down to better understand the regional effects of regulatory instruments as well as options available to state DOTs.
Adaptation Research Categories

1. Climate change impact data and analysis,
2. Risk and vulnerability assessment,
3. Monitoring,
4. Operational adaptation responses,
5. Design standard and material adaptation responses,
6. Evaluation, and
7. Decision support tools

<table>
<thead>
<tr>
<th>Adaptation Topic</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Climate Change Impact Data and</td>
<td>Efforts to understand our current climate conditions, assess how climatic processes (e.g., temperature, precipitation, SLR) will likely change in the future, and gauge how these changes will affect other weather-related hazards (e.g., flooding, soil stability, drought).</td>
<td>Historical analogues, global circulation models, downscaling methods, and integrated assessment models.</td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk and Vulnerability Assessments</td>
<td>Initiatives that aim to assess the vulnerability (a function of exposure, sensitivity and adaptive capacity) of transportation assets to specific climate change impacts and/or quantify climate risk (function of consequence and likelihood).</td>
<td>Tools, frameworks, or guidance that identify vulnerable assets and/or locations, assess exposure, sensitivity and adaptive capacity (or resilience), or characterize risk. This may include understanding the change in life of facilities or identifying the modes and consequence of failure.</td>
</tr>
</tbody>
</table>
Federal Adaptation Research

- Climate change adaptation has begun to gain significant interest at the federal level

- Research initiatives are heavily cross-cutting across adaptation topics

- U.S. DOT was the main agency found to have record of transportation-related adaptation initiatives

- Much of the work on adaptation at U.S. DOT has been spearheaded by FHWA, particularly through the Surface Transportation Environment and Planning Cooperative Research Program (STEP) which has targeted climate change adaptation as a research area in their 2010 Research Plan

- FHWA and AASHTO have been holding peer exchanges on climate change adaptation
State DOT Adaptation Research

Percent of State DOT Studies that Address Each Adaptation Topic

- Impact Data/Analysis: 80%
- Risk/Vulnerability Assessment: 80%
- Design Standards & Materials: 47%
- Operational Responses: 40%
- Monitoring: 20%
- Decision Support Tools: 20%
- Evaluation: 0%
- Monitoring: 20%
- Impact Data/Analysis: 80%
- Risk/Vulnerability Assessment: 80%
- Design Standards & Materials: 47%
- Operational Responses: 40%
- Monitoring: 20%
- Decision Support Tools: 20%
- Evaluation: 0%

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University Adaptation Research

Percent of University Studies that Address Each Adaptation Topic

- Risk/Vuln. Assessment: 84%
- Impact Data/Analysis: 76%
- Decision Support Tools: 68%
- Design Standards & Materials: 60%
- Operational Responses: 32%
- Monitoring: 16%
- Evaluation: 0%
- Operational Responses: 32%
- Monitoring: 16%
- Evaluation: 0%
Adaptation Research Gaps

- None of the initiatives identified specifically addressed the *Evaluation Topic* category, which covers efforts to assess the effectiveness of adaptation strategies.

- The topics researched to date are in line with the sequence of steps outlined in most adaptation frameworks, therefore, as the field progresses it is likely that evaluation mechanisms will be developed.

- Collaboration and information exchange are critical in streamlining adaptation into transportation planning.

- Important for research initiatives to target citizens and local stakeholders as the local context of adaptation is one of the most effective types of information.
Thank You!

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