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

Prepared By:

ICF International

9300 Lee Highway

Fairfax, Virginia 22031

July 2011

The information contained in this report was prepared as part of NCHRP Project 25-25 Task 65, National Cooperative Highway Research Program, Transportation Research Board.

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.

Acknowledgements

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of the National Cooperative Highway Research Program (NCHRP) Project 25-25. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 25-25 is intended to fund quick response studies on behalf of the AASHTO Standing Committee on the Environment. The report was prepared by ICF International. The work was guided by a task group chaired by John Zamurs (NY DOT) which included Gina Campoli (VT DOT), Garth Hopkins (CA DOT), Alex Kasprak (MA DOT), Karin Landsberg (WA DOT), John Thomas (US EPA), Jeff Houk (FHWA), Caroline Paulsen (AASHTO), and Robert Kafalenos (FHWA). The project was managed by Nanda Srinivasan, NCHRP Senior Program Officer.

Disclaimer

The opinions and conclusions expressed or implied are those of the research agency that performed the research and are not necessarily those of the Transportation Research Board or its sponsors. The information contained in this document was taken directly from the submission of the author(s). This document is not a report of the Transportation Research Board or of the National Research Council.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

EXECUTIVE SUMMARY

Increasingly State DOTs, as part of state governments, are performing greenhouse gas (GHG) emission inventories of their operations to understand the manner and magnitude of their contribution to climate change, and to help them make informed GHG management decisions.

These Guidelines, entitled *Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments*, provide GHG accounting procedures to help state DOTs prepare a GHG emission inventory of their operations as well as to increase consistency across state DOT inventories. "Operations" refers to the GHG emissions that occur through the daily activities associated with running a state DOT as a governmental body. These GHG emissions occur directly through the operation of state DOT buildings and fleet and indirectly through the products the state DOT consumes, the waste it generates, the individuals it employs, and the contracts it manages. The Guidelines overview GHG accounting basics, identifies emission sources relevant to state DOTs, points to methods for completing GHG emission estimates, provides approaches for obtaining or approximating data, and discusses resources and materials available to state DOTs to help them complete operational GHG inventories.

The Guidelines provide state DOTs with several recommendations that address key decision points that state DOTs will face when preparing a GHG inventory. These recommendations are summarized below and presented throughout the body of the Guidelines.

GUIDELINE RECOMMENDATIONS

The recommendations presented below are intended to simplify state DOT's decision-making process when preparing a GHG inventory and to increase consistency across state DOT GHG inventories.

- It is good practice for state DOTs to apply the five principles of GHG accounting (first developed by the World Resources Institute and World Business Council for Sustainable Development) when preparing their 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 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 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.
- It is good practice for state DOTs to include all scope 1 (direct) and scope 2 (indirect) emission sources in their GHG emission inventory. Scope 1 emissions are direct emissions from operations, facilities, and sources under the DOT's operational control. Scope 2 includes indirect emissions from purchased electricity, steam, and chilled water that are consumed within the organizational boundaries of the DOT.

- It is good practice for state DOTs to consider including the following 5 scope 3 (indirect emissions not included in scope 2) 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 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.

INTRODUCTION

A GHG emission inventory is the first step in accounting for, monitoring, and eventually reducing GHG emissions. In current policy and planning debates, the responsibility of DOTs for GHG emissions from transportation has become a focal point. Much attention centers on vehicle tailpipe emissions, but some attention focuses on the ability of state DOTs to affect emissions from their own operations. Increasingly, state DOTs, as part of state governments, are being required to perform GHG inventories of their operations.

A primary advantage of compiling a GHG inventory is the ability to define, categorize, and quantify emissions, thus establishing responsibility for GHG emissions according to accepted national and international standards. Once compiled, a GHG inventory will assist state DOTs in:

- Developing strategies to manage and reduce GHG emissions
- Monitoring GHG emissions and tracking performance over time
- Planning long-term approaches to operational management in a carbon-constrained world
- Communicating with stakeholders about GHG emissions and climate change

These Guidelines provide GHG accounting procedures to help state DOTs prepare a GHG emission inventory of their operations as well as to increase consistency across state DOT inventories.[1] "Operations" refers to the GHG emissions that occur through the daily activities associated with running a state DOT as a governmental body. These GHG emissions occur directly through the operation of state DOT buildings and fleet and indirectly through the products it consumes, the waste it generates, the individuals it employs, and the contracts it manages. The Guidelines overviews GHG accounting basics, identifies emission sources relevant to state DOTs, points to methods for completing GHG emission estimates, provides approaches for obtaining or approximating data, and discusses resources and materials available to state DOTs to help them complete operational GHG inventories.

The Guidelines document is organized into the following sections:

1. GHG Accounting Basics
2. Defining A GHG Inventory Boundary
3. Identifying and Calculating GHG Emissions
4. Tools Available for GHG Accounting
5. Managing Inventory Quality
6. Reporting GHG Emissions
7. Appendices

---

[1] These Guidelines do not address GHG emissions from third-party travel on state roads, which are described to be outside the organizational boundaries of a state DOT. Accounting for GHGs from third party travel on state roads are more appropriately included in state-level GHG emission inventories.

GHG ACCOUNTING BASICS

A state DOT GHG emission inventory provides an understanding of the GHG emissions released through the activities of a state DOT. It provides both an understanding of the magnitude of emissions as well as the relative emissions released by one source when compared to another. The GHG inventory provides a baseline against which future performance can be compared, and provides the understanding needed to make informed GHG management decisions.

The critical elements of a GHG emission inventory as relevant to state DOTs include:

1) **GHGs to include:** International guidelines require including six GHG emissions in a GHG emission inventory. They are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).
2) **Inventory boundaries:** Boundaries define the structure of the state DOT for the purposes of conducting the current and future GHG emission inventories. These Guidelines are focused on GHG emissions that result from state DOT <u>operations</u> and the boundaries are derived accordingly. An operational control approach, which is described in the *Defining A GHG Inventory Boundary* section, is the recommended approach for establishing state DOT GHG inventory boundaries.
3) **Inventory baseline year:** The baseline year is the year against which all future GHG emission inventories will be compared. It is typically the first year for which a GHG emission inventory is performed. State DOTs should select a baseline year that represents the earliest year for which they have relatively complete and reliable data. Where possible, these Guidelines recommend using calendar year 2010 as the baseline year.
4) **Emission sources:** The sources or activities that produce GHG emissions that are to be included in the GHG emission inventory. Emission sources are either directly or indirectly tied to the state DOT depending on the inventory boundaries. This link is defined according to a source's scope, which is described in the *Defining A GHG Inventory Boundary* section of these Guidelines.
5) It is commonly accepted inventory practice to include all scope 1 and scope 2 emission sources in a GHG inventory. If DOTs choose to include scope 3 emission sources, these Guidelines recommend including emissions associated with vendor and contractor emissions, employee commutes, business air travel, transmission and distribution, contracted solid waste, and business ground travel.
6) **Inventory principles:** Inventory principles ensure that the inventory is of the highest quality possible, and that those factors that limit inventory quality are addressed. Inventory principles address items such as inventory accuracy and completeness, data quality, and the certainty associated with emission estimates.
    - State DOTs should adhere to accepted inventory principles (i.e., relevance, completeness, consistency, transparency and accuracy) when completing GHG inventories for their operations.
7) **Inventory methods:** Inventory methods specify the approaches and calculations that should be used to estimate GHG emissions for emission sources included in the GHG inventory.
    - These Guidelines describe several GHG guidance documents that will help to inform state DOT inventory methods, including the *Public Sector Standard*, the *Federal GHG Accounting and Reporting Guidance* and various GHG accounting tools. Inventory methods are detailed in the *Identifying and Calculating GHG Emissions* section of these Guidelines.
8) **Activity data:** Activity data are the data specified by the inventory methods that are needed to complete the emission estimates.

- State DOTs are currently collecting some of the data elements needed to complete a GHG emission inventory, especially for mobile combustion in vehicle fleets and purchased electricity. The needed activity data by emission source are specified in the *Identifying and Calculating GHG Emissions* section of these Guidelines. Where possible, approaches for approximating activity data to fill data gaps are provided.

9) **Inventory reporting:** Reporting ensures that the inventory results are structured for the inventory audience, which may be verifiers, state DOT management, registries or other reporting bodies, and/or the public.
    - There are currently several mandatory and voluntary GHG reporting bodies. State DOTs may report to these bodies or may prepare GHG inventories for other audiences, such as DOT management, the public or state governments. Adhering to accepted inventory principles will ensure that the final inventory accommodates reporting to multiple audiences.

The remainder of these Guidelines details the critical inventory elements and, where appropriate, provides descriptions of resources that support them.

GHG ACCOUNTING AND REPORTING PRINCIPLES

Attention to five principles of GHG accounting ensures a high-quality GHG emission inventory; they are relevance, completeness, consistency, transparency, and accuracy. These five principles were developed by the World Resources Institute/World Business Council on Sustainable Development's (WRI/WBCSD) *Corporate Accounting and Reporting Guidance*[2], and are described below as they relate to state DOTs are described below.

> These Guidelines recommend that state DOTs apply the five principles of GHG accounting to their GHG emission inventories.

1) **Relevance**: Include relevant emission sources that both reflect the emissions impact of a state DOT as well as serve the needs of decision-makers, both within the state DOT and external stakeholders.
2) **Completeness**: Include all GHG emission sources that are within the DOT's defined organizational and operational boundaries. Document and justify any excluded emission sources.
3) **Consistency**: Use consistent methodologies to estimate DOT emissions to enable meaningful comparison of inventories over time. Document any changes in methodologies used, inventory boundary, data, and other factors that impact emissions.
4) **Transparency**: Disclose all relevant assumptions, data sources, and calculation methodologies used to estimate GHG emissions.
5) **Accuracy**: Achieve sufficient accuracy in emission estimates to prove useful to decision-makers and stakeholders. Ensure that GHG emission estimates are neither systematically underestimated nor overestimated. Reduce estimate uncertainties to the extent possible.

It is good practice for state DOTs to apply these five principles in order to ensure that their GHG inventories are fair and comprehensive representations of their GHG emissions. Strategies for addressing each principle are discussed below.

[2] World Resources Institute/ World Business Council on Sustainable Development (WRI/WBCSD). 2004. Corporate Accounting and Reporting Standard.

RELEVANCE

A key aspect of relevance is the process of selecting an appropriate inventory boundary for the GHG inventory; in other words, choosing which activities should be accounted for in the inventory and reported and which should not. When selecting the inventory boundary, a state DOT should consider (1) organizational structures (i.e., determine which activities it owns, controls or operates); (2) operational boundaries (i.e., identify on-site and off-site activities, processes, services, and shared facilities); (3) operational context (i.e., understand the nature, sector, and geographic location of the activities, as well as the purposes and users of the information). Relevance may also be impacted by regulatory requirements that dictate the information to be included or the reporting frequency. The process of defining an inventory boundary is discussed in more detail in the section of these Guidelines, entitled *Defining* A GHG Inventory Boundary.

COMPLETENESS

An essential element of completeness is ensuring that all relevant emission sources within the selected inventory boundary are accounted for in the state DOT GHG inventory so that a comprehensive inventory is compiled. Challenges to this principle can include a lack of available data or costs associated with gathering data. To address such challenges, many GHG reporting programs such as The Climate Registry apply a "simplified estimation methodology" or an "alternate methodology" to calculate emissions from sources for which data are difficult to locate or use; this eases the reporting burden while still achieving the principle of a complete inventory.

In some cases, DOTs will not be able to quantify emissions from a source because it is too costly or resource-intensive to gather the necessary data. Some GHG guidance documents, such as the WRI/WBCSD's *GHG Protocol: Corporate Accounting and Reporting Standard*, define a *de minimis* threshold that allows organizations to exclude small emission sources that together account for no more than 5 percent of their total operational emissions. Intentional exclusions violate the principle of completeness, but support the principle of relevance by acknowledging that resources may be better spent mitigating emissions than perfecting inventory estimates.

> These Guidelines recognize a 5 percent de minimis threshold for state DOTs that wish to exclude comparatively small GHG emission sources from their inventory. These Guidelines recommend that the state DOT note any GHG sources that were excluded because the source, when summed with other de minimis sources, did not meet the de minims threshold.

The WRI/WBCSD's *GHG Protocol for the U.S. Public Sector* and The Climate Registry's *General Reporting Protocol* propose simplified methodologies for estimating emissions from small emission sources that are less accurate but enable organizations to have complete GHG inventories. These Guidelines support using simplified methodologies and recognizes a 5 percent de minimis threshold. To apply a 5 percent de minimis threshold, all de minimis sources, when summed, should not exceed 5 percent of total GHG emissions. All de minimis sources should be clearly noted.

CONSISTENCY

A key aspect of consistency is applying consistent accounting approaches, inventory boundary, and calculation methodologies so that GHG emissions data can be compared internally over time as well as externally with inventories from other reporting organizations. Comparisons over time will allow the state DOT to identify trends and to assess progress towards its goals and objectives. Any necessary changes to the inventory boundary, methodologies, activity data, or other factors that affect emission estimates must be transparently documented and justified. The process of ensuring consistency is discussed in more detail in the next section, *Tracking Emissions Over Time*.

TRANSPARENCY

The key aspects of transparency are to record, compile, and analyze information on the processes, procedures, assumptions, and limitations of the state DOT GHG inventory in a way that allows internal reviewers and external verifiers to confirm the inventory's credibility. All activity exclusions or inclusions should be clearly identified and justified, all assumptions should be disclosed, and clear documentation should be available for all methodologies and data sources used, such that a third party verifier could derive the same results if provided with the same source data. Transparency will allow for a clear understanding and meaningful assessment of the state DOT's performance in context. One way to ensure transparency is through an independent external verification process.

ACCURACY

A key aspect of accuracy is ensuring that GHG measurements, estimates, or calculations neither systematically overstate nor understate the actual emission values, and that uncertainties are reduced as far as practicable. Reporting in the GHG inventory on measures taken to help ensure accuracy will simultaneously promote credibility and enhance transparency. Inventory accuracy and quality assurance/quality control (QA/QC) processes are described in the *Managing Inventory Quality* section of these Guidelines.

TRACKING EMISSIONS OVER TIME

To compile a consistent record of emissions over time, a baseline year is set in order to track progress towards reducing emissions. Although the Kyoto Protocol uses a 1990 baseline, it is important that state DOTs choose a baseline year at the earliest relevant point in time for which they have complete and accurate data. The baseline year should be representative of the general level of emissions over a surrounding period. It is good practice for state DOTs to choose a single year for the baseline emission inventory; however, in some cases, an average of annual emissions over several consecutive years can be used if there are significant inter-annual fluctuations due to external influences such as particularly hot or cold weather.

> These 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.

In selecting a baseline year for an emissions inventory, it is good practice for DOTs to choose the earliest relevant year for which there is reliable data. In addition, baseline years may be mandated externally through state or regional reporting requirements.

Another consideration in selecting a baseline year is whether to report by calendar year or by fiscal year. Calendar year reporting is consistent with the United Nations Framework Convention on Climate Change (UNFCCC) and several voluntary reporting programs, but fiscal years may make more sense for agencies if utility and other activity data are reported on a fiscal year basis.

Recalculating the baseline inventory may be necessary to reflect changes that would compromise the consistency of reported emissions information such as,

- Data quality improves considerably in later years,
- Additional data becomes available,
- The state DOT acquires an existing emission source,[3]
- The state DOT undergoes a significant organizational change,
- Significant errors were discovered in the original inventory,
- The state DOT outsources or insources activities that significantly change their emissions,
- The methodologies to calculate GHGs change.

Of these, the most likely changes to a state DOT's emissions will occur when data quality improves over time or when more data becomes available. Also, when more accurate procedures for capturing data to estimate emission for several scope 3 sources (e.g., vendor and contractor emissions, supply chain emissions) become available, state DOTs may choose to recalculate their baseline inventories.

If a change in calculation procedure, data quality, or structure of the organization occurs, state DOTs can establish a "materiality threshold" which can help define significant changes to the emissions data. If a change affects total emissions estimates by more than a set amount (such as 5 percent), then the baseline year should be recalculated. Once the state DOT has established a materiality threshold, they should consistently apply it to their emissions estimates. See *The Greenhouse Gas Protocol for the U.S. Public Sector* for more information and specific examples on recalculating baseline emissions.

TRACKING EMISSIONS AT DIFFERENT SCALES

Preparing a GHG emission inventory requires coordination among many different individuals stationed at different levels and different locations within a state DOT organization. A high-quality inventory will follow the GHG accounting and reporting principles and include sufficient detail to allow stakeholders to make informed GHG management decisions. Ideally, state DOTs will have activity data—the data used to estimate emissions such as fuel consumption—at the building or vehicle level; however, a process for collecting data at this fine resolution may take many years to implement.

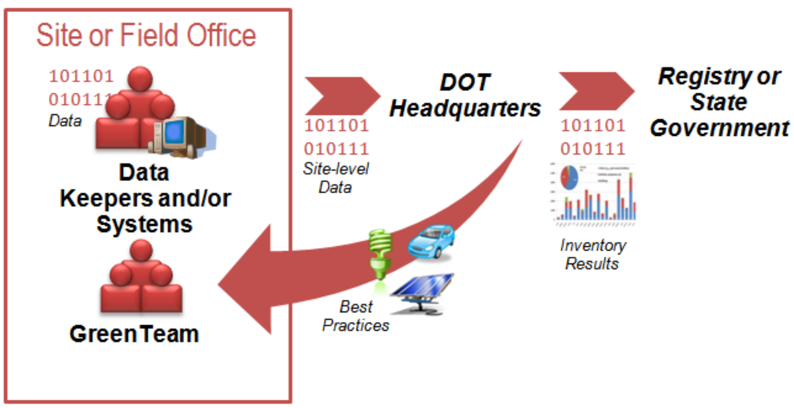
A state DOTs GHG emission inventory approach should adhere to the GHG accounting and reporting principles, include procedures for continual improvement and refinement, recognize that finer detailed data will improve the state DOTs ability to make informed GHG management decisions, and help the state DOT reduce GHGs.

[3] As an example, if a state DOT acquires new land that contains facilities, the baseline can be recalculated to account for the facilities if the facilities existed during the baseline year. DOTs cannot recalculate the baseline to accommodate internal growth occurring after the baseline year.

The approach used to prepare a GHG emission inventory will vary among state DOTs depending on the types of existing data management systems the state DOT have in place, any planned GHG management systems, and the parties involved in preparing the GHG emission inventory. Most GHG emission inventory approaches can be classified as one of three possible approaches—a centralized approach, a decentralized approach, and a hybrid approach.

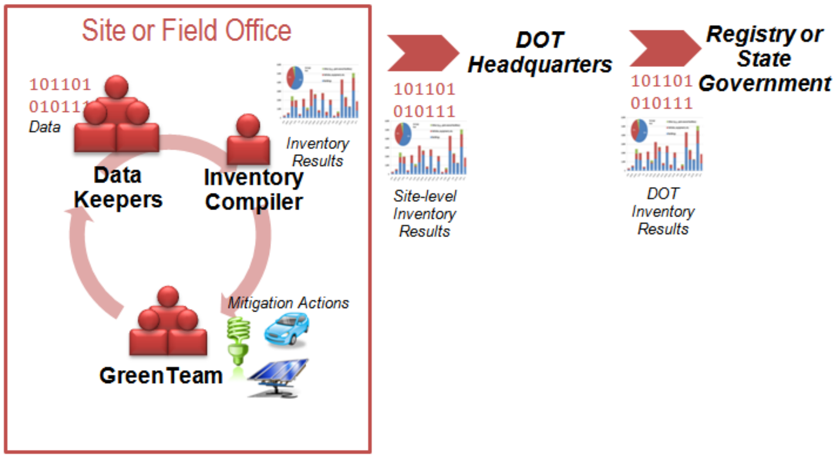
Under a centralized approach, activity data are collected at the site or field office level (e.g., district offices) and reported to DOT headquarters, either through an automated system—such as a financial accounting system—or manually by individuals at the field office (Figure 1). The GHG emission inventory is prepared at headquarters using the site-level activity data and reported to a registry, state governmental body or other interested party. The GHG inventory data are typically analyzed at the headquarters level and used to develop best practices or standard operating procedures (SOPs) that are rolled out to the sites or field offices. The benefits of a centralized approach are centralized data control and analysis and the ability to roll out consistent best practices. The drawbacks are limited understanding at the site or field office level and, as a result, limited buy-in among site or field office staff.

Figure 1. Centralized GHG Inventory Approach



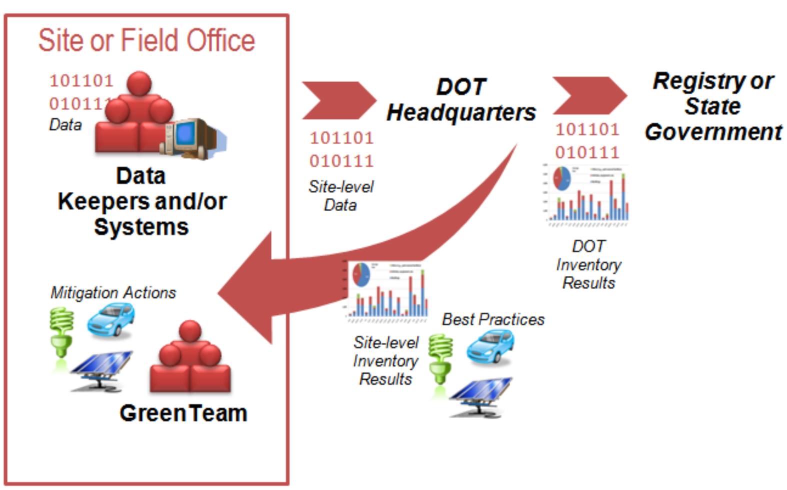
Under a decentralized approach, activity data are collected at the site or field office level where they are used directly to prepare a site-level GHG emission inventory (Figure 2). The GHG emission inventory results are reported to headquarters where they are compiled and reported to a registry, state governmental body or other interested party. The GHG inventory data are typically analyzed at the site or field-office level and used to develop site-level GHG mitigation actions. The benefits of a decentralized approach are that site or field office staff is invested in producing high-quality data and that they understand their GHG emission profile and are therefore positioned to make informed GHG management decisions. The drawbacks are limited understanding at DOT headquarters about the process used to prepare the GHG inventory, which can lead to inconsistent approaches and limited access to the activity data used to prepare the GHG inventory.

Figure 2. Decentralized GHG Inventory Approach



Under a hybrid approach, activity data are collected at the site or field office level and reported to DOT headquarters, either through an automated system—such as an energy, GHG, or financial accounting system—or manually by individuals at the field office (Figure 3). The GHG emission inventory is prepared automatically by the system or at headquarters using the site-level activity data. The inventory results are reported to a registry, state governmental body or other interested party. Individual site-level inventory results are also prepared and are rolled out to the sites or field offices along with best practices and SOPs that were developed at headquarters based on DOT-wide analyses. Site or field office staff review the results of their GHG inventory as well as the best practices recommended by headquarters and make their own GHG management decisions based on this information. The benefits of a hybrid approach are centralized data control and analysis at the headquarters level, the ability to roll out consistent best practices across the state DOT, and informed site-level staff that understand their site's GHG emission profile and have the tools needed to mitigate GHGs. The hybrid approach increases understanding among all staff, which demonstrates relevance and encourages ownership over mitigation actions. The drawback of the hybrid approach is that it typically takes more staff time to conduct and may require implementing or developing a GHG management system.

Figure 3. Hybrid GHG Inventory 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—and subsequent GHG mitigation activities—at all levels of the state DOT. Irrespective of the approach that is selected, it is good practice for a state DOT to adhere to the GHG accounting and reporting principles when preparing the GHG inventory, work towards continually improving the quality and resolution of their inventory, understand that finer detailed data will improve the state DOTs ability to make informed GHG management decisions, and recognize that the purpose of a GHG inventory is to help the state DOT reduce GHGs. A GHG emission inventory is the first step in an ongoing GHG management and mitigation effort.

DEFINING A GHG INVENTORY BOUNDARY

Clear organizational and operational boundaries establish the framework for structuring a GHG emission inventory. *Organizational boundaries* define the operations, facilities, and sources that are to be included in a GHG emission inventory, while *operational boundaries* categorize the emissions associated with the operations, facilities, and sources as resulting either directly or indirectly from the DOT's activities.

Determining how to set these boundaries is a critical first step in developing a GHG emission inventory: this step defines what is included and what is not. Defining the boundary of an organization can be one of the most challenging steps in developing an inventory, and GHG inventory protocols differ slightly on how to define these boundaries. As an example, historically, GHG protocols—such as the WRI/WBCSD *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*—have called for organizations to account for emissions associated with leased space if the organization *has signed a lease agreement* for the space. The *Federal Greenhouse Gas Accounting and Reporting Guidance* (*Federal GHG Guidance*) diverges from this approach by requiring only that Federal agencies account for emissions associated with leased space for which they *pay the utility bills*. The differences are subtle, but as carbon accounting becomes more common and more regulated they may have significant (and unintended) impacts—such as incentivizing leasing rather than owning building space.

When evaluating how an organization can structure themselves to develop a GHG inventory, the first step is to review the organization's organizational structure – what functions yield emissions and how the facilities and staff are organized—and using that information, identify the organizational and then operational boundaries of the GHG inventory. The following sections provide a description of state DOT organizational structure followed by a discussion of how organizational and operational GHG inventory boundaries apply to typical state DOT structures.

STATE DOT ORGANIZATIONAL STRUCTURE

Every state has an agency or department responsible for coordinating statewide transportation planning, programming, and project implementation. State DOTs are responsible for allocating state and some federal transportation funding within their states and are the principal planning and funding partners for transportation projects involving state-owned facilities. DOT responsibilities include the 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.

State DOTs are the owners and operators of state highway systems, which consist of all interstate highways, US highways, and numbered state highways. Other roads are owned and operated by the local government jurisdiction under which they fall—usually either a city or county government. The proportion of total roadway mileage owned by state DOTs varies widely by state, depending on the dominance of the state highway system within the road network. For example, New Jersey's DOT owns about 6 percent of total state roadway mileage, while West Virginia's DOT owns 89 percent of state roadway mileage. State DOTs are often involved in planning and funding public transit services, particularly rural and intercity service. Most state DOTs do not own and operate rail and bus systems, although there are exceptions (e.g., the Maryland Transit Administration owns and operates commuter rail and buses and is part of the Maryland DOT). Some DOTs operate airports and ferry systems, such as Washington state and Alaska, whereas in Oregon, for example, the Department of Aviation is separate from the Department of Transportation.

Most state DOTs are organized both by geography and by functional area. A typical DOT will have a headquarters office in the state capital. Although the organization of departments within each DOT varies widely, the core departments within a typical DOT will include departments of planning (long-term), project delivery (including construction, design, engineering, and environmental analysis), and 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. The organization of a district office is similar to the main office, although district offices tend to have a greater focus on project delivery and on operations and maintenance, rather than long term planning.

A survey of state DOTs was conducted in October 2010 to support the development of these Guidelines; the survey was provided for all 50 state DOTs, out of which were received 28 responses. In this survey, state DOTs indicated that operational decision-making authority is split between the DOT headquarters, regional or district office, or both, depending on the state and the type of decision. State DOTs also indicated that the degree of autonomy of regional offices varies based on the type of decision and the individual state. Fifty percent of the survey respondents indicated that their operational or decision-making authorities lie in the DOT headquarters. Around a third of respondents reported that the location of their authority varies, while the remaining, smaller portion of respondents indicated that their decision makers reside in their regional or district offices.

Where decision-making authority resides typically dictates whether an organization will prepare a centralized or de-centralized GHG emission inventory. Under a centralized approach, decision-making authority and data collection reside in a central location (typically headquarters) and the inventory is prepared there. Under a decentralized approach, decision-making authority and data collection reside among the divisions; inventories are typically conducted at the division level and sent to headquarters for compiling. A centralized inventory approach increases consistency while a decentralized approach often increases buy-in.

For both the centralized and decentralized approaches, coordination between the DOT headquarters and regional offices will be essential. See the previous section on *Tracking Emissions at Different Scales* for more discussion of these two approaches.

ORGANIZATIONAL BOUNDARIES

> These Guidelines recommend that state DOTs adopt an operational control approach to set organizational boundaries.

Historically, organizations have determined their GHG inventory organizational boundaries using either a control approach or an equity share approach. Under an equity share approach, an organization accounts for all facilities in which it has an equity interest, while under a control approach an organization accounts for all facilities where it has authority to implement either financial or operational control. Financial control refers to the ability of an organization to direct the financial policies of a facility while operational control refers to the authority to implement operating procedures. The entity that holds the operating license for a source of emissions typically has operational control.

The operational control approach has gained wide acceptance within the public sector, notably within WRI's *Greenhouse Gas Protocol for the U.S. Public Sector* and the Local Government Operations (LGO) Protocol, because it most accurately represents the emission sources that an organization can influence—largely due to the fact that most organizations operate, but do not own, a large portion of their GHG emitting sources, such as buildings leased from a private landlord or another government entity.

These Guidelines recommend that state DOTs adopt an operational control approach to set organizational boundaries. Under the operational control approach, the organizational boundaries for state DOTs will include 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.[4] For DOTs that own facilities, emissions associated with tenant activities in those facilities are not included under the operational control approach. DOTs typically have a large number of subdivisions with varying levels of autonomy, but the state DOT should include all operations over which it can influence operational decisions, including all regional and other offices.

LEASED ASSETS

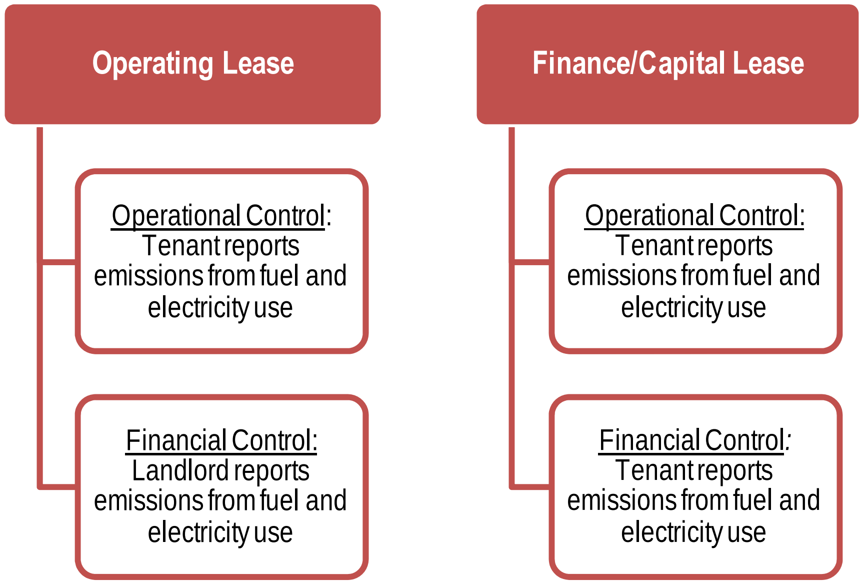
The process of determining how to account for GHG emissions from leased assets can be challenging, as both landlords and tenants contribute to the total emissions incurred from the leased asset. Ultimately, a state DOT's treatment of GHG emissions from leased assets will depend on the consolidation approach used for setting its organizational boundary (i.e., control approach or equity share approach, as discussed in the section above) as well as the type of lease maintained. These factors impact whether emissions should be considered direct or indirect.

These Guidelines recommend that state DOTs include emissions associated with space they lease in their GHG emission inventories.

Under the operational control approach, recommended by these Guidelines, the tenant is assumed to have operational control for both a capital lease and an operating lease. Under the financial control approach, the landlord is assumed to have financial control under an operating lease, and would therefore be responsible for reporting emissions. The figure below shows how to allocate emissions from the operation of leased buildings.

[4] 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.

Figure 4. Allocation of Emissions in Leased Spaced



Under a financial control or equity share approach, with a capital lease the emissions allocations would remain the same as with the operational control approach. However, for operating leases under a financial control or equity approach, the landlord has financial control over the asset and would therefore be responsible for reporting emissions.

In the scenarios presented in Figure 4, the tenant reports emissions from fuel use as scope 1 and emissions from purchased electricity as scope 2 in all cases except under the Financial Control/Operating Lease scenario; wherein, they would be reported as scope 3. Scope classifications are discussed further in the section of these Guidelines entitled *Operational Boundaries*.

It is good practice for state DOTs to report emissions from electricity use, heating and cooling of facilities that they lease whenever possible.

OPERATIONAL BOUNDARIES

After specifying the organizational boundaries of a GHG emission inventory, the next step is to specify the operational boundaries, which categorize emissions as resulting either directly or indirectly from the DOT's activities.

- *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).

Indirect emissions, by definition, are the direct emissions of the separate organization that owns or controls the emission source. Direct and indirect emissions are further categorized by scope, as follows:

SCOPE 1

Scope 1 emissions include direct emissions from operations, facilities, and sources under the DOT's operational control. Scope 1 emissions result from activities such as on-site combustion of fossil fuels to generate electricity or heat, use of fleet vehicles, and fugitive GHG emissions from DOT-owned refrigeration and air-conditioning equipment.

These Guidelines recommend including all scope 1 and scope 2 emission sources as well as select scope 3 emission sources in a state DOT GHG emission inventory.

In an October 2010 NCHRP survey conducted to support development of these Guidelines, of state DOTs that had completed GHG inventories indicated that they had included the following scope 1 sources: Mobile Combustion (100 percent), Stationary Combustion (90 percent), Fugitive Fluorinated GHGs (30 percent), Land Management (20 percent), and On-site Wastewater Treatment (10 percent).

SCOPE 2

Scope 2 includes indirect emissions from purchased electricity, steam, and chilled water that are consumed within the organizational boundaries of the DOT.

SCOPE 3

Scope 3 includes all indirect emissions that are not included in scope 2. Similar to scope 2, scope 3 emissions are indirect emissions that are a consequence of the activities of the DOT, but the actual emissions are generated by sources not controlled by the DOT.

These Guidelines recommend including 5 scope 3 emission sources in state DOT GHG emission inventories:

1. Vendor and Contractor Emissions
2. Contracted Solid Waste
3. Transmission and Distribution Losses
4. Employee Commuting
5. Business Travel

There are many scope 3 emission sources. Scope 3 emission sources are typically more difficult to estimate and may be more challenging to reduce due to the lack of direct control over the emission source, but they are often significantly larger than scope 1 or 2 emission sources and thus provide greater emission reduction potential.

Historically, many organizations have chosen not to include scope 3 emission sources in their inventory or to include a select few. The *Federal GHG Guidance* requires that agencies account for scope 3 emissions from six scope 3 sources: business air travel, business ground travel, employee commuting, transmission and distribution (T&D) losses associated with purchased electricity and steam, contracted solid waste, and contracted wastewater treatment. State DOTs may choose to include these scope 3 emissions as well as other scope 3 emission sources in their inventory, such as supply chain emissions associated with material purchases and contractor/vendor activities.

In a survey of state DOTs conducted to support these Guidelines, approximately 50 percent of the survey respondents indicated that their state DOT included, or plans to include, employee commuting—a scope 3 emission source—in their inventory. Among other scope 3 emission sources, approximately 30 percent of respondent state DOTs included business air travel in their inventory, while just about 50 percent included business ground travel. Less than 25 percent of survey respondents indicated that they included any other scope 3 emission sources, and around 20 percent indicated that they did not include any scope 3 emission sources.

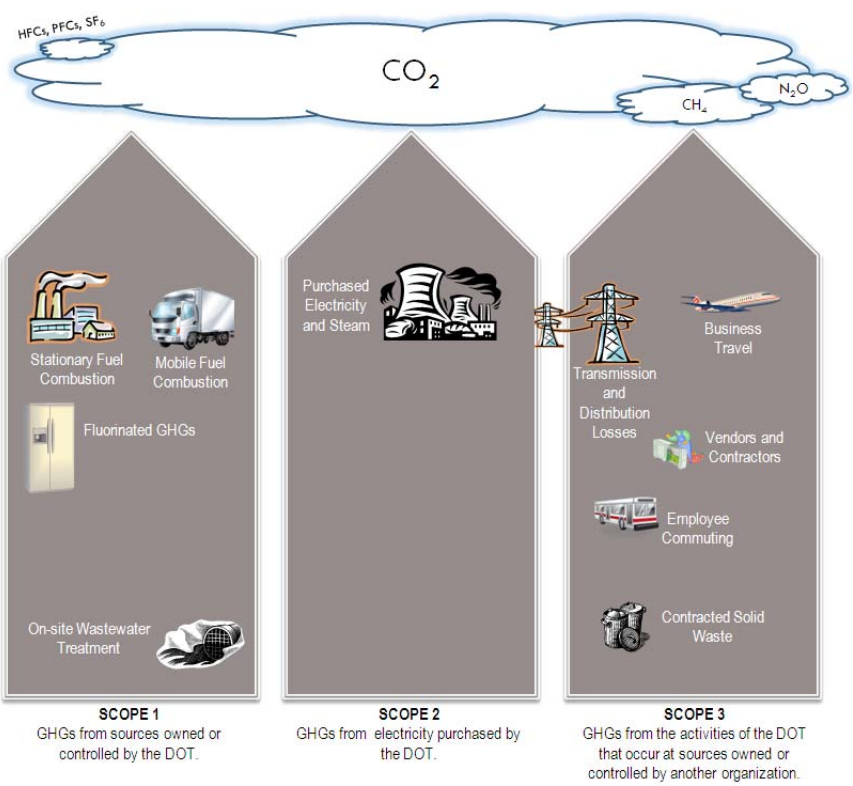
As described in the section of these Guidelines that details methods to estimate scope 3 emissions, these Guidelines recommend that state DOTs include the following scope 3 emission sources in their inventories:

1) Vendor and Contractor Emissions,[5]
2) Contracted Solid Waste,
3) Transmission and Distribution Losses,
4) Employee Commuting, and
5) Business Travel.

Appendix D: Scope 3 Evaluation Approach of these Guidelines provides an approach for state DOTs to consider which scope 3 emission sources to include in their GHG emission inventory.

Figure 5 presents scope 1, scope 2, and potential scope 3 emission sources that may be included in a state DOT GHG emission inventory.

Figure 5. State DOT Scope 1, Scope 2, and Potential Scope 3 Emission Sources



5 While state DOTs can exert control over the activities of vendors and contractors through policy and financial measures they do not have operational control over the vehicles, equipment, and other emission sources used by the vendors and contractors. Under the strict definition of operational control these emission sources are a scope 3 emission source for the state DOT even though the state DOT can exert indirect influence over the amount of emissions generated.

IDENTIFYING AND CALCULATING GHG EMISSIONS

Greenhouse gas emissions are almost never measured directly. Rather, emissions are estimated using activity data, emission factors and global warming potentials (GWPs). Equation 1 presents the general equation used to estimate GHG emissions, referencing these components.

Equation 1: General Calculation for Estimating GHG Emissions

GHG Emissions = Activity Data x Emission Factor x Global Warming Potential (GWP)

Activity data is a measurement of the activities that generate GHG emissions. Examples of activity data include facility energy use, gasoline consumption in vehicles, and amount of electricity purchased by state DOTs.

Emission factors are ratios of the GHGs emitted per unit of activity data; for example, metric tons of CO_2 emitted per kilowatt hour of generated electricity. Emission factors are calculated from laboratory data or calculations based on the heat and carbon content of fuels, and default emission factors are provided in GHG protocols and guidance documents. If a state DOT has site-specific data about the carbon content or other characteristics of their fuels or technology used at their facilities, they may derive their own emission factors; however, it is common inventory practice to use the standard emission factors provided in GHG guidance documents.

Global warming potential (GWP) is a factor that describes the atmospheric heat-trapping impact of one mass unit of a GHG relative to one mass unit of CO_2; GWPs are calculated and published widely by bodies such as the World Meteorological Organization and the Intergovernmental Panel on Climate Change (IPCC). GWPs for particular gases may change over time as the state of the science advances; however, a specific set of GWPs governs reporting under any reporting program. The convention is to use 100-year GWPs published by the *IPCC's Second Assessment Report* (1996) for consistency with other inventories and across time.

The general procedure for calculating GHG emissions from each emission source is as follows:

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_2O, HFCs, PFCs, and SF_6) by multiplying activity data by the appropriate emission factors

Step 5. Convert emissions to metric tons CO_2-equivalent ($MTCO_2e$) using each GHG's GWP and sum to obtain total emissions

Monitored, measured, or otherwise tracked activity data are preferred to estimate emissions within each emission source, but, in the absence of tracked data, most GHG reporting programs allow the use of proxy methodologies to approximate activity data.

This chapter presents GHG accounting methods by emission source categorized by scope. The methods presented in this chapter are taken or adapted from other GHG guidance materials. These guidance materials are summarized briefly in the next section and are detailed in *Appendix E: Relevant GHG Guidance Materials*.

RELEVANT GHG GUIDANCE MATERIALS

A survey conducted to support development of these Guidelines indicated that state DOTs use a variety of GHG guidance materials to prepare their GHG emission inventories. For consistency, state DOTs should be using the same guidance materials to prepare GHG emission estimates. These Guidelines overview available guidance materials and recommends the best available methods for estimating GHG emissions by emission source to improve consistency and accuracy. The GHG accounting methods and procedures presented in these Guidelines are based off of several existing GHG guidance materials for consistency with other GHG accounting protocols and to ensure that the best available accounting procedures and methods are provided to state DOTs.

> These Guidelines primarily reference the *Local Government Operations Protocol* and the *Federal Greenhouse Gas Accounting and Reporting Guidance* for methods to calculate GHG emissions.

Referenced GHG guidance materials are summarized below and are detailed in *Appendix E: Relevant GHG Guidance Materials* . Where appropriate the reader is directed to the supporting guidance materials for detailed calculation methodologies.

There are two main types of GHG inventory guidance materials, *GHG protocols* and *GHG guidelines*.

- Protocols establish *inventory design principles*, such as how to define operational and organizational boundaries, guidelines for completeness, accuracy and transparency, and how to deal with uncertainty.
- GHG guidelines provide *methods* to estimate GHG emissions.

Both GHG protocols and GHG guidelines play an important role in providing uniform guidance for organizations to prepare GHG emission inventories and some guidance materials (e.g., the *LGO Protocol* and the *Federal GHG Guidance*) provide both inventory design principles and methodologies.

These Guidelines recommend that state DOTs primarily reference the WRI's *GHG Protocol for the U.S. Public Sector* (Public Sector Standard) for GHG protocols and the *Local Government Operations Protocol* (LGO Protocol) for GHG methodologies. The Climate Registry's General Reporting Protocol and the White House Council on Environmental Quality's *Federal GHG Guidance* should also be referenced for select GHG protocols and methods, respectively. Table 1 presents relevant GHG guidance materials. The remainder of this chapter presents methods to estimate GHG emissions by source based on, and referencing, these guidance materials.

Table 1. Comparison of Common Inventory Components of GHG Guidance Documents

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

METHODOLOGIES TO CALCULATE SCOPE 1 EMISSIONS

Scope 1 emissions include direct emissions from operations, facilities, and sources under the state DOT's operational control. Scope 1 emissions result from activities such as on-site combustion of fossil fuels to generate electricity or heat, use of fleet vehicles, and fugitive GHG emissions from DOT-owned refrigeration and air-conditioning equipment.

In an NCHRP survey of state DOTs conducted to support these Guidelines, respondent DOTs indicated that they included the following scope 1 sources in their GHG inventory: Mobile Combustion (100 percent), Stationary Combustion (90 percent), Fugitive Fluorinated GHGs (30 percent), Land Management (20 percent), and On-site Wastewater Treatment (10 percent).

This section describes each scope 1 emission source as it relates to state DOT activities and the activity data and recommended methodologies for estimating scope 1 GHG emissions.

Where possible, each source description contains two tables detailing the activity data and emission factors a state DOT will need to estimate emissions from that source. The first table notes the needed activity data, likely source containing the data, and location where that data source will be located for state DOTs. The second table details emission factors, the types of emission factors available, and the location for obtaining those emission factors by guidance document. A list of GWPs is provided in Appendix B: Global Warming Potentials.

Where possible, methods for approximating activity data (proxy data) to assist state DOTs in estimating emissions if they do not maintain the requested activity data are also provided.

The scope 1 emission sources detailed in this section include:

1) Stationary Combustion (associated GHGs: CO_2, CH_4, N_2O)
2) Mobile Combustion (associated GHGs: CO_2, CH_4, N_2O)
3) Fugitive Emissions: Refrigerants and F-GHGs (associated GHGs: HFCs, PFCs, SF_6)
4) Fugitive Emissions: On-site Wastewater Treatment (associated GHGs: CH_4, N_2O)

STATIONARY COMBUSTION

Stationary combustion includes emissions from state DOT-owned or controlled stationary equipment used to generate heat, electricity, or steam. Common stationary combustion equipment includes boilers, furnaces, and generators used in state DOT offices, maintenance facilities, storage sheds (for salt, sand, or vehicles), and other buildings. The combustion of fossil fuels such as natural gas, propane, coal, fuel oil, or diesel results in emissions of CO_2, CH_4 and N_2O.

GHGs from stationary combustion are calculated by multiplying fuel consumption by a fuel-specific emission factor. While methodologies for calculating stationary combustion emissions are similar across protocols, the *LGO Protocol* provides a detailed calculation methodology for stationary combustion as well as data sources relevant to state DOTs. The following tables summarize the main activity data, likely data sources and locations, and emission factors for estimating stationary combustion emissions.

Table 2 presents the activity data needed to complete GHG emission estimates for stationary combustion while Table 3 describes the emission factors. See *Appendix A: Converted Emission Factors* for a complete list of GHG emission factors by fuel type.

Table 2. Stationary Combustion Activity Data

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

Table 3. Stationary Combustion Emission Factors

Description	Type of Emission Factor	Source
CO_2 Emission Factors: Unique to each type of fuel (metric tons CO_2/unit of fuel use)	Default national emission factors	LGO Protocol Appendix G.1; Appendix A of this memo for converted emission factors in units of activity data
CH_4 and N_2O Emission Factors: Unique to each type of fuel (metric tons CH_4 or N_2O/unit of fuel use)	Default national emission factors; varies by type of technology, combustion characteristics, and other factors	LGO Protocol Appendix G.1

PROXY DATA

If stationary fuel combustion is unavailable for certain buildings for the inventory year, energy use can be approximated using data from another year or data from buildings with comparable size and function. To use a proxy year's activity data, energy use should be normalized between the proxy and inventory year by accounting for the number of heating and cooling degree days and the percentage of fuel used for heating versus cooling. To use a proxy building's facility's activity data, determine the fuel use per square foot at a building of similar size and function, and multiply the area of the building with missing data by the fuel use per square foot value. See the *LGO Protocol* for a more detailed description and examples of proxy data calculations. A more detailed description of proxy building data is provided in Table 4.

Table 4. Proxy Data Sources for Stationary Combustion

Proxy Data Source	Alternative Activity Data	Data Source
Method 1: Proxy Year Data	Alternate year's fuel consumption by type of fuel	Equipment meters Fuel purchase records Fuel receipts
	Percentage of fuel used for heating and cooling	Facility manager Department Records
	Heating and cooling degree days in proxy and inventory year	NOAA[6]
Method 2: Proxy Building Data	Square footage of building	Facility manager
	Energy use of buildings with comparable size	Equipment meters, Fuel purchase records Fuel receipts, EIA's Commercial Building Energy Consumption Survey[7] (Consumption and Expenditures Tables, C1-C38)
	Energy use per square foot of comparable buildings	Calculation

Proxy Building Data

To use another building's energy consumption to estimate a building's fuel use (Method 2), the state DOT should first determine which fuels are used in the building with missing data. Then, the state DOT can choose which buildings to use as a proxy for energy consumption. State DOTs may choose to use energy data from buildings with similar functions (i.e., office buildings), fuel mix used, building size, or types of HVAC systems. Once a proxy building is chosen, the state DOT can obtain fuel consumption and square footage data for the proxy building, or average fuel consumption across similar types of buildings. The fuel use of the missing building is then calculated using the following equation:

Equation 2. Proxy Calculation for Estimating Building Fuel Consumption

$$\text{Annual Fuel Consumption} = \frac{\text{Fuel Consumption of Proxy Building(s)}}{\text{Square Footage of Proxy Building(s)}} \times \text{Square Footage of Building in Question}$$

[6] www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#

[7] www.eia.doe.gov/emeu/cbecs

Equation 3. Example Proxy Calculation for Estimating Building Fuel Consumption

Assume a state DOT has a 10,500 square foot building but does not keep records of the amount of fuel combusted by the facility. The state DOT has determined that the building uses both natural gas and fuel oil. In addition, assume that the state DOT does have fuel combustion data for similar buildings that use both fuel oil and natural gas.

The average fuel consumption per square foot of the other buildings are:

- 30 cubic feet of natural gas per square foot, and
- 0.05 gallons of fuel oil per square foot

The building's annual natural gas consumption can be calculated as follows:

Annual natural gas consumption = 30 [cubic feet/square foot] x 10,500 [square feet]

= **315,000 cubic feet**

Similarly, the building's annual fuel oil consumption can be calculated as follows:

Annual fuel oil consumption = 0.05 [gallons/square foot] x 10,500 [square feet]

= **525 gallons**

If energy use for other state DOT buildings is not available, state DOTs may refer to the Energy Information Administration's (EIA) Commercial Building Energy Consumption Survey (CBECS) for national average energy use per square foot in commercial buildings. CBECS is a national sample survey of the stock of U.S. commercial (non-residential) buildings, their energy-related building characteristics, and their energy consumption and expenditures. Average energy consumption factors are provided based on building sizes (floorspace), principal building activities, year of construction, region, ownership (government versus non-government owned), number of workers, number of floors per building, and others.

Table 5 provides select CBECS factors for natural gas and fuel oil consumption in buildings that may be relevant to state DOTs. A complete listing of CBECS factors for natural gas and other fuels used in stationary combustion can be found in the CBECS Consumption and Expenditures tables.

Table 5. Select Average Building Consumption Factors for Natural Gas and Fuel Oil (CBECS)[8]

Building Category	Natural Gas Consumption (cubic feet) per Square Foot	Fuel Oil Consumption (gallons) per Square Foot
All Buildings	43.0	0.11
Principal Building Activity		
Office	31.8	0.03
Warehouse and Storage	23.4	0.05
Vacant	23.0	NA

To estimate GHG emissions based on square footage, multiply the fuel use per square footage (ideally, based on other state DOT-owned facilities) by the square footage of the building:

Equation 4. Proxy Calculation for Estimating Annual Fuel Consumption using Average Energy Intensity

Annual Fuel Consumption = Fuel Consumption Factor per Square Foot x Square Footage of Building in Question

BIOGENIC CO_2 EMISSIONS FROM COMBUSTION OF BIOFUEL

Biofuel and biomass combustion in stationary equipment also result in GHG emissions, but CO_2 emitted from biogenic portion of the fuel is reported separately from stationary combustion emissions under scope 1.[9] The following example calculation demonstrates how to separate biogenic CO_2 emissions from anthropogenic CO_2 emissions for biomass or biofuel consumed in stationary combustion equipment. Methane (CH_4) and N_2O emissions from biofuel combustion are reported with scope 1 stationary combustion.[10]

[8] Source: Energy Information Administration. (December 2006). 2003 Commercial Buildings Energy Consumption Survey (CBECS): Consumption and Expenditures Tables, Table C24 and C34.

[9] Source: Federal GHG Guidance, Section 3.2.

[10] Carbon dioxide emissions from the combustion of fossil fuel are reported separately because the carbon is assumed to mimic natural short-term carbon cycles wherein the carbon is drawn from the atmosphere to grow the plant and later released to the atmosphere through combustion of the plant or plant-based fuel. This contrasts fossil fuel combustion, which adds carbon to the atmosphere that had been geologically sequestered for millions of years.

Methane and N_2O emissions are to be treated as a normal fuel combustion emission and included in the scope 1 inventory totals. Plants do not absorb CH_4 or N_2O as they grow; therefore, the CH_4 and N_2O released through biofuel and biomass combustion represent a net increase of these GHGs to the atmosphere.

Equation 5. How to Separate Biogenic CO2 emissions from Stationary Biofuel Combustion

To calculate emissions from 1000 gallons of B-20 biodiesel, first separate the biofuel blend into its bio-based and petroleum-based parts:

Diesel Use = 1000 [gallons B-20] x 0.80 [% non-biofuel] = 800 gallons of diesel

Biofuel Use = 1000 [gallons B-20] x 0.20 [% biofuel] = 200 gallons of biodiesel

Next, calculate biogenic and anthropogenic CO_2 emissions:

Anthropogenic CO_2 Emissions (Scope 1):

CO_2 emissions (MT) = Quantity of Diesel x Diesel CO_2 Emission Factor
=800 [gallons of diesel] x 10.21 [kg CO_2 /gallon] x 0.001 [MT/kg]
= **8.168** MT CO_2

Biogenic CO_2 Emissions (Reported Separately):

CO_2 emissions (MT) = Quantity of Biofuel x Biofuel CO_2 Emission Factor
=200 [gallons of diesel] x 9.45 [kg CO_2 /gallon] x 0.001 [MT/kg]
= **1.89** MT CO_2

All CH_4 and N_2O emissions from biofuel or biomass combustion are reported as scope 1 emissions. To calculate CH_4 and N_2O emissions, multiply the 800 gallons of diesel by the diesel emission factors and the remaining 200 gallons by the biodiesel emission factors.

Total Scope 1 Emissions = [MT Anthropogenic CO_2] + ([MT CH_4] x 21 [GWP]) + ([MT N_2O] x 310 [GWP])

MOBILE COMBUSTION

Mobile combustion includes emissions from state DOT-owned or controlled vehicles and mobile equipment. Examples of fleet vehicles include state DOT-owned or operated passenger cars, light-duty trucks, emergency vehicles and heavy-duty vehicles such as snowplows, graders, and street-sweepers, as well as off-road equipment such as agricultural equipment, bulldozers and movers used for construction and maintenance of roadways. Aircraft and waterborne vessels, such as ferry fleets, are included under the mobile combustion category. If a state DOT owns or operates a public transportation system, transit fleets would fall under this category as well. Like stationary combustion, biogenic CO_2 emissions from mobile biofuel consumption should be reported separately from mobile combustion emissions within scope 1.

This category includes emissions from all types of fuel combusted in mobile sources, including both conventional fossil fuels and alternative fuels (e.g., gasoline, diesel, compressed natural gas (CNG), liquefied petroleum gas

(LPG), aviation gas, jet fuel, navy special, ethanol). However, electricity purchased for Federal fleet electric vehicles should be reported under scope 2.[11]

Carbon dioxide emissions from mobile combustion are based on the amount of carbon contained in each fuel, and are calculated by multiplying fuel consumption by a fuel-specific emission factor. However, CH_4 and N_2O emissions vary depending on type of vehicle technology, fuel type, and distance traveled. The *LGO Protocol* provides a detailed calculation methodology for mobile combustion. The following tables summarize the main activity data and likely data sources for estimating mobile combustion emissions.

Table 6 presents the activity data needed to complete GHG emission estimates for mobile combustion while Table 7 describes the emission factors. See *Appendix A: Converted Emission Factors* for a complete list of GHG emission factors by fuel and vehicle type.

Table 6. Mobile Combustion Activity Data

Activity Data Description	Data Sources	Location of Data
Annual Fuel Use: Quantity of fuel consumed by mobile sources in physical units (i.e., gallons) (required for CO_2 emissions)	Fuel purchase receipts Mileage reimbursement records Maintenance records	Accounts payable Department records Fleet manager Fuel tracking system Fuel vendors or suppliers Contractor records
Annual Mileage: Distance traveled by vehicle type (i.e., light duty auto, light duty truck, heavy duty truck), fuel type (i.e., gasoline or diesel), and model year[12] (required for CH_4 and N_2O emissions)	Odometer readings Vehicle mileage logs Mileage reimbursement records Maintenance records	Department records Fleet manager Contractor records
Hours of Use (Non-road equipment): The number of hours of use by equipment type.	Maintenance records Equipment tracking software Estimated from fuel use	Department records Fleet manager Equipment tracking software Contractor records

[11] Source: Federal GHG Guidance, Section 2.2.2

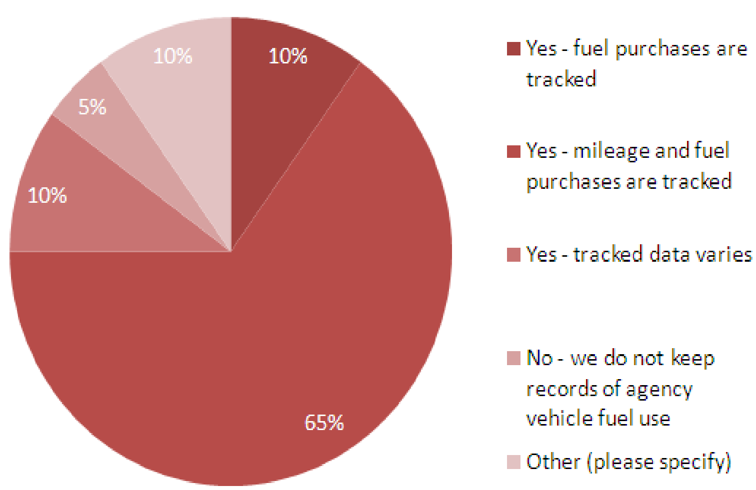
[12] If vehicle model years are unavailable, DOTs may calculate emissions using only vehicle type and fuel type.

Table 7. Mobile Combustion Emission Factors

Description	Type of Emission Factor	Source
CO_2: For each type of fuel; based on the carbon content of fuels	State-specific emission factor model inputs; Default national emission factors	Inputs to emission models for State Implementation Plans; LGO Protocol Table G.1; MOVES model
CH_4 and N_2O: For each type of fuel, vehicle type, and model year	State-specific emission factor model inputs; Default national emission factors	Inputs to emission models for State Implementation Plans; LGO Protocol Tables G.12, G.13,and G.14 Non-road equipment: Emissions factors can be derived from the NONROAD Model (see the Tools Available for GHG Accounting section of these Guidelines); MOVES model

In the survey of state DOTs conducted to support these Guidelines, most respondent state DOTs indicated that they track fuel consumed and miles traveled by their fleet vehicles and equipment. In many cases, this is done through state credit cards for fuel purchases. Many state DOTs also have centralized refueling stations where bulk fuel purchases are tracked. Others maintain records of mileage through regular odometer readings. Still, data availability, completeness, or quality may be a concern for state DOTs in compiling a GHG inventory. Alternative estimation methodologies based on proxy data are presented below.

Figure 6. Status of State DOT Fleet Fuel Consumption Data Tracking



Source: NCHRP State DOT GHG Survey, October 2010

PROXY DATA

If state DOTs do not track the amount of fuel they purchase, there are proxy data that can be used to estimate mobile fuel combustion. A detailed description and example calculations for these methodologies is provided in the *LGO Protocol.* A summary of activity data and likely data sources for several proxy methodologies is in Table 8.

Table 8. Proxy Activity Data for Mobile Combustion

Proxy Methodology	Alternative Activity Data	Data Source
Method 1: Estimate fuel use from annual mileage and vehicle fuel economy (for CO_2 emissions)	Vehicle classifications and fuel type for all vehicles in fleet and mobile equipment	Vehicle inventory Fleet manager
	Annual mileage traveled by each vehicle classification	Odometer readings Maintenance records Trip manifests Mileage logs
	Average fuel economy of vehicles	www.fueleconomy.gov
Method 2: Estimate fuel use from dollars spent on fuel and price of fuel (for CO_2 emissions)	Dollars spent on fuel purchases for each type of fuel	Fuel receipts Fuel station purchase records Reimbursement records
	Cost per gallon of fuel	Fuel receipts Average cost of fuel (EIA)[13]
Method 3: Proxy year's fuel use data (for CO_2 emissions)	Alternative year's fuel use data	Accounts payable Department records Fleet manager Fuel tracking system Fuel vendors or suppliers Mileage reimbursement records Maintenance records
	Changes in fleet composition or size from proxy year	Fleet manager
Method 4: Estimate mileage from fuel purchases (for CH_4 and N_2O emissions)	Fuel consumption by vehicle type	Fuel purchase receipts Mileage reimbursement records Maintenance records
	City and highway MPG of vehicles	Department records Fueleconomy.gov
	Breakdown of city versus highway driving for DOT vehicles	Department records National average used by EPA: 55% city, 45% highway
Method 5: Estimate fuel use using MOVES model	State DOT fleet's annual VMT by vehicle type	Odometer readings Maintenance records Trip manifests Mileage logs

[13] http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp. Please note that national average costs of fuel will not reflect differences in local fuel taxes.

If state DOTs do not have the level of detail required by the proxy methodologies, they may make reasonable assumptions to convert activity data to the appropriate format. For example, if a state DOT has bulk fuel purchases but does not have fuel use by vehicle type, they may allocate total fuel consumption across vehicle types based on the consumption patterns of their fleet.

As with stationary combustion, biogenic CO_2 emissions from biofuel combustion are reported separately from anthropogenic CO_2. Please see the example calculation of biogenic biofuel emissions under stationary combustion.

FUGITIVE EMISSIONS: REFRIGERANTS AND FLUORINATED GHGS

Refrigerant and fluorinated GHG emissions result from state DOT-owned or controlled sources most commonly related to heating, ventilation and air conditioning (HVAC) or refrigeration equipment. This includes HVAC or refrigeration systems in DOT buildings as well as mobile HVAC or refrigeration in state DOT vehicles or mobile equipment that emit HFCs, PFCs, and SF_6. Refrigerant emissions are considered a fugitive source because these emissions do not originate from a point source and are not captured by an emissions control system.

Ideally, GHG emissions from refrigerants are calculated by multiplying the quantity of refrigerants emitted by the GWP of each type of refrigerant. This requires knowledge of the exact types and amounts of refrigerants being used by state DOT HVAC or refrigeration systems and mobile air conditioning. Refrigerant and fluorinated GHG emissions are generally difficult to calculate because most state DOTs do not maintain a centralized inventory of their refrigeration equipment and maintenance records.

The *Federal GHG Guidance* and the *LGO Protocol* offer detailed methodologies to calculate refrigerant emissions from facilities using either a screening approach or a mass balance approach. The LGO Protocol also provides methodologies for estimating emissions of SF_6 emissions from transmission and distribution, and refrigerant emissions from mobile AC. The screening approach estimates emissions based on an inventory of the types and sizes of refrigeration and AC equipment owned and operated by the state DOT and emission rates of existing, new, and retired equipment. The mass balance approach assumes that changes in the net quantity of refrigerants added to a state DOT's equipment are due to losses or emissions of refrigerants due to leaks. The amount of refrigerant leaked is assumed to equal the amount of refrigerant returned or recharged to the equipment during servicing.

Not all refrigerants are required in a GHG emission inventory. Some refrigerants are both GHGs and ozone-depleting substances. Ozone-depleting refrigerants, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are being phased out under the Montreal Protocol and are therefore excluded from GHG inventories. Please see *Appendix* B: Global Warming Potentials for a list of HFC and PFC GHGs that are included in GHG inventories.

Table 9 presents the activity data needed to complete GHG emission estimates for fluorinated GHGs using either the screening approach or the mass balance approach.

Table 9. Refrigerant Activity Data

Activity Data	Data Sources	Location of Data
Screening Approach - Types of refrigerants used by DOT: Type of refrigerant (i.e., R-410 or R-132), and, ideally, charge size (lbs of refrigerant contained in equipment) of refrigeration equipment (i.e., HVAC systems)	Purchase records Maintenance records	Facility managers Contractor in charge of maintaining equipment Accounts Payable
Screening Approach - Change in refrigeration equipment: If any refrigeration equipment has been installed or retired in the inventory year	Purchase records Maintenance records	Facility managers Contractor in charge of maintaining equipment Accounts Payable
Mass Balance Approach - Change in quantity of refrigerants in DOT-owned or operated equipment: Amount of each refrigerant purchased and returned in a year (lbs) from a supplier, net changes in inventory of refrigerants (lbs) if kept on-site, or addition/removal of refrigerant to existing equipment.	Purchase records Maintenance records	Facility managers Contractor in charge of maintaining equipment Accounts Payable

PROXY DATA

Based on the experience of many public sector agencies, state DOTs will likely not have the detailed refrigerant data required to estimate fluorinated GHG emissions using the screening or mass balance approaches. As an alternative, state DOTs may choose to use a proxy methodology to determine refrigerant use in their buildings based on the square footage of their buildings, average refrigerant leakage rates, and average GWP-weight of refrigerants used in HVAC systems. Proxy methodologies for estimating refrigerant use are described in the *LGO Protocol*, chapter 6.6 (facility refrigerants) and 7.4 (for mobile air conditioning).

Table 10 summarizes the data needed to complete proxy estimates.

Table 10. Alternate Data for Refrigerant Emissions

Alternate Methodology	Alternative Activity Data	Data Sources
Mobile AC Equipment	Number of vehicles with air conditioning equipment	Facility managers Contractor in charge of maintaining equipment Accounts Payable
	Types of refrigerant used	Facility managers Contractor in charge of maintaining equipment Accounts Payable
	Refrigerant charge capacity of each piece of equipment	Upper bound of refrigerant charge capacity from IPCC (LGO Protocol Table 7.2) – 0.5-1.5 kg charge
Refrigeration/AC Equipment in Facilities	Number and types of refrigeration/AC equipment by equipment category	Facility managers Contractor in charge of maintaining equipment Accounts Payable
	Types of refrigerant use	Facility managers Contractor in charge of maintaining equipment Accounts Payable
	Refrigerant charge capacity of each piece of equipment	Upper bound of refrigerant charge capacity from IPCC (LGO Protocol Table 6.4)

If state DOTs do not know the refrigerant charge capacity of their refrigerant equipment, state DOTs can use the upper bound of the charge capacity ranges provided by the IPCC and listed in the *LGO Protocol* (Table 11)*;* for a full list of default emission factors, see the *IPCC Guidelines for National GHG Inventories (2006), Volume 3: Industrial Processes and Product Use*.

Table 11. Default Emission Factors for Refrigeration and AC Equipment[14]

Equipment Type	Capacity (kg)	Annual Loss Rate (% of Capacity)
Domestic Refrigeration	0.05 – 0.5	0.5%
Stand-Alone Commercial Applications	0.2 – 6	15%
Medium & Large Commercial Refrigeration	50 – 2,000	35%
Chillers	10 – 2,000	15%
Residential and Commercial A/C, including Heat Pumps	0.5 - 100	10%
Transport Refrigeration	3 – 8	50%
Mobile Air Conditioning	0.5 – 1.5	20%

[14] Source: LGO Protocol, Table 6.4 (adapted from IPCC Volume 3, Table 7.9)

The California Climate Action Registry's *General Reporting Protocol* describes a very simplified emissions calculation that can be performed to estimate whether refrigerant emissions are likely to be significant for state DOTs (i.e., fall under the state DOT's de minimis threshold).

Equation 6. Calculation for Estimating Rough F-GHG Emissions from Refrigeration/AC Equipment

HFC Leakage Emissions (kg) = Total Annual Refrigerant Charge x Assumed Annual Loss Rate (%)

This calculation, when combined with the data provided in Table 11, may be used to estimate potential refrigerant emissions and determine the relative size of refrigerants as an emission source, but should be replaced by state DOT-specific refrigerant use data when possible to increase accuracy.

An additional proxy methodology to use in the absence of refrigerant data is to use the square footage of buildings, an approximate amount of refrigerant required to cool the average building (0.003968 lbs refrigerant per square foot; based on interviews with HVAC experts), and the average annual refrigerant leakage rate, provided by IPCC. An example calculation is provided below. This approach is less accurate than the other approaches provided and should only be used if other options are not available.

Equation 7. Proxy Calculation of Refrigerant Use

Refrigerant Use = Building Square Footage x Approximate Refrigerant Charge per Square Foot
x Annual Refrigerant Leakage Rate

As an example, for a 20,000 square foot building using medium or large commercial refrigeration equipment, estimated refrigerant use could be approximated by the following:

Refrigerant Use = 20,000 [ft^2] x 0.003968 [lbs/ ft^2] x 0.35 = 27.8 [lbs]

While this seems to be a relatively minute amount, refrigerants have very high GWPs. If the refrigerant used in that building is HFC-134a, then total GHG emissions from refrigerants at that facility would be:

GHG Emissions = 27.8 [lbs HFC-134a] x 0.000454 [MT/lb] x 1,300 [GWP of HFC-134a] = 16.4 [MT CO_2E]

FUGITIVE EMISSIONS: ON-SITE WASTEWATER TREATMENT

On-site wastewater treatment will likely be a relatively small source of GHG emissions for state DOTs. On-site wastewater treatment emissions result from the decomposition of organics in wastewater from septic systems, on-site wastewater treatment lagoons, or other on-site wastewater treatment facilities owned or operated by state DOTs. The most likely type of on-site wastewater treatment process will be septic systems. For a detailed description of other types of on-site wastewater treatment, state DOTs can refer to the *LGO Protocol*.

Wastewater treatment emissions are calculated by multiplying the quantity of wastewater treated by emission factors specific to the type and characteristics of wastewater treatment method. Often, the amount of wastewater treated is approximated based on estimates of the population served by the wastewater treatment type. Table 12 summarizes main activity used by the *LGO Protocol* and *Federal GHG Guidance* to calculate wastewater treatment emissions.

Table 12. On-Site Septic Wastewater Treatment Activity Data

Activity Data	Data Sources	Location of Data
Employee Population Served by Septic: Number of employees at each facility served primarily by septic (or other on-site wastewater treatment)	Personnel Records Inventory of septic systems	Human Resources Asset Management Database
Advanced: Amount of BOD_5 produced per day (kg BOD_5/day)	Water testing – biological oxygen demand (BOD) monitoring	Environmental Compliance Manager

While seemingly straightforward, determining the population served by on-site wastewater treatment will likely pose a challenge for state DOTs unless records are kept of which facilities have on-site septic tanks or other wastewater treatment systems. In the absence of detailed data on wastewater treatment assets, state DOTs can use the following methodology to determine the percentage of a state DOT employees that are served by on- or off-site wastewater treatment.

There are two major decision points needed to determine how many employees use each type of wastewater treatment:

1. Does the DOT facility use primarily on- or off-site (contracted) wastewater treatment?
2. If the DOT uses on-site wastewater treatment, what is its primary method of wastewater treatment? (likely septic)

Some facilities may have both a septic system and use off-site wastewater treatment. If the facility does not have an on-site septic or other wastewater treatment system, it can be assumed that the facility uses contracted wastewater treatment (scope 3).

PROXY DATA

If the facility has an on-site septic system, its primary wastewater treatment location may still be off-site if the facility's expected wastewater generation is greater than the on-site treatment capacity. To estimate the expected daily wastewater generation at each facility, the average wastewater generation from the number of toilet flushes per person per day is multiplied by the number of employees at that facility.

The average toilet manufactured after 1995 has a wastewater generation rate of 1.6 gallons per flush (gpf), although toilets from the 1980s use about 3.5 gpf and pre-1980 toilets use between 5 and 7 gpf. An average wastewater generation of 4 gallons per flush can be used as a conservative estimate as it is unlikely that all toilets are of the more efficient models.

The average daily WW generation rate for each facility can therefore be estimated by:

Equation 8. Average Daily Wastewater Generation

Daily Wastewater Generation = 4gpf x Number of Flushes/day[15] x Number of Employees

If the facility's expected wastewater generation from the number of flushes per day per person is more than half of their on-site wastewater treatment capacity, the primary wastewater treatment location is off-site and the wastewater treatment type is contracted wastewater treatment (scope 3).

If expected wastewater generation is less than half of the facility's wastewater treatment capacity, the primary location of treatment is on-site and is included under scope 1.

OTHER SCOPE 1 EMISSION SOURCES

Two additional scope 1 emission sources are fugitive emissions from on-site landfills and process emissions. State DOTs are unlikely to have landfills on site. Process emissions refers to fugitive GHG emissions that are released as a result of an industrial process—typically material manufacturing (e.g., cement manufacture)—and are not likely to occur through state DOT operations. State DOTs can refer to the *LGO Protocol* and the *IPCC Guidelines for National Greenhouse Gas Inventories* for more information concerning these emission sources. Standard GHG protocols and registries require the inclusion of emissions from on-site solid waste disposal and industrial processes if these emission sources exist.

LAND USE/LAND USE CHANGE

GHG emissions from land use or land use change are typically excluded from an entity's operational GHG inventory primarily because, at this point, there are not standardized methodologies to estimate emissions from biological sequestration from local land use or land use change. However, as these methodologies develop it may be useful for state DOTs to consider the impact of land management practices on GHG emissions. Examples of land use changes that may be relevant to state DOTs are:

- Application of fertilizers or sewage sludge to land
- Deforestation of right-of-ways
- Reforestation of right-of-ways
- Conversion of grasslands or forestlands to paved surfaces

[15] The average number of flushes per person per day is approximately 5. In the absence of data, 5 flushes per day can be used in this equation; alternatively, the average value of 5 flushes per day can be allocated based on time spent at the workplace. Source: American Water Works Association Research Foundation, 1999. *Residential End Uses of Water.* http://www.waterrf.org/ProjectsReports/PublicReportLibrary/RFR90781_1999_241A.pdf.

METHODOLOGIES TO CALCULATE SCOPE 2 EMISSIONS

Scope 2 includes indirect emissions from purchased electricity and steam that are consumed within the organizational boundaries of the DOT but not generated on-site. The NCHRP survey conducted to support these Guidelines indicated that about 80 percent of state DOTs that have completed GHG inventories included purchased electricity and 20 percent included purchased steam.

This section describes the activity data, data sources, and recommended methodologies for estimating GHG emissions from scope 2 emission sources. The scope 2 emission sources detailed in this section include:

1) Purchased Electricity (associated GHGs: CO_2, CH_4, N_2O)
2) Purchased Steam, Hot Water, and Chilled Water (associated GHGs: CO_2, CH_4, N_2O)

PURCHASED ELECTRICITY

The generation of electricity purchased by the state DOT from an energy provider produces CO_2, CH_4, and N_2O emissions. While not generated on-site, state DOTs are indirectly responsible for emissions from their purchased electricity. Electricity consumption includes electricity used in DOT facilities as well as traffic services, which can include traffic signals, streetlights, cameras, variable message signs, tunnel ventilation systems, etc. Purchased electricity is typically one of the largest sources of GHG emissions and will be an important component of a state DOT's GHG emissions inventory.

Emissions from electricity are calculated by multiplying electricity consumption in kilowatt hours (kWh) by geographically-specific emission factors that represent the average fuel mix of a region's electricity generation.

Table 13. Purchased Electricity Activity Data

Activity Data	Data Sources	Location of Data
Facility Electricity Use	Electricity meters Utility bills	Accounts payable Energy office Facility managers Utility providers
Facility's eGRID Subregion	Facility's zip code	

Emission factors for electricity consumption can be either utility-specific or based on regional eGRID emission factors.[16] *Appendix A: Converted Emission Factors* provides electricity emission factors by eGRID subregion.

PROXY DATA

If electricity use is unavailable, state DOTs can use proxy data from another year or a facility of comparable size and function. These methodologies are the same as those presented under scope 1 stationary combustion and are discussed in detail in the *LGO Protocol*. As with stationary combustion, the proxy data can be obtained from

[16] Available at EPA's Clean Energy website (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html)

electricity consumption in buildings of similar size, primary function, age, or similar levels of energy efficiency. The following equation shows how to calculate estimated annual electricity consumption based on proxy building data:

Equation 9. Proxy Calculation for Estimating Building Electricity Consumption

$$\text{Annual Electricity Consumption} = \frac{\text{Electricity Consumption of Proxy Building(s)}}{\text{Square Footage of Proxy Building(s)}} \times \text{Square Footage of Building}$$

In the absence of data on electricity use in state DOT-owned or operated buildings, CBECS building survey energy consumption factors may be substituted to provide a rough estimate of electricity use in buildings with no data. The table below provides select CBECS factors for electricity consumption in buildings that may be relevant to state DOTs. A complete listing of CBECS factors for electricity consumption can be found in the CBECS Consumption and Expenditures tables.

Table 14. Select Average Building Electricity Consumption Factors (CBECS) [17]

Building Category	Electricity Consumption (kWh) per Square Foot
All Buildings	14.1
Principal Building Activity	
Office	17.3
Warehouse and Storage	7.6
Vacant	2.4

To estimate GHG emissions based on square footage, multiply the electricity consumption per square foot (ideally, based on other state DOT-owned facilities) by the square footage of the building:

Equation 10. Proxy Calculation for Estimating Building Electricity Consumption Based on Square Footage

$$\text{Annual Electricity Use} = \text{Electricity Use Factor per Square Foot} \times \text{Square Footage of Building in Question}$$

Equation 11. Example Proxy Calculation for Estimating Building Electricity Consumption based on Square Footage

Assume a state DOT office building has 10,500 square feet of space. Using the CBECS factor based on principal building activity, the estimated annual electricity consumption of the building can be calculated as follows:

$$\text{Annual Electricity Consumption [kWh]} = 17.3\ [\text{kWh/ft}^2] \times 10{,}500\ [\text{ft}^2] = \mathbf{181{,}650\ [kWh]}$$

The next section discusses the special case of electricity consumed through traffic lighting.

[17] Source: Energy Information Administration. (December 2006). 2003 Commercial Buildings Energy Consumption Survey (CBECS): Consumption and Expenditures Tables, Table C14.

Estimating Electricity Use from Streetlights – Installed Wattage

For many traffic services such as streetlights and traffic signals, there may not be available activity data. Instead, electricity use can be calculated based on the installed wattage of these lights. This methodology is described in the *LGO Protocol* and summarized below.

Table 15. Activity Data for Installed Wattage Proxy Methodology

Activity Data	Data Source
Number and wattage of bulbs in system	Streets Department Utility
Average annual daily operating hours for lights (hours/day; depends on management and operation)	Streets Department; typical assumption for streetlights is 10-13 hours per day; for traffic signals, 24 hours per day.

To estimate streetlight and traffic signal electricity consumption, perform the following calculation for each type of traffic service lighting:

Equation 12. Calculating Electricity Use of Traffic Services using Installed Wattage

Electricity Use (kWh) = Total installed wattage (watts) x Average operating hours (hours/day) x 365 (days/year) x 0.001 (kilowatts/watt)

Equation 13. Example Calculation of Traffic Services Electricity Consumption using Installed Wattage

State DOTs will need 2 pieces of data to estimate electricity consumption of traffic services using the installed wattage methodology:

(1) Total installed wattage of lights in each lighting category

(2) Average annual daily operating hours of each lighting category

As an example, assume a state DOT uses 1000 100-watt high pressure sodium streetlights that, on average, operate for 12 hours per day throughout the year. Electricity consumption from these streetlights can be estimated as follows:

Annual Electricity Consumption [kWh] =

1000 [units] x 100 [watts/unit] x 12 [hours/day] x 365 [days/year] x 0.001 [kilowatts/watt]

= **438,000 [kWh/year]**

PURCHASED STEAM, HOT WATER, AND CHILLED WATER

The generation of steam, hot water, or chilled water purchased by DOTs produces CO_2, CH_4, and N_2O emissions. This includes steam purchased for use by state DOT facilities primarily as hot or chilled water purchased for heating and cooling.

GHGs from purchased steam and chilled water are calculated by multiplying steam, hot water, or chilled water consumption in energy units (million British thermal units, MMBtu) by standardized national emission factors and other factors that account for boiler/chiller efficiency and transmission losses. The following table summarizes the main activity data and likely data sources for estimating purchased steam and chilled water emissions.

Table 16. Steam, Hot Water, or Chilled Water Activity Data

Activity Data	Data Sources	Location of Data
Steam, hot water, or chilled water consumption (MMBtu)	Metered energy use records Utility/supplier energy bills	Accounts payable Utility or supplier records
Fuels burned at generation plant (to obtain fuel-specific emission factors)	Metered energy use records Utility/supplier energy bills	Energy provider
Temperature and pressure of purchased steam (to determine energy content of steam)	Metered energy use records Utility/supplier energy bills	Energy provider
Chilled Water: Supplier's Coefficient of Performance (COP)	Utility supplier; default values (absorption chiller – 0.8, engine-driven chiller -1.2, electric-driven chiller-4.2)	Federal GHG Guidance (Table D-10)
Transmission Loss Factor	Default value – 10%	Federal GHG Guidance

Steam consumption should be reported in MMBtu. If steam consumption is reported in therms, it can be converted to MMBtu using a conversion factor of 0.1 MMBtu/therm. If steam consumption is reported in pounds, the DOT will need to know the temperature and pressure of purchased steam in order to calculate the steam's energy content using standard steam tables. The *LGO Protocol* has a more thorough discussion of unit conversions for purchased steam data. Emission factors for steam, hot water, or chilled water vary depending on the fuels burned at the generation plant. Default emission factors for steam and hot water are provided in the *Federal GHG Guidance.*

A thorough description of methodologies to estimate emissions from purchased steam, hot water, and heat and power purchases is available in the *LGO Protocol.*

METHODOLOGIES TO CALCULATE SCOPE 3 EMISSIONS

Scope 3 includes all indirect emissions that are not included in Scope 2. Similar to scope 2, scope 3 emissions are indirect emissions that are a consequence of the activities of the state DOT, but the actual emissions are generated by sources not controlled by the state DOT.

Historically, many organizations may have chosen not to include scope 3 emission sources in their inventory or to include a select few. The *Federal GHG Guidance* requires that federal agencies account for scope 3 emissions from six scope 3 sources: business air travel, business ground travel, employee commuting, transmission and distribution (T&D) losses associated with purchased electricity and steam, contracted solid waste, and contracted wastewater treatment. State DOTs may choose to include these scope 3 emissions as well as other scope 3 emission sources in their inventory—such as supply chain emissions associated with material purchases and contractor/vendor activities.

Similarly, the *LGO Protocol* encourages local governments to "identify and measure all scope 3 emission sources to the extent possible… [as] doing so provides an opportunity for innovation in GHG management." The *WRI Draft Scope 3 Accounting and Reporting Standard* (*WRI Scope 3 Standard*) presents several reasons for including scope 3 emissions in a GHG inventory, including:

> These Guidelines recommend including 5 scope 3 emission sources in state DOT GHG emission inventories:
>
> 1. Vendor and Contractor Emissions
> 2. Employee Commuting
> 3. Business Travel
> 4. Transmission and Distribution Losses
> 5. Contracted Solid Waste

- Scope 3 emissions are often a significant source of emissions for an organization
- Scope 3 emission sources often have significant GHG reduction potential
- State mandates or regional reporting programs may encourage the inclusion of certain scope 3 emission sources
- Scope 3 emission sources present an opportunity to engage suppliers and enable supply chain GHG management

State DOTs have the option to (1) not include scope 3 emission sources in their inventory, (2) include the scope 3 emission sources recommended in these Guidelines, or (3) include their own preferred set of scope 3 emission sources. The next section overviews the approach that was used to determine the scope 3 emission sources that these Guidelines recommend including in a state DOT GHG inventory. A similar methodology that state DOTs can use to evaluate which scope 3 emission sources are relevant for their GHG inventory is included in *Appendix* D: Scope 3 Evaluation Approach.

The WRI *Scope 3 Accounting and Reporting Standard* outlines a basic methodology for determining which scope 3 emission sources to include in an organization's GHG inventory, including four steps:

1. Establish a list of evaluation criteria
2. Assign weights to each criterion based on relative importance
3. Rank the evaluation criteria for each scope 3 emission source
4. Sources with the highest scores are included in the inventory

Five evaluation criteria were identified as being relevant to state DOTs. These criteria were used to identify the scope 3 emission sources that are recommended by these Guidelines.

- Magnitude of emissions,
- Level of effort (LOE) required to estimate emissions,
- GHG mitigation potential,
- Importance to stakeholders, and
- Consistency with other inventories and programs.

Based on the analysis conducted using these criteria, these Guidelines recommend including Vendor and Contractor Emissions, Employee Commuting, Employee Business Travel, , Contracted Solid Waste Disposal, and Transmission and Distribution Losses in state DOT GHG inventories if the state DOT chooses to include scope 3 emission sources.

The remainder of this section provides methodologies for estimating scope 3 emissions for select sources. The section begins with those sources that these Guidelines recommend including in a state DOT GHG emission inventory and follows with discussions of additional scope 3 sources. The scope 3 emission sources detailed in this section include:

1) Vendor and Contractor Emissions (associated GHGs: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6)
2) Employee Commuting (associated GHGs: CO_2, CH_4, N_2O)
3) Employee Business Travel (associated GHGs: CO_2, CH_4, N_2O)
4) Transmission and Distribution Losses (associated GHGs: CO_2, CH_4, N_2O)
5) Contracted Solid Waste Disposal (associated GHGs: biogenic CO_2, CH_4, N_2O)
6) Contracted Wastewater Treatment (associated GHGs: CH_4, N_2O)
7) Supply Chain Emissions (associated GHGs: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6)

VENDOR AND CONTRACTOR EMISSIONS

This category quantifies emissions from the operations of a state DOT's vendors and contractors, and includes the contractor's scope 1 and scope 2 emissions attributable to the state DOT. This includes a state DOT's "Tier 1" suppliers, which are vendors or contractors with whom the state DOT has a purchase order for goods or services. For example, a construction company that is contracted to perform road maintenance work for a state DOT is considered a Tier 1 supplier of a service for the state DOT and that construction company's scope 1 and scope 2 emissions can be included in the state DOT's scope 3 emission estimate. Tier 2 suppliers with whom Tier 1 suppliers have a purchase order for goods or services, such as a company from which the construction company purchases materials used in road maintenance work, are outside the scope of a state DOT's inventory (i.e., they are not considered the state DOT's scope 3 emissions) and instead fall under the vendor/contractor's scope 3 emissions inventory.[18] Emissions from state DOT vendors and contractors should be reported separately from other state DOT scope 3 emissions sources.

As state DOTs will have a number of contracted services, the *LGO Protocol* provides the following considerations for whether to include emissions from contracted services in a GHG emissions inventory:[19]

[18] WRI Draft Corporate Value Chain (Scope 3) Standard (November 2010)

[19] LGO Protocol (2010)

1. Is the contracted service a service that is normally provided by state DOTs, and therefore included in other state DOT GHG inventories?
2. Was the contracted service previously provided by the state DOT and would thus be included in previous GHG emission inventories?
3. Does the state DOT exert significant influence over the contractor's emission sources?

If these considerations apply to a state DOT's contracted services, the *LGO Protocol* recommends that the contractor's scope 1 and scope 2 emissions be included in a GHG inventory as a state DOT scope 3 emission source in order to have a comparable and complete emissions inventory to inform policies and decision-making.

Construction and maintenance contracts are likely to be the most significant emission sources in this category. State DOTs typically hire contractors to construct and repair roadways, bridges, tunnels, and buildings. Contractors may also provide essential maintenance services such as mowing and snow removal. The bulk of emissions associated with these contracts come from the tailpipes of vehicles and equipment used in construction, repair, and maintenance. Off-road construction equipment may use diesel fuel, compressed natural gas (CNG), or electricity provided by a generator. On-road vehicles and maintenance equipment typically use gasoline or diesel fuel.[20]

Other types of contractors, such as consultants and caterers, also produce GHG emissions from their operations; however those are smaller emission sources and might not be attributable to specific projects.

To quantify vendor and contractor emissions, the following general procedure is recommended, based on the WRI/WBCSD *Draft Scope 3 Standard*:

1. Identify and select relevant "Tier 1" vendors and contractors with which a DOT has a direct purchase order for goods or services. This includes construction and maintenance contracts for maintaining transportation facilities, construction materials (if purchased directly by the DOT), and contractor-owned vehicles or off-road equipment.
2. Collect emissions data from suppliers. This could mean either collecting activity data and calculating the vendor or contractor's emissions, or requiring vendors and contractors to compile their own scope 1 and scope 2 emissions inventory. DOTs will have to prioritize which vendors and contractors they include in this category as it will likely be infeasible to collect emissions data for all vendors and suppliers. DOTs can choose to prioritize vendors and contractors based on their largest contracts or other criteria.
3. Allocate supplier emissions attributable to the DOT, based on the percent of the vendor/contractor's business (on an hours or dollars basis) conducted with the state DOT or other criteria. This will be necessary if activity data or emission estimates specific to the work performed or products purchased under the state DOT contract is unavailable.
4. Aggregate emissions data across all Tier 1 suppliers to obtain total vendor and contractor emissions.

The recommended activity data and methodologies presented in the *Methodologies to Calculate Scope 1 Emissions* and *Methodologies to Calculate Scope 2 Emissions* sections can be used to quantify a vendor or contractor's relevant scope 1 and scope 2 emissions. Expanded methodologies for collecting vendor and contractor emissions data can be found in the WRI/WBCSD's *Draft Scope 3 Standard.*

[20] Methodologies for estimating GHG emissions associated with construction, repair, and maintenance projects require improvement. State DOTs do not typically have access to records of fuel consumed on particular projects, and contractors may not even maintain these data. Earlier methodologies used a ratio of fuel consumed per project dollar to estimate fuel consumption and GHG emissions; however, that method is based on dated conversion factors and is deemed inaccurate. Current research is exploring options to improve the conversion factors as well as to use a simple methodology that invokes basic project characteristics such as project size, type, and duration. Advanced methodologies would require a robust analysis of empirical data across many types of projects to develop reliable estimation parameters and assumptions.

PROXY DATA

In the absence of actual vendor and contractor emissions data for construction projects, state DOTs may choose to use a dataset compiled for the California Department of Transportation to approximate GHGs. This dataset presents the average number of hours that different equipment types were used during the following six construction activities:

- Resurface Existing Highway
- Construct Freeway – Extra Lane
- Pavement Rehabilitation/Widening
- Construct/Reconstruct Bridge
- Construct Median/Thrie Beam Barrier, and
- Landscaping

Emissions from these construction activities can be calculated using the following equation:

Equation 14. Calculating CO_2 Emissions for Construction Projects

CO_2 emissions (MT CO_2) = Hours of operation by equipment type (hours) x CO_2 emission factor (MT CO_2/hour)

The hours of operation and CO_2 emission factors for each project type are shown in Table 17. These numbers include idle equipment hours.

Table 17. Average Equipment Hours of Operation and CO_2 Emission Factors for Highway Construction Projects

Type of Construction Equipment	CO_2 Emission Factor[21]	Hours of Operation by Type of Construction Project[22]					
	(MT CO_2/ Hour)	Resurface Existing Highway	Construct Freeway / Extra Lane	Pavement Rehabilitation/ Widening	Construct / Reconstruct Bridge	Construct Median, Three Beam Barrier	Landscaping
Bore/Drill Rigs	0.326	43	54	81	43	581	0
Cement & Mortar Mixers	0.521	0	110	11	78	0	0
Dumpers/Tenders	0.467	8	2	0	11	0	0
Concrete/Industrial Saws	0.255	27	152	67	121	4	0
Cranes	4.6	5	54	3	147	0	0
Crushing/Processing Equipment	0.935	0	0	0	0	0	0
Crawler Tractors/ Dozers	27.03	0	315	98	234	0	8
Excavators	5.774	91	437	164	751	35	0

[21] Greenhouse Gas Mitigation Measures for Transportation Construction, Maintenance, and Operations Activities (ICF 2010)

[22] Caltrans Construction Equipment Activity Database: http://www.uctc.net/papers/828.pdf (2004)

Graders	6.585	139	452	415	198	78	0
Off-Highway Tractors	27.03	0	0	0	0	0	0
Off-Highway Trucks	27.078	0	0	0	0	0	0
Pavers	3.81	391	390	367	205	7	0
Paving Equipment	0.655	111	150	143	122	22	0
Plate Compactors	0.367	22	67	2	55	5	0
Rollers	3.07	754	973	935	735	95	18
Rough Terrain Forklifts	3.2	19	390	19	524	11	0
Rubber Tire Loaders	7.815	313	466	379	1092	142	93
Scrapers	12.412	13	413	121	37	0	0
Signal Boards	0.513	950	2265	2645	3478	990	0
Skid Steer Loaders	0.724	45	110	22	175	222	1289
Surfacing Equipment	0.543	193	153	213	231	20	0
Trenchers	2.512	23	36	2	20	0	870
Tampers/Rammers	NA	4	25	4	10	6	24
Tractors/Loaders/Backhoes	1.342	480	996	243	560	190	131
Other Construction Equipment	10.19	0	0	0	0	0	0
Aerial Lifts	0.739	0	126	3	452	0	0
Forklifts	1.353	0	12	8	33	0	0
Sweepers/Scrubbers	2.22	244	214	461	38	2	0
Other General Industrial Equipment	0.474	104	106	59	196	0	0
Other Material Handling Equipment	1.673	0	2	0	0	0	0
Chain Saws (<6HP (commercial))	NA	0	34	0	0	0	0
Chippers/Stump Grinders	NA	0	0	0	0	0	7
Commercial Turf Equipment	NA	1	26	0	0	0	0
Generator Set	0.83	37	662	41	1279	0	36
Pumps	0.621	14	232	2	68	0	0
Air Compressors	0.777	43	468	84	1506	287	0
Welders	0.619	33	21	0	114	0	0
Pressure Washers	0.75	4	1	0	117	0	0
Heavy Duty Truck	NA	1412	4328	2774	2997	923	3389
Light Duty Truck	NA	1882	4632	2255	6324	1617	5563
Water Truck	27.078	237	371	440	520	179	0

EMPLOYEE COMMUTING

When state DOT employees commute to and from work, the combustion of fuels in their vehicles results in emissions of CO_2, CH_4, and N_2O. This includes employee travel between their home and primary worksite, or between home and alternate worksites in vehicles or modes of transport not owned by the state DOT. To estimate emissions from employee commuting, required activity data are commute frequency as well as information on the average one-way distance of the commute and the mode of transport used.

The best source of employee commuting data is through a voluntary survey of employees on their daily commuting habits. Once commuter data are obtained, GHG emissions from employee commuting can be calculated using the same methodology as mobile combustion emissions from the DOT's vehicle fleet: by multiplying fuel consumption by its fuel-specific emission factor. The *Federal GHG Guidance* describes how to gather data and estimate emissions from employee commuting. Table 18 summarizes the main activity data and likely data sources for estimating mobile combustion emissions.

Table 18. Employee Commuting Activity Data

Activity Data	Data Sources
Number of passengers that commute by each mode	Commuter survey
Number of weekly commuting trips by mode (i.e., personal vehicle, carpools, train, bus)	Commuter survey; Regional/national transportation surveys (i.e., Census Bureau)
Number of commute days per year	Commuter survey; annual number of business days. Default value used by *Federal GHG Guidance* is 230 days/year
Distance of trip by mode (miles)	Commuter survey; Computer address (payroll records, personnel records, parking permits); Regional/national transportation surveys (i.e., Census Bureau)

PROXY DATA

Employee commuter miles traveled by transportation mode can be approximated using state DOT employee population data and commuter statistics provided by the Journey to Work data of the US Census 2008 American Community Survey (ACS)[23] and the 2009 National Household Travel Survey (NHTS).[24] Metropolitan planning organizations (MPOs) may have more location-specific data on employee commuting; regional or municipal commuting data are preferable to national averages.

The Census ACS contains data on the mode of travel by state and can be used to determine the percentage of state DOT commuters that use each mode of travel. These percentages, augmented by similar data from the 2009 NHTS, can be mapped to the 10 transportation modes provided in the *U.S. EPA Climate Leaders Program, Technical Guidance, Optional Emissions from Commuting, Business Travel, and Product Transport* document. These

23 US Census American FactFinder, American Community Survey, 2008, Journey To Work Data

24 National Household Travel Survey, 2009, US DOT

categories are: POV Passenger Car, POV SUV or Truck (Gasoline), POV SUV or Truck (Diesel), Car Pool, Van Pool, Bus, Metro/Transit Rail, Commuter Rail, Intercity Rail and Walking and/or Bicycling[25].

After determining the percent of commuters using each mode, the average commute distance (miles/day) by mode can be determined using the NHTS 2009 dataset. This value is then multiplied by the number of state DOT employees and the percent of commuters using each mode to determine the number of state DOT miles traveled (per day) by DOT employees by mode. Next, the annual commuter miles traveled by mode can be calculated by multiplying the average number of commute days each year at each DOT location. The default number of workdays per year is 230, unless otherwise indicated. The number of workdays per year can be adjusted to accommodate compressed work week schedules.

Table 19 and Table 20 present alternative activity data sources and GHG emission factors by mode of transportation.

Table 19. Alternative Activity Data Sources for Employee Commuting

Alternative Activity Data	Data Source
Average commuting data by state	US Census, American Community Survey 2008 Journey to Work data; National Household Travel Survey 2009 MPO commuting data
Number of state DOT employees	Personnel Records/ Human Resources
Number of workdays per year	Default = 230 days

Table 20. Employee Commuting Emission Factors by Mode[26]

Commuter Mode	Fuel	CO_2 (MT/mile)	CH_4 (MT/mile)	N_2O (MT/mile)
POV Passenger Car	Gasoline	0.000364	3.1×10^{-8}	3.2×10^{-8}
POV SUV or Truck	Gasoline	0.000519	3.6×10^{-8}	4.7×10^{-8}
POV SUV or Truck	Diesel	0.000561	1×10^{-9}	2×10^{-9}
Car Pool*	Gasoline	0.000182	1.6×10^{-8}	1.6×10^{-8}
Van Pool**	Gasoline	0.00013	9×10^{-9}	1.2×10^{-8}
Bus	Diesel	0.000107	1×10^{-9}	1×10^{-9}
Metro/Transit Rail	Electric	0.000163	4×10^{-9}	2×10^{-9}
Commuter Rail	Diesel	0.000172	2×10^{-9}	1×10^{-9}
Intercity Rail	Diesel	0.000185	2×10^{-9}	1×10^{-9}
Walking/Bicycling	NA	NA	NA	NA

* Assumes 2 passengers per vehicle
**Assumes 4 passengers per vehicle
NA – Not Applicable; POV – Personal Operated Vehicle

[25] U.S. EPA Climate Leaders Program, Technical Guidance, Optional Emissions from Commuting, Business Travel, and Product Transport

[26] Source: Federal GHG Guidance. Values are weighted based on modes provided by U.S. EPA Climate Leaders Program, Technical Guidance, Optional Emissions from Commuting, Business Travel, and Product Transport, see: http://www.epa.gov/stateply/documents/resources/commute_travel_product.pdf

Equation 15. Example Employee Commuting Calculation

As an example, assume an MPO has collected regional commuter data that indicates, on average, the following breakdown of commuter modes:

- 75% drive to work alone
- 10% carpool to work
- 10% use metro/transit rail to get to work
- 5% use buses to get to work

Furthermore, of the 75% of workers that drive alone, the MPO's data indicates that approximately 60% drive passenger cars and the other 40% drive SUVs.

If the state DOT has 200 employees in this region, calculate the number of employees using each mode as follows:

Passenger Car Commutes = 200 [employees] x 0.75 [% drive alone] x 0.60 [% passenger cars]

= 90 employees

SUV Commutes = 200 [employees] x 0.75 [% drive alone] x 0.40 [% SUVs]

= 60 employees

Carpool Commutes = 200 [employees] x 0.10 [% carpool] = 20 employees

Next, assume the MPO has determined the average commute distance traveled by commuters in the region is 16 miles (8 miles each way). Therefore, an average employee is assumed to commute 3,680 miles to work each year (16 miles x 230 workdays per year).

Multiplying the average commute distance (3,680 miles/year) by the number of employees that use each mode, the state DOT can estimate the miles traveled by each mode of transportation:

Mode of Transportation	Number of Employees	Annual Miles Traveled
Drive Alone, Passenger Car	90	331,200
Drive Alone, SUV	60	220,800
Carpool	20	73,600
Transit Rail	20	73,600
Bus	10	36,800

Finally, multiply the annual miles traveled by each mode of transportation by the appropriate emission factors in Table 20 to estimate GHG emissions from employee commuting.

EMPLOYEE BUSINESS TRAVEL

This category includes CO_2, CH_4, and N_2O emissions from business-related travel undertaken by state DOT employees aboard third-party owned or operated aircraft and vehicles, such as for conferences or site visits. This source includes passenger vehicle travel using rental cars and taxis as well as public transportation such as rail and bus. This does not include commutes to or from the primary workplace and emissions from company-owned or leased aircraft and vehicles, as these are captured under scope 1. Only emissions related to the combustion of fuels (e.g. consumed by aircraft) are included in this source; life-cycle emissions associated with fuel production and vehicle manufacture (capital equipment and infrastructure) are excluded.

GHG emissions from employee business travel can be calculated by distance traveled tracked through a travel agency and/or travel forms completed by employees. Once trip frequency and distance are obtained, GHG emissions from business air travel are calculated by multiplying activity data, in the form of person-miles traveled, by a mode-specific emission factor. The *Federal GHG Guidance* provides detailed calculation methodologies for estimating emissions from employee business travel. Employee air and ground travel are presented separately in the following sections.

EMPLOYEE BUSINESS AIR TRAVEL

Business air travel GHG emissions are calculated using information on passenger air miles traveled. Table 21 summarizes the main activity data and likely data sources for estimating emissions from air travel, and Table 22 provides GHG emission factors for air travel. Detailed methodology descriptions are provided in the *Federal GHG Guidance*.

Table 21. Business Air Travel Activity Data

Activity Data	Data Sources	Location of Data
Passenger Miles Traveled by Segment (short, medium or long haul [miles])	Agency Travel records, Travel forms such as expense reporting forms or Reimbursement receipts	(Official) Travel Agency Budget office

Table 22. Business Air Travel Emission Factors

Distance Category	CO_2 Emission Factor (MT CO_2/passenger-mi)	N_2O Emission Factor (MT N_2O/passenger-mi)	CH_4 Emission Factor (MT CH_4/passenger-mi)
Short Haul (< 300 miles)	0.000277	8.5×10^{-9}	1.04×10^{-8}
Medium Haul (≥ 300 and < 700 miles)	0.000229	8.5x 10-9	1.04 x 10-8
Long Haul (≥ 700 miles)	0.000185	8.5x 10-9	1.04 x 10-8
Unknown segment class	0.000271	8.5x 10-9	1.04 x 10-8

Source: Adapted from Table C-3: Emission Factors for Airline Business Travel, Federal GHG Guidance.

Advanced Methodology

If more detailed data are available for employees a more accurate methodology can be used to estimate emissions.

Table 23. Business Air Travel Activity Data for Advanced Methodology

Activity Data	Data Source
Distance traveled for each trip	Employee records, Central recording system (e.g. the GSA Travel MIS tool)
Fuel burn rate for each aircraft; weighted average number of seats per aircraft/occupancy rates	EMEP/CORINAIR Emission Inventory Guidebook (EIG) 2006; Airlines/ Aircraft manufacturers/ OAG Aviations Solutions' Schedules Database and Fleet database/www. SeatGuru.com
CO_2 Emission Factor	3.15 kg CO_2/kg fuel[1] from the EIG (2006)
Cargo and Passenger Allocation	U.S. Department of Transportation, Bureau of Transportation Statistics (BTS)
Passenger Load Factor Data	UN International Civil Aviation Organization (ICAO); average load factor 0f 75.93% for U.S. carriers and 67.35% for non U.S. carriers

[1] A conversion factor of 2.20 lb/kg can be used

EMPLOYEE BUSINESS GROUND TRAVEL

The *Federal GHG Guidance* provides two methodologies for estimating emissions from employee business ground travel: one that includes only rental vehicles, and a second that addresses all modes of ground travel. The emission calculation methods and emission factors are similar to those for calculating mobile combustion emissions.

The basic information required to estimate emissions resulting from business car rental are the number of car rentals in each inventory year. Table 24 summarizes the main activity data and likely data sources for estimating mobile combustion emissions. Emission factors are specific to vehicle class.

Table 24. Employee Business Ground Travel Activity Data

Activity Data	Data Sources	Location of Data
Number of Rentals	Travel reimbursement forms Rental agency records	Car rental agencies; travel agency
Miles Traveled	Employee receipts; State DOT travel agency	Default average factor 419 miles traveled per rental (and average duration of 5.1 days)

Alternatively, rental car distance can be estimated using the following activity data:

Table 25. Alternate Rental Car Activity Data

Activity Data	Data Sources
Number of rental days by vehicle class	Rental Vehicles: State DOT's travel agency Personally-owned vehicles (POVs): Travel reimbursement forms
Mileage per rental	Rental Vehicles: State DOT's travel agency

Alternate Methodology

The *Federal GHG Guidance* also provides an alternative distance-traveled methodology that agencies can use to calculate emissions from employee ground business travel. Table 26 summarizes the main activity data and likely data sources for estimating emissions based on distance travelled by employees during business travel. Emission factors for each mode of transportation are the same as those used for employee commuting (see Table 20).

Table 26. Alternate Business Ground Travel Activity Data

Activity Data	Data Sources
Distance traveled (miles) by mode of ground transport (rental car, POV/taxis, bus, train) [miles]	Rental Vehicles: Agency's travel agent; Personal Vehicles: Travel reimbursement forms Representative sample of distance-based data

TRANSMISSION AND DISTRIBUTION OF PURCHASED ELECTRICITY

There are energy losses associated with the transmission and distribution of purchased electricity that result in CO_2, CH_4, and N_2O emissions. Similar to scope 2 GHG emissions from purchased electricity, transmission and distribution (T&D) emissions result from purchased electricity used to power state DOT facilities and traffic services such as streetlights. T&D emissions are calculated by multiplying purchased electricity consumption by a national average T&D loss adjustment factor. The *Federal GHG Guidance* describes the calculation methodology for T&D losses, and uses a 6.18% average T&D loss percentage. The T&D loss adjustment factor is:

Equation 16. T&D Loss Adjustment Factor

$$T / (1-T) = 0.0618/(1-0.0618) = 0.0659$$

The adjusted loss factor is multiplied by the state DOT's electricity consumption to determine electricity lost through T&D:

Equation 17. T&D Electricity Losses Calculation

$$\text{T\&D Electricity Losses (kWh)} = \text{Electricity consumption (kWh)} \times 0.0659$$

T&D electricity losses are multiplied by the regional emission factor based on the state DOT's eGRID subregion (see *Appendix A: Converted Emission Factors*). Table 27 summarizes the activity data for calculating GHG emissions from T&D losses.

Table 27. T&D Activity Data

Activity Data	Data Sources	Location of Data
Amount of electricity purchased (kWh) (equal to scope 2 electricity consumption)	Electricity meters Utility bills	Accounts payable Energy office Facility managers Utility providers
T&D Loss Factor	Default national average	0.0659 (*Federal GHG Guidance*)

CONTRACTED SOLID WASTE DISPOSAL

Most state DOTs will likely dispose of their solid waste off-site through contracted solid waste disposal services, which results in CH_4 and biogenic CO_2 emissions from the decomposition of waste. Table 28 presents the activity data needed to calculate GHG emissions from solid waste disposal, which can be calculated using EPA's LandGEM model. [27] The *Federal GHG Guidance* details an approach for calculating GHG emissions form contracted solid waste disposal using the LandGEM model.

Table 28. Contracted Solid Waste Disposal Activity Data

Activity Data	Data Sources
Mass of solid waste disposed in inventory year (short ton)	Waste manager
Does the landfill have a LFG collection system?	Default assumption: 50% of landfills have LFG collection (Federal GHG Guidance)

PROXY DATA

Most state DOTs, indeed most organizations, do not track the amount of solid waste disposed. State DOTs are, however, likely to maintain information on the frequency of waste collection by the waste disposal vendor. Waste collection, or pick-ups, typically occurs on a weekly or bi-weekly basis depending on the remoteness of the waste disposal locations. Pick-up frequency is typically agreed upon in the contract with, and specified in the billing from, the waste disposal vendor.

Approximating solid waste disposed will need to occur at the level where the vendor contracts or billing are maintained. To estimate the amount of solid waste disposed, the individual will need to know the annual number of pick-ups, the number and average size of dumpsters included in pick-ups, the average fill-level of dumpsters when they are emptied, and the average waste density (Table 29).

Table 29. Alternative Activity Data Sources for Contracted Solid Waste Disposal

Alternate Activity Data	Data Sources	Default
Annual number of pick-ups	Service records or contract	NA
Dumpster number	Staff survey or asset records	NA
Average dumpster size	Staff survey or asset records	6 cubic yards[28]
Average dumpster fill-level	Vendor provided or default	75 percent
Average waste density	Vendor provided or default	150 lbs/cubic yard[29]

NA – Not Applicable

[27] http://www.epa.gov/ttncatc1/dir1/landgem-v302-guide.pdf

[28] http://breezelogic.com/discountdumpstershop/DumpsterSizes.aspx

[29] EPA's Wastewise Volume-to-Weight Conversion Factors. www.epa.gov/osw/partnerships/wastewise/pubs/conversions.pdf (assume 50 percent mixed organics and 50 percent comingled glass, plastic, and metal)

The following equation outlines the calculation to approximate solid waste disposal in the absence of measured or reported data.

Equation 18. Proxy Calculation for Estimating Solid Waste Tonnage

Annual Solid Waste Disposal (tons) = Annual Number of Pick-ups x Number of Dumpsters x Average Dumpster Size (cubic yard) x Average Dumpster Fill-level (%) x Average Waste Density (lbs/cubic yard) x 1 ton/2000 lbs

CONTRACTED WASTEWATER TREATMENT EMISSIONS

Most state DOTs will likely use contracted wastewater treatment services instead of or in addition to on-site wastewater treatment systems. Contracted wastewater treatment results in emissions of CH_4 and N_2O emissions from the decomposition of organics in wastewater.

Wastewater treatment emissions are calculated by multiplying the quantity of wastewater treated by emission factors specific to the type and characteristics of wastewater treatment method. Often, the amount of wastewater treated is approximated based on estimates of the population served by the wastewater treatment type. Table 30 presents the activity data needed to calculate GHG emissions from contracted wastewater treatment based on methods detailed in the *Federal GHG Guidance*.

Table 30. Contracted Wastewater Treatment Activity Data

Activity Data	Data Sources	Location of Data
Employee Population Using Contracted Wastewater: Number of employees at each facility served primarily by off-site wastewater treatment	Personnel Records Inventory of septic systems	Human Resources Asset Management Database
National breakdown of wastewater treatment systems by type	Default national averages[30]	Federal GHG Guidance

Facilities that have either no on-site wastewater treatment systems or primarily use contracted wastewater treatment services will fall under this category. As discussed under the *Scope 1* section, the biggest challenges to determining the employee population that uses contracted wastewater is determining if sites primarily have on-or off-site wastewater treatment. If the state DOT treats wastewater using both on- and off-site treatment the state DOT should determine the percent of wastewater generation that is attributable to off-site (or contracted) wastewater using the methods described in the *Fugitive Emissions: On-Site Wastewater Treatment* section of these Guidelines.

[30] The Federal GHG Guidance assumes that 36.5% of wastewater is treated by contracted centralized wastewater treatment plants with nitrificiation/denitrificiation, and 63.5% of wastewater is treated by centralized (aerobic) WWTPs without nitrification/denitrification. In addition, it is assumed that treated effluent is discharged into receiving bodies of water. This is based on the U.S. EPA Clean Watersheds survey (2004), which indicated that 36.5% of WWT systems surveyed had an advanced wastewater treatment processes with a nitrification/denitrification stage.

SUPPLY CHAIN EMISSIONS

Supply chain emissions include emissions associated with upstream activities to produce materials and fuels purchased by state DOTs. The purchased materials and fuels are defined as materials or fuels purchased or otherwise brought into the organizational boundary of the state DOT. For example, the purchase of gasoline would be accounted for under supply chain emissions. Although the actual combustion of the gasoline is covered under scope 1 emissions (mobile combustion), the drilling for and refinement of the oil expends a significant amount of energy and emits GHGs that can be accounted for as supply chain emissions.

While the Vendor/Contractor emissions are emissions associated with the activities of entities that state DOTs contract with (e.g., the emissions associated with construction activities of State DOT contractors), supply chain emissions are emissions associated with the production of goods, materials, and fuels that state DOT purchases or procures.

The production of materials and fuels encompass a range of upstream activities including raw material extraction or mining, refining, manufacturing, and transportation of materials throughout the production process. State DOTs procure and/or purchase a range of materials and fuels including asphalt, deicing materials, concrete, office supplies, diesel fuel, gasoline, etc. These procured materials and fuels require upstream energy and material inputs in their production. The emissions associated with the required upstream energy and material inputs used in the production of the procured materials and fuels are considered supply chain emissions. For example, the purchase of gasoline as a fuel source would be accounted for under this category. Although the actual combustion of the gasoline is covered under scope 1 emissions (mobile combustion), upstream supply chain including extraction, drilling, and refining of the oil emits GHGs that can be accounted for as supply chain emissions. Another example is the supply chain emissions associated with the state DOT procurement of asphalt concrete. For asphalt concrete, supply chain GHG emissions include those associated with raw materials acquisition, manufacturing, and energy used to transport raw materials. Since asphalt concrete is composed primarily of aggregate and road asphalt binder, a co-product of petroleum refining, the upstream process energy GHG emissions result from the manufacture of these main raw materials as well as the asphalt production process which involves sorting and drying the aggregate, heating the asphalt binder, heating and applying the mixture. Supply chain emissions associated with this process can be included in the GHG inventory as a state DOT scope 3 emission source if the state DOT purchases the materials directly. If the materials are purchased by a contractor and used for state DOT projects they are not included in the state DOT inventory because only contractor scope 1 and scope 2 emissions fall within the organizational boundaries of the state DOT. Please see the Vendor and Contractor Emissions, section of these Guidelines for additional information regarding this accounting approach. Table 31 provides a list of selected materials relevant to State DOT for which there exists upstream product GHG emission factors based on U.S. national average life-cycle data.

Table 31. Select Materials Upstream GHG Supply Chain Emission Factors

Material or Fuel	Upstream Emission Factor	Tool	Source
Diesel fuel	0.0191 grams CO_2e/BTU	GREET	Argonne National Labs
Gasoline fuel	0.0188 grams CO_2e/BTU	GREET	Argonne National Labs
LNG fuel	0.0179 grams CO_2e/BTU	GREET	Argonne National Labs
Asphalt Concrete	0.11 $MTCO_2$e/Ton	WARM	US EPA
Steel	3.71 $MTCO_2$e/Ton	WARM	US EPA
Aluminum	15.69 $MTCO_2$e/Ton	WARM	US EPA

In practice, supply chain scope 3 emissions are difficult to quantify and reporting of them is currently optional by accepted protocols including the *LGO Protocol* and WRI's *Scope 3 Accounting and Reporting protocol*. Accounting for supply chain emissions for the procured materials and fuels requires detailed information on the upstream life-cycle emissions associated with producing a wide range of materials. Some common materials' life-cycle emission factors are available in tools and databases such as EPA's WARM, DOE's GREET model, the European Ecoinvent life cycle database, and the NREL's US LCI database. However, many materials and fuels upstream production emission factors are unavailable and/or may not be geographically or technically specific to state DOTs.

THIRD-PARTY TRAVEL ON STATE ROADS

Another potential scope 3 emissions source that DOTs do not control but can influence through transportation projects and planning is transportation by third parties on state roads. It may be useful to quantify this scope 3 emission source so that the impact of travel demand management and other environmental projects on the state's transportation emissions can be measured.

While state DOTs own and operate state roads, GHG emissions associated with travel on these roads is outside the boundaries of the *operational* GHG emission inventory covered by these Guidelines. Third-party travel on state roads is more appropriately included within a state-level GHG emission inventory.[31]

RENEWABLE ENERGY GENERATION AND RECS

To reduce GHG emissions state DOTs may wish to incorporate on-site renewable energy generation into their operations. Renewable energy is specifically defined as energy that is derived from indefinitely renewable resources. According to Section 3 of EPAct 2005, these sources include solar, wind, biomass, landfill gas, ocean (including tidal, wave, current and thermal), geothermal, municipal solid waste, and new hydroelectric generation capacity.[32] The use of energy generated from these resources displaces the need for conventional fossil fuel use and the release of GHG emissions.

On-site renewable energy use may result in a reduction of on-site natural gas use or other fossil fuel combustion, in which case the resulting lower use of these fuels should be reflected in lower scope 1 GHG emissions. When on-site renewable energy results in the production of electricity and the subsequent reduction in electricity consumption from the grid, lower scope 2 GHG emissions from purchased electricity and lower scope 3 emissions from transmission and distribution losses should be reflected. Other forms of on-site renewable energy that reduce energy consumption through thermal energy methods (such as solar water heating, ground source heat pumps, and geothermal direct use) do not require direct reporting or verification, as their impact is directly accounted for in decreased electricity and fossil fuel consumption. However, it is good practice to routinely informally report and assess thermal systems to ensure their efficient operation and use.

It is conventional practice to always report the total consumption of on-site renewable energy in GHG emission and energy use reporting for transparency and year-to-year comparisons. For proper and sufficient reporting, each source

[31] For more information on state-level GHG emission inventories, please refer to EPA's State and Local Climate and Energy Program. http://www.epa.gov/statelocalclimate/state/activities/ghg-inventory.html

[32] http://www1.eere.energy.gov/femp/regulations/epact2005.html

of on-site energy generation should include the type of generation, the specific location of the installation and corresponding eGRID subregion, the amount of energy generated as measured in MWh or MMBtu, and the placement of all facility meter locations relative to the renewable installation.

If a state DOT finds that installing and operating a renewable energy system is impractical at a given location, another option is to use Renewable Energy Certificates (RECs). RECs provide a useful way for state DOTs to reduce GHG emissions by purchasing credit for off-site renewable energy when the location, ownership, or operation of a renewable energy-creating asset is impractical. For electricity (the most common application), a REC is a tradable certificate created when one MWh of electricity is produced by an individual renewable energy source. By purchasing a REC, a state DOT can claim the production of the corresponding amount of renewable electricity and thereby reducing scope 2 GHG emissions. A REC can only be claimed once through acquisition and retirement, meaning that a particular 1 MWh of renewable electricity and the GHG emissions benefits belong to the holder of the REC and no longer the producer of that renewable electricity. RECs are often formally issued to generators by regional or state tracking systems that provide authenticity and verification of the individual attributes of RECs. Even if RECs are not issued by a governing organization, private parties can contractually agree to terms where RECs are created, traded, and retired. Key attributes for RECs include the source of the renewable electricity, the generator vintage, and year and location of generation. Table 32 presents activity data for state DOTs to account for emissions reductions from renewable energy and RECs.

Table 32. Renewable Energy/REC Activity Data

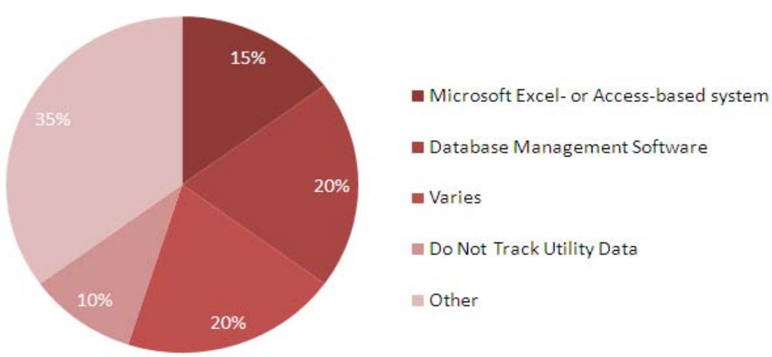
Activity Data	Location of Data
Amount of Renewable Energy (MWh or MMBtu)	Facilities or Asset Records; utility bills; on-site meter readings
Source/Type of Renewable Generation (e.g., wind)	Facilities or Asset Records; utility bills; on-site meter readings
Location/eGRID Subregion of Renewable Generation and Meter	See *Appendix A: Converted Emission Factors*
Number of Renewable Energy Credits (REC) (MWh)	REC seller/provider; EPA eGRID map
Source/Type of REC (e.g., wind)	REC seller/provider; EPA eGRID map
Location/eGRID Subregion of REC Generation	See *Appendix A: Converted Emission Factors*
Meter location if generator is on-site	Facilities or Asset Records; utility bills; on-site meter readings

TOOLS AVAILABLE FOR GHG ACCOUNTING

State DOTs have many GHG accounting tool options available to them for preparing a GHG emission inventory. Currently, state DOTs do not have a GHG accounting tool that is specifically tailored to their operations; however, there are many tools available that can be leveraged to meet a state DOTs needs. The tool that a state DOT chooses to use will depend on their unique situation and preferences. Generally, the tool options available to state DOTs can be grouped into three categories 1) Internal Tools, 2) Commercially Available Tools, and 3) Publicly Available Tools.

1) **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 using Microsoft Excel, Access or other platforms to supplement other state DOT systems, to supplement publicly available tools, or to perform all GHG calculations for their inventory. In a survey of state DOTs conducted to support these Guidelines, approximately 90 percent of respondent state DOTs indicated that they tracked utility data (Figure 7).
2) **Commercially Available Tools** – many firms and software companies sell GHG accounting tools either as an off-the-shelf product or bundled as part of GHG accounting services. These commercially-available options range from Microsoft Excel- or Access-driven tools to robust environmental management information systems (EMIS). EMIS are software that, in addition to managing GHGs, can also be designed to manage other environmental and energy performance metrics. The options available have a range of capabilities, features, and implementation and operation costs.
3) **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. Descriptions of several publicly-available GHG accounting tools are provided in the following section.

Figure 7. Utility Data Collection Systems Used by State DOTs



Source: NCHRP 25-25 (65) State DOT GHG Survey, October 2010

In selecting a GHG accounting tool, state DOTs should compare their GHG management needs with the capabilities and costs of these three options to identify the best fit. Generally, it is good practice for state DOT staff to familiarize themselves with GHG accounting procedures using publicly-available and internally-developed tools and calculators. As staff become more familiar with the steps needed to prepare a GHG inventory they will be better positioned to identify a long-term fit for the state DOT's GHG management.

A state DOT will have many requirements, or needs, 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:

- **Data resolution:** Generally, finer data allow for more detailed analysis, which better informs stakeholders and leads to better management decisions. Daily or monthly energy and other consumption information at the building, vehicle, and equipment level will provide better insight on GHG emissions than total annual fuel consumption for an entire site.
- **System compatibility:** GHG accounting tools that can share data with other state DOT systems, such as a financial management system, or external systems and tools, such as EPA's Portfolio Manager, will ease the data collection burden on state DOT staff and leverage the capabilities of other analysis tools.
- **Inventory boundaries:** GHG inventory structure varies depending on the purpose of the inventory. As an example, a municipality can choose to prepare an inventory of its own government operations or for all activities that occur within its city boundaries. There are tools available to account for each type of inventory. State DOTs should be sure to choose a GHG accounting tool that focuses on operations and organizes the inventory by scope.
- **GHG accounting procedures:** GHG accounting tools should adhere to the GHG accounting principles cited in these Guidelines and should clearly present the methods and emission factors used to prepare the GHG emission estimates.
- **Reporting:** The state DOT needs to report GHG emissions to other state agencies or to GHG registries, the state DOT may wish to ensure that the GHG accounting tool generate standard reports or files to fulfill these GHG reporting requirements.
- **Dashboards and Analytics:** Preparing a GHG emission inventory is the first step in ongoing GHG management. A state DOT may wish to make sure that the GHG accounting tool has the capability to view GHG inventory information in various charts, tables, and graphs across various temporal and spatial scales using visualization "dashboards". The state DOT may also want to be able to analyze their data, calculate potential GHG emission reductions of planned mitigation actions, and prioritize efforts to reduce emissions using various analytical and planning calculators that can be included in GHG accounting tools.

PUBLICLY AVAILABLE GHG ACCOUNTING TOOLS

Below are descriptions of several GHG accounting tools that state DOTs may find useful when preparing their GHG emission inventory. For consistency, these Guidelines recommend that state DOTs who use publicly available tools to prepare their GHG emission inventory reference the FEMP GHG and Sustainability Workbook and GreenDOT tool where possible. State DOTs that have internal tools or are using commercially available tools should cross-walk the methods and emission factors used by these tools with their own to understand and note where differences in accounting procedures reside.

Federal Energy Management Program (FEMP) GHG and Sustainability Workbook33

The FEMP GHG and Sustainability Workbook is an Excel-based calculator released by FEMP to help federal agencies prepare GHG emission in response to Executive Order 13514. The calculator follows the methods presented in the Federal GHG Guidance and is geared towards federal agencies, but will produce emission estimates using activity data similar to the activity data noted in these guidelines for scope 1 and 2 emission sources as well as six scope 3 emission sources.

Greenhouse Gas Calculator for State Departments of Transportation (GreenDOT)

GreenDOT is a spreadsheet-based calculator tool, available through NCHRP. It calculates carbon dioxide (CO_2) emissions from the operations, construction, and maintenance activities of state Departments of Transportation (DOTs). GreenDOT is designed to calculate emissions for geographical areas ranging from a single project to an entire state, and over time periods ranging from one day to several years. The two most likely uses of the tool are: (1) calculate agency-wide emissions, and (2) calculate emissions related to a specific project, covering a period of days or years. GreenDOT calculates emissions in four separate modules:

1. The Electricity Module calculates emissions from electricity used in street lights, street lamps, signs, and other roadway appurtenances, based on either electricity consumption or detailed data on types of appurtenances and hours of use. The module estimates the impact of mitigation strategies including more efficient lighting technologies and reducing the amount of lighting used.
2. The On-Road Module calculates emissions from cars and trucks, based on either fuel consumption or detailed data on VMT and vehicle types. The module estimates the impact of mitigation strategies including VMT reduction, measures to improve the fuel economy of vehicles, and alternative fuels and vehicle types.
3. The Off-Road Module calculates emissions from construction and maintenance equipment, based on either fuel consumption or detailed data on equipment types and hours of use. The module estimates the impact of mitigation strategies including activity reduction, measures to improve the fuel economy of equipment, and alternative fuels and vehicle types.
4. The Materials Module calculates emissions embodied in roadways, based on volumes and types of materials used. Embodied emissions are associated with energy used in the extraction, processing, and transportation of materials. The module estimates the impact of mitigation strategies including using recycled materials and warm mix asphalt.

An auxiliary calculator included in the tool also estimates the impact of traffic management strategies, based on changes in average vehicle speeds. DOTs can use GreenDOT to help calculate their current emissions and to evaluate mitigation strategies.

World Resources Institute Greenhouse Gas Protocol Initiative Cross Sector Tools[34]

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). The WRI GHG accounting tools are particularly useful if state DOTs choose to build a GHG accounting system in-house or supplement existing systems as they provide transparent calculations and emission

[33] http://www.fedcenter.gov/Documents/index.cfm?id=16387

[34] http://www.ghgprotocol.org/calculation-tools/all-tools

factors for estimating GHG emissions. Calculators that are relevant to state DOTs include stationary combustion, purchased electricity, transport or mobile sources, and refrigeration and air conditioning.

CARROT[35]

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 for estimating GHG emissions and comes pre-loaded with GHG emission factors and calculations. It is available online to the Registry members, verifiers, and the public. Web access allows for simultaneous usage by more than one state DOT staff at any one time.

ADDITIONAL TRANSPORTATION-SPECIFIC TOOLS FOR EMISSION ESTIMATION AND MITIGATION

In addition to the GHG accounting tools noted above, the following transportation-specific 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[36]

MOVES is an emissions model developed by U.S. EPA that can be used for multiple purposes, 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. MOVES can calculate emission factors based on the characteristics of a specific vehicle and the project facility, including congestion patterns, grade, and pavement quality.

Of note for state DOTs is that MOVES can be used to generate fuel economy factors specific to modes and travel patterns. In addition, MOVES can be used to directly calculate total emissions from state DOT vehicles.

EPA's NONROAD Model[37]

The NONROAD model estimates emissions of CO_2 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. It does not cover emissions from commercial marine, aircraft, and locomotives. Fuel types include gasoline, diesel, compressed natural gas (CNG), and liquefied petroleum gas (LPG). DOTs can input data on equipment types, horsepower, and hours of operation to calculate emissions.

---

[35] http://www.climateregistry.org/

[36] http://www.epa.gov/otaq/models/moves/index.htm

[37] http://www.epa.gov/otaq/nonrdmdl.htm

The Pavement Lifecycle Assessment Tool for Environmental and Economic Effects (PaLATE)[38]

PaLATE is a spreadsheet tool designed for life-cycle assessment (LCA) of environmental and economic effects of pavements and roads. PaLATE is a product of the University of California at Berkeley. A copy of the tool is available upon request. 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. PaLATE calculates embodied emissions from roadway materials using an economic input output (EIO) model. Inputs to the model include specific volumes and transportation distances of raw materials by roadway layer.

Argonne National Laboratory's GREET Fleet Footprint Calculator (GREET Fleet)

GREET Fleet is a simple spreadsheet calculator that can be used to estimate the lifecycle (well to wheels) GHG emissions of on-road and off-road fleets. The model is designed to allow fleet managers to estimate their GHG emissions in just a few steps. For on-road vehicles, the user can estimate emissions either inputting data on fuel use or inputting data on fleet size, VMT, and fuel economy by vehicle type. Vehicle types include a range of conventional and alternative propulsion technologies. For off-road equipment, the user can estimate emissions either inputting data on fuel use or inputting data on fleet size, annual hourly usage, and brake horsepower (a measure of fuel economy) by equipment type. Equipment types include a range of conventional and alternative propulsion technologies. Users can also select different fuel production pathways for both on-road and off-road fleets.

Sacramento Air Quality Management District's Road Construction Model (RCM)[39]

RCM is a Microsoft Excel spreadsheet model developed by the Sacramento Metropolitan Air Quality Management District (SMAQMD). RCM's primary use is to estimate construction-related air pollution emissions (criteria pollutants and CO2) associated with road and bridge projects subject to CEQA and/or NEPA. RCM estimates off-road emissions from operation of heavy-duty construction equipment. RCM also estimates on-road emissions from employee trips, and from the import and/or export of fill material.

RCM allows the user to estimate construction emissions using very basic inputs such as project type, duration, size, soil type, and start year. The model then predicts the type of equipment and hours of equipment use on the project; however, the model estimates equipment use based on data from only a handful of actual projects.

RCM is likely to overestimate off-road emissions for many projects. The model assumes that each piece of equipment operating during a given phase of construction operates every day for eight hours. In practice, some equipment is likely used less. On the other hand, RCM is thought to underestimate the total equipment fleet used in bridge and interchange projects. No detailed information on the scale of these discrepancies is currently available.

---

[38] http://www.ce.berkeley.edu/~horvath/palate.html

[39] http://www.airquality.org/ceqa/index.shtml.

MANAGING INVENTORY QUALITY

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. This understanding underscores the fact that state DOTs should work to collect activity data that is as accurate as possible, use best available methodologies to estimate GHGs, keep careful record of the data and methods used to produce the inventory, speak to the uncertainty of emission estimates and assumptions used to produce them, and continually strive to improve the quality of GHG emission estimates. This continual improvement process should include a clear and methodic approach to controlling and assuring quality in the inventory estimates. The following section lays out appropriate quality control (QC) and quality assurance (QA) measures state DOTs should use to prepare a GHG emission inventory.

After completing a GHG emission inventory, QAQC procedures should be put in place 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. Key QAQC considerations are:

- Inventory documentation should be sufficiently detailed and clear as to allow an independent but knowledgeable individual to obtain and review the data and methods used and reproduce the emission estimates.
- When possible, internal reviews should be conducted by qualified technical reviewers who were not involved in developing the inventory
- Uncertainty should be addressed in a qualitative manner.

QUALITY CONTROL PROCEDURES

All inventories should adhere to the principles of GHG accounting noted in the GHG Accounting Basics section of these Guidelines. Additionally, a set of quality control and quality assurance procedures should be implemented to ensure that the inventories are of the highest quality. Quality control, as defined by the IPCC in its *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* is a system of routine technical activities to measure and control the quality of the inventory as it is being developed.[40] A basic QC system should provide consistent checks to ensure data integrity, correctness, and completeness, and to identify and address errors and omissions. It should also provide procedures for documenting and archiving inventory material and recording all QC activities. Techniques for implementing these checks and procedures are discussed below within the categories of *Data Collection and Estimating Emissions* and *Data Documentation*.

DATA COLLECTION AND ESTIMATING EMISSIONS

Several common sense procedures govern the collection, maintenance, and use of activity data, emission factors, and other primary data elements used to prepare a GHG emission inventory. Appropriate procedures can minimize

[40] IPCC (2000) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. , National Greenhouse Gas Inventories Programme, Intergovernmental Panel on Climate Change. Montreal. May 2000. IPCC-XVI/Doc. 10 (1.IV.2000).

the extent to which errors in data collection occur; various checks on the data and files can further reduce the errors that occur. QC procedures for gathering, inputting, and handling data include:

- Use existing GHG calculation tools where possible to minimize incorrect applications of GHG inventory methods and incorrect entry of emission and conversion factors.
- Collect data electronically where possible to minimize transcription errors.
- If preparing calculation spreadsheets, avoid hardwiring conversion and other factors into formulas.
- If identical activity data are used in multiple emission estimates, ensure that all estimates reference the single activity data source.
- Build in computerized checks to highlight possible calculation errors.
- Back-calculate emissions by dividing final emission estimates by the activity data to determine an "implied" emission factor. Compare the implied emission factor to emission factors used to prepare the emission estimate.

DATA DOCUMENTATION

Inventory documentation should be sufficiently detailed and clear as to allow an independent but knowledgeable individual to obtain and review the data and methods used and reproduce the emission estimates. Complete and accessible documentation of methods, data and data sources, assumptions, phone logs, contacted personnel, and other data information is necessary. This information should be referenced in a GHG emission inventory plan and maintained in supporting files.

Supporting files should be maintained for all inventory years and should include:

- Lists of the methods, emission factors, data sources, and assumptions made for each emission source.
- List of the names, position, and contact information for all individuals who supplied data to the inventory.
- Lists of the names and locations of all GHG calculation tools, spreadsheets, and systems used to prepare the GHG inventory.
- Contact Reports for telephone conversations or meetings, copies of written communications (letters, e-mails, or facsimiles) containing data or other information related to producing emission estimates or evaluating inventory quality.
- Copies of reference materials or data that are new to the current inventory year, such as:
  - Scanned versions of data received in hard copy.
  - A complete reference citation for any published data used in the inventory.
  - Copies of data downloads, PDFs, and other electronic data.

QUALITY ASSURANCE PROCEDURES

After completing a GHG emission inventory, QA procedures should be put in place to ensure that the inventory receives a thorough review to ensure that it adheres to the GHG accounting principles of relevance, completeness, consistency, transparency, and accuracy. Consistent and thorough procedures should be followed throughout the review processes to ensure the highest quality of the final inventory product. Inventories can either be reviewed internally or can be submitted for external verification. Irrespective of the review approach that is used, careful selection of reviewers, clear instructions for reviewers, and open presentation of emission estimates and inventory documentation will result in the highest quality review.

INTERNAL REVIEW

When possible, internal reviews should be conducted by qualified technical reviewers who were not involved in developing the inventory (second-party verification). When that is not feasible, individuals involved in inventory development may review the inventory. Reviewers should be asked to review the inventory and compare the product against the GHG accounting principles previously noted. They should be provided with all inventory materials, such as all data source files, the GHG inventory plan, contact information for individuals who provided data, and inventory documentation. The reviewers should also be provided access to all GHG systems or calculation tools used to complete the GHG emission estimates. Reviewers should conduct spot checks of the emission calculations, approve assumptions, and check to make sure that the data, emission factors, and methods used to produce the inventory have been properly referenced.

Reviewers should provide the inventory developers with a document that assesses the inventory within the context of the GHG accounting principles and that notes any data or methodological concerns. Inventory developers should revise the inventory as agreed upon in response to the reviewer's comments and resubmit the inventory for a final review. The reviewer should verify that all comments and recommendations were sufficiently addressed before approving the final GHG inventory.

EXTERNAL VERIFICATION

Some state DOTs may choose to have their GHG inventory reviewed by an entity external to the state DOT—third party verification. This will likely most often be the case for state DOTs that are participating in a GHG registry as many GHG registries require that organizations receive third-party verification prior to submitting the GHG inventory. Many firms provide third-party verification services. External verifications should be treated in a manner similar to internal reviews, wherein the entity performing the verification should be provided with all inventory materials such as all data source files, the GHG inventory plan, contact information for individuals who provided data, and inventory documentation. The verifier should note any concerns or recommendations in a verification file and work with the state DOT to revise the inventory as needed.

UNCERTAINTY

GHG emission estimates are subject to several types of uncertainty, ranging from uncertainty associated with the accuracy of the activity data (often called *parameter uncertainty*) to uncertainty associated with the ability of the calculations to accurately account for real-world emissions (often called *model uncertainty*). These types of uncertainty are generally categorized as *estimation uncertainty*—they are associated with the actual calculations used to estimate emissions. There is also scientific uncertainty, which arises only when the science of actual emissions (or sequestration) is not fully understood. Scientific uncertainty is most often associated with methods to estimate emissions from land management because estimating emissions from natural processes, or practices that mimic natural processes, is complex given the dynamics of natural systems.

Individuals involved in preparing a GHG emission inventory should recognize that every emission estimate has a degree of uncertainty associated with it. These individuals should address uncertainty either qualitatively, by noting areas of uncertainty in a formal inventory report or when presenting emissions, or quantitatively by conducting statistical analyses that speak to the degree of uncertainty associated with an emission estimates.

State DOTs should address uncertainty in a qualitative manner. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks* presents a good model for those state DOTs that are interested in addressing uncertainty using a quantitative approach as does the IPCC's *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.*[41] [42]

[41] http://www.epa.gov/climatechange/emissions/usinventoryreport.html

[42] IPCC (2000) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. , National Greenhouse Gas Inventories Programme, Intergovernmental Panel on Climate Change. Montreal. May 2000. IPCC-XVI/Doc. 10 (1.IV.2000).

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. Irrespective of whether GHG emissions are reported through voluntary or mandatory measures, the principles of GHG accounting should be followed.

MANDATORY GHG REPORTING

Recently the Consolidated Appropriations Act empowered the US EPA to require reporting of GHG emissions for facilities that annually emit more than a specified threshold. Additionally, eighteen states have passed legislation that requires mandatory reporting of GHG emissions. These include California, Oregon, Washington, New Mexico, Iowa, Wisconsin, North Carolina, Maryland, Delaware, and the New England states.

EPA's Greenhouse Gas Reporting Program

In response to the FY2008 Consolidated Appropriations Act, EPA, beginning in January 2010, began to require reporting of GHG emissions from large sources and suppliers in the United States with intent to collect accurate and timely emissions data to inform future policy decisions. Under the Greenhouse Gas Reporting Program, suppliers of fossil fuels or industrial GHGs, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions are required to submit annual reports to EPA. To do so, reporters using the technical support documents provided by subpart.[43] State DOT facilities are unlikely to exceed the threshold for reporting under the GHG Reporting Program, and therefore this rule is not likely to affect state DOT reporting.

California Air Resources Board (CARB) California Global Warming Solutions Act

Under the California Global Warming Solutions Act, California's Air Resources Board approved mandatory reporting of GHG emissions effective in January 2009. Similar to EPA's Greenhouse Gas Reporting Program, facilities that emit more than 25,000 metric tons or more per year are required to report their GHG emissions.[44]

VOLUNTARY GHG REPORTING

THE CLIMATE REGISTRY

The Climate Registry is a non-profit collaboration among states, provinces, territories, and Native Sovereign Nations in North America that sets standards for members to calculate, verify, and report greenhouse gas emissions in a single, public registry. By providing standard reporting guidelines through its *General Reporting Protocol* and acting as a central repository for voluntary GHG emissions inventories of entities across North America, The Climate Registry facilitates comparison among a variety of non-profit, corporate, and governmental organizations. The

[43] http://www.epa.gov/climatechange/emissions/subpart.html

[44] http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm

Climate Registry utilizes the Climate Registry Information System (CRIS) as an online GHG calculation, reporting, and verification tool for members. In addition, GHG emissions inventories submitted to the Climate Registry must be verified by a third party.[45]

STATE GHG REPORTING

Many states voluntarily prepare GHG emission inventories and report the GHG emission inventory results to EPA's State Climate and Energy Program. EPA's State Climate and Energy Program helps states develop policies and programs that can reduce GHG emissions, lower energy costs, improve air quality and public health, and help achieve economic development goals. EPA provides states with and advises them on proven, cost-effective best practices, peer exchange opportunities, and analytical tools. The Program also provides tools and resources for states to perform state-level GHG emission inventories in a consistent manner. To date, at least 32 states have prepared and reported GHG emission inventories to EPA's State Climate and Energy Program.[46]

REGIONAL GHG REPORTING

In addition to state-level reporting, there are several regional GHG reporting initiatives, including the Regional GHG Initiative (RGGI), Western Climate Initiative (WCI), and Midwest Regional GHG Reduction Accord. Regional GHG reporting programs often utilize existing state-level reporting requirements where possible to ease reporting burdens.

Regional Greenhouse Gas Initiative (RGGI)

The Regional Greenhouse Gas Initiative, or "RGGI," was the first mandatory and market-based effort in the U.S. to reduce GHG emissions, beginning January 1, 2009. RGGI includes 10 states in the Northeast and Mid-Atlantic, and requires reporting exclusively for the electric power sector. RGGI includes an auction of permits and a trading system, and uses offsets to reduce emissions.[47] It is unlikely that state DOTs will need to report emissions under RGGI, as this program focuses on the electric power sector.

Western Climate Initiative (WCI)

The Western Climate Initiative (WCI) is a collaboration of 7 western states and 4 Canadian provinces that is designing a cap and trade system for major emitters. In addition to the member states, there are numerous other states and provinces in the US, Canada and Mexico that are "observers." The cap-and-trade program is set to begin in 2012.[48] Depending on regional or state emissions reductions set by the WCI, state DOTs may be indirectly impacted by state-government-wide efforts to account for and reduce GHGs

Midwest Regional Greenhouse Gas Reduction Accord

The Midwest Regional Greenhouse Gas Reduction Accord is the result of an agreement among governors in the Midwest to establish a Midwestern GHG reduction program for member states and also acts as a working group to provide recommendations regarding the implementation of the accord. Member states include Iowa, Illinois, Kansas,

---

[45] http://www.theclimateregistry.org/resources/reporting-toolkit/voluntary-reporting/

[46] http://www.epa.gov/statelocalclimate/state/state-examples/index.html

[47] http://www.rggi.org/home

[48] http://www.westernclimateinitiative.org/

Manitoba, Michigan, Minnesota, and Wisconsin. Indiana, Ohio, Ontario, and South Dakota are observers of the Accord.[49] Depending on regional or state emissions reductions set by the Midwest Regional GHG Reduction Accord, state DOTs may be indirectly impacted by state-government-wide efforts to account for and reduce GHGs.

[49] http://www.midwesternaccord.org/

REFERENCES

California Air Resources Board, California Climate Action Registry, ICLEI – Local Governments for Sustainability, & The Climate Registry. May 2010. Local Government Operations Protocol: For the quantification and reporting of greenhouse gas emissions inventories. Version 1.1. http://www.theclimateregistry.org/downloads/2010/05/2010-05-06-LGO-1.1.pdf

California Climate Action Registry. January 2009. General Reporting Protocol, Version 3.1. http://www.climateregistry.org/resources/docs/protocols/grp/GRP_3.1_January2009.pdf

Council on Environmental Quality. October 6, 2010. Federal Greenhouse Gas Accounting and Reporting Guidance. http://www.whitehouse.gov/sites/default/files/microsites/ceq/GHG%20Guidance%20Document_0.pdf

Council on Environmental Quality. October 6, 2010. Federal Greenhouse Gas Accounting and Reporting Guidance: Technical Support Document. http://www.whitehouse.gov/sites/default/files/microsites/ceq/Technical%20Support%20Document_1.pdf

National Oceanic and Atmospheric Administration (NOAA) Satellite and Information Service. National Climatic Data Center. www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#

The Climate Registry. May 2008. General Reporting Protocol, Version 1.1. http://www.theclimateregistry.org/downloads/GRP.pdf

U.S. Census American Fact Finder, American Community Survey. March 2004. Journey To Work: 2000. Census 2000 Brief. http://www.census.gov/prod/2004pubs/c2kbr-33.pdf

U.S. Department of Transportation, Federal Highway Administration. 2009. 2009 National Household Travel Survey. http://nhts.ornl.gov/introduction.shtml

U.S. Energy Information Administration (EIA), Independent Statistics and Analysis. September 2008. 2003 Commercial Buildings Energy Consumption Survey: Consumption and Expenditures Tables. www.eia.doe.gov/emeu/cbecs

U.S. Energy Information Administration (EIA), Independent Statistics and Analysis. January 2011. Gasoline and Diesel Fuel Update: "U.S. Gasoline and Diesel Fuel Prices." http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp

U.S. EPA Climate Leaders. http://www.epa.gov/stateply/resources/inventory-guidance.html

U.S. EPA Climate Leaders Program. May 2008. Technical Guidance, Optional Emissions from Commuting, Business Travel, and Product Transport. http://www.epa.gov/climateleaders/documents/resources/commute_travel_product.pdf

World Resources Institute & Logistics Management Institute. October 2010. The GHG Protocol for the U.S. Public Sector: Interpreting the Corporate Standards for U.S. Public Sector Organizations. http://www.ghgprotocol.org/files/us-public-sector-protocol_final_oct13.pdf

World Resources Institute & World Business Council for Sustainable Development. November 2010. Corporate Value Chain (Scope 3) Accounting and Reporting Standard: Draft for Stakeholder Review. http://www.ghgprotocol.org/files/ghg-protocol-scope-3-standard-draft-november-20101.pdf

World Resources Institute & World Business Council for Sustainable Development. 2004. The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition.

APPENDIX A: CONVERTED EMISSION FACTORS

Table A- 1. Converted CO2 Emission Factors for Various Types of Fuel [50]

Fuel Type	Default HHV*	Default CO_2 Content	CO_2 Emission Factor
Coal and Coke	**MMBtu/short ton**	**kg CO_2/MMBtu**	**MT CO_2/short ton**
Anthracite	25.09	103.54	2.59782
Bituminous	24.93	93.40	2.32846
Subbituminous	17.25	97.02	1.67360
Lignite	14.21	96.36	1.36928
Coke	24.80	102.04	2.53059
Mixed (commercial sector)	21.39	95.26	2.03761
Mixed (industrial coking)	26.28	93.65	2.46112
Mixed (industrial sector)	22.35	93.91	2.09889
Mixed (electric power sector)	19.73	94.38	1.86212
Natural Gas	**MMBtu/scf**	**kg CO_2/MMBtu**	**MT CO_2/scf**
Pipeline (weighted U.S. average)	0.001028	53.02	0.0000545
Petroleum Products	**MMBtu/gallon**	**kg CO_2/MMBtu**	**MT CO_2/gallon**
Distillate Fuel Oil No. 1	0.139	73.25	0.010182
Distillate Fuel Oil No. 2	0.138	73.96	0.010206
Distillate Fuel Oil No. 4	0.146	75.04	0.010956
Distillate Fuel Oil No. 5	0.140	72.93	0.010210
Distillate Fuel Oil No. 6	0.150	75.10	0.011265
Still gas	0.143	66.72	0.009541
Kerosene	0.135	75.20	0.010152
LPG	0.092	62.98	0.005794
Propane	0.091	61.46	0.005593
Propylene	0.091	65.95	0.006001
Ethane	0.096	62.64	0.006013
Ethylene	0.100	67.43	0.006743
Isobutene	0.097	64.91	0.006296
Isobutylene	0.103	67.74	0.006977
Butane	0.101	65.15	0.006580
Butylene	0.103	67.73	0.006976
Naphtha (<401 degrees F)	0.125	68.02	0.008503
Natural gasoline	0.110	66.83	0.007351
Other oil (>401 degrees F)	0.139	76.22	0.010595
Pentanes plus	0.110	70.02	0.007702
Petrochemical feedstocks	0.129	70.97	0.009155
Petroleum coke	0.143	102.41	0.014645
Special naphtha	0.125	72.34	0.009043
Unfinished oils	0.139	74.49	0.010354
Heavy gas oils	0.148	74.92	0.011088
Lubricants	0.144	74.27	0.010695

[50] Adapted from the Federal Greenhouse Gas Accounting and Reporting Guidance: Technical Support Document Appendix D (October 6, 2010), Appendix D, Table D-1

Motor gasoline	0.125	70.22	0.008778
Motor diesel	0.138	73.96	0.010206
Aviation gasoline	0.120	69.25	0.008310
Kerosenx10-type jet fuel	0.135	72.22	0.009750
Asphalt and road oil	0.158	75.36	0.011907
Crude oil	0.138	74.49	0.010280
Fossil fuel-derived fuels (solid)	**MMBtu/short ton**	**kg CO_2/MMBtu**	**MT CO_2/short ton**
Municipal solid waste	9.95	90.7	0.902465
Tires	26.87	85.97	2.310014
Fossil fuel-derived fuels (gaseous)	**MMBtu/scf**	**kg CO_2/MMBtu**	**MT CO_2/scf**
Blast furnace gas	0.000092	274.32	$2.52374X10^{-5}$
Coke oven gas	0.000599	46.85	$2.80632X10^{-5}$
Biomass fuels—solid	**MMBtu/short ton**	**kg CO_2/MMBtu**	**MT CO_2/short ton**
Wood and wood residuals	15.38	93.80	1.442644
Agricultural byproducts	8.25	118.17	0.974903
Peat	8.00	111.84	0.894720
Solid byproducts	25.83	105.51	2.725323
Biomass fuels—gaseous	**MMBtu/scf**	**kg CO_2/MMBtu**	**MT CO_2/scf**
Biogas (captured methane)	0.000841	52.07	$4.37909X10^{-5}$
Biomass fuels—liquid	**MMBtu/gallon**	**kg CO_2/MMBtu**	**MT CO_2/gallon**
Ethanol (100%)	0.084	68.44	0.005749
Biodiesel (100%)	0.128	73.84	0.009452
Rendered animal fat	0.125	71.06	0.008883
Vegetable oil	0.120	81.55	0.009786

* Higher heating value

Table A- 2. CH4 and N2O Emission Factors for Stationary Combustion[51]

Fuel type	CH_4 Emission Factor ($MT\ CH_4$/MMBtu)	N_2O Emission Factor ($MT\ CH_4$/MMBtu)
Coal and coke (all fuel types in Table A-1)	$1.1x10^{-5}$	$1.6x10^{-6}$
Natural gas	$1.0x10^{-6}$	$1.0x10^{-7}$
Petroleum (all fuel types in Table A-1)	$3.0x10^{-6}$	$6.0x10^{-7}$
Municipal solid waste	$3.2x10^{-5}$	$4.2x10^{-6}$
Tires	$3.2x10^{-5}$	$4.2x10^{-6}$
Blast furnace gas	$2.2x10^{-8}$	$1.0x10^{-7}$
Coke oven gas	$4.8x10^{-7}$	$1.0x10^{-7}$
Biomass fuels—solid (all fuel types in Table A-1)	$3.2x10^{-5}$	$4.2x10^{-6}$
Biogas	$3.2x10^{-6}$	$6.3x10^{-7}$
Biomass fuels—liquid (all fuel types in Table A-1)	$1.1x10^{-6}$	$1.1x10^{-7}$

[51] Source: Federal GHG Guidance Technical Support Document (October 6, 2010), Appendix D Table D-2

Table A- 3. CH4 and N2O Emission Factors for On-Road Mobile Combustion [52]

Fuel Type	CH_4 Emission Factor (MT CH_4/mile)	N_2O Emission Factor (MT N_2O/mile)
Gasoline Passenger Cars		
Low emission vehicles	$1.05x10^{-8}$	$1.5x10^{-8}$
Tier 2	$1.73x10^{-8}$	$3.6x10^{-9}$
Tier 1	$2.71x10^{-8}$	$4.29x10^{-8}$
Tier 0	$7.04x10^{-8}$	$6.47x10^{-8}$
Oxidation catalyst	$1.355x10^{-7}$	$5.04x10^{-8}$
Non-catalyst	$1.696x10^{-7}$	$1.97x10^{-8}$
Uncontrolled	$1.78x10^{-7}$	$1.97x10^{-8}$
Gasoline Light-Duty Trucks		
Low emission vehicles	$1.48x10^{-8}$	$1.57x10^{-8}$
Tier 2	$1.63x10^{-8}$	$6.6x10^{-9}$
Tier 1	$4.52x10^{-8}$	$8.71x10^{-8}$
Tier 0	$7.76x10^{-8}$	$1.056x10^{-7}$
Oxidation catalyst	$1.516x10^{-7}$	$6.390x10^{-8}$
Non-catalyst	$1.908x10^{-7}$	$2.180x10^{-8}$
Uncontrolled	$2.024x10^{-7}$	$2.200x10^{-8}$
Gasoline Heavy-Duty Trucks		
Low emission vehicles	$3.03x10^{-8}$	$3.2x10^{-8}$
Tier 2	$3.33x10^{-8}$	$1.34x10^{-8}$
Tier 1	$6.55x10^{-8}$	$1.75x10^{-7}$
Tier 0	$2.63x10^{-7}$	$2.135x10^{-7}$
Oxidation catalyst	$2.356x10^{-7}$	$1.317x10^{-7}$
Non-catalyst	$4.181x10^{-7}$	$4.73x10^{-8}$
Uncontrolled	$4.604x10^{-7}$	$4.97x10^{-8}$
Diesel Passenger Cars		
Advanced	$5.0x10^{-10}$	$1.0x10^{-9}$
Moderate	$5.0x10^{-10}$	$1.0x10^{-9}$
Uncontrolled	$6.0x10^{-10}$	$1.2x10^{-9}$
Diesel Light Trucks		
Advanced	$1.0x10^{-9}$	$1.5x10^{-9}$
Moderate	$9.0x10^{-10}$	$1.4x10^{-9}$
Uncontrolled	$1.1x10^{-9}$	$1.7x10^{-9}$
Diesel Heavy-Duty Trucks		
Advanced	$5.1x10^{-9}$	$4.8x10^{-9}$
Moderate	$5.1x10^{-9}$	$4.8x10^{-9}$
Uncontrolled	$5.1x10^{-9}$	$4.8x10^{-9}$
Motorcycles		
Non-Catalyst	$6.72x10^{-8}$	$6.9x10^{-9}$
Uncontrolled	$8.99x10^{-8}$	$8.7x10^{-9}$
Alternative Fuel Light Duty Vehicles		
Methanol	$1.8x10^{-8}$	$6.7x10^{-8}$

[52] Source: Federal GHG Guidance Technical Support Document (October 6, 2010), Appendix D, Tables D-4 and D-5

CNG	$7.37x10^{-7}$	$5.0x10^{-8}$
LPG	$3.7x10^{-8}$	$6.7x10^{-8}$
Ethanol	$5.5x10^{-8}$	$6.7x10^{-8}$
Alternative Fuel Heavy Duty Vehicles		
Methanol	$6.6x10^{-8}$	$1.75x10^{-7}$
CNG	$1.97x10^{-6}$	$1.75x10^{-7}$
LNG	$1.97x10^{-6}$	$1.75x10^{-7}$
LPG	$6.6x10^{-8}$	$1.75x10^{-7}$
Ethanol	$1.97x10^{-7}$	$1.75x10^{-7}$
Alternative Fuel Buses		
Methanol	$6.6x10^{-8}$	$1.75x10^{-7}$
CNG	$1.97x10^{-6}$	$1.75x10^{-7}$
Ethanol	$1.97x10^{-7}$	$1.75x10^{-7}$

Table A- 4. CH_4 and N_2O Emission Factors for Off-Road Mobile Combustion[53]

Fuel type	Fuel Density (kg/gal)	CH_4 Emission Factor (MT CH_4/gal fuel)	N_2O Emission Factor (MT N_2O/gal fuel)
Ships and Boats			
Residual fuel oil	3.75	$8.60 x10^{-7}$	$3.0 x10^{-7}$
Diesel fuel	3.2	$7.40 x10^{-7}$	$2.6 x10^{-7}$
Gasoline	2.8	$6.40 x10^{-7}$	$2.2 x10^{-7}$
Locomotives			
Diesel Fuel	3.2	$8.0 x10^{-7}$	$2.6 x10^{-7}$
Agricultural Equipment			
Gasoline	2.8	$1.26 x10^{-6}$	$2.2 x10^{-7}$
Diesel fuel	3.2	$1.44 x10^{-6}$	$2.6 x10^{-7}$
Construction Equipment			
Gasoline	2.8	$5.0 x10^{-7}$	$2.2 x10^{-7}$
Diesel fuel	3.2	$5.8 x10^{-7}$	$2.6 x10^{-7}$
Other Non-Highway			
Snowmobiles (gasoline)	2.8	$5.0 x10^{-7}$	$2.2 x10^{-7}$
Other recreational (gasoline)	2.8	$5.0 x10^{-7}$	$2.2 x10^{-7}$
Other small utility (gasoline)	2.8	$5.0 x10^{-7}$	$2.2 x10^{-7}$
Other large utility (gasoline)	2.8	$5.0 x10^{-7}$	$2.2 x10^{-7}$
Other large utility (diesel)	3.2	$5.8 x10^{-7}$	$2.6 x10^{-7}$
Aircraft			
Jet fuel	3.08	$2.7 x10^{-7}$	$3.1 x10^{-7}$
Aviation gasoline	2.67	$7.04 x10^{-6}$	$1.1 x10^{-7}$

[53] Source: Federal GHG Guidance Technical Support Document (October 6, 2010), Appendix D, Table D-6

Table A- 5. Purchased Electricity GHG Emission Factors by eGRID Subregion (Baseload)*[54]

eGRID Acronym	eGRID Subregion Name	MT CO_2/MWh	MT CH_4/GWh	MT N_2O/GWh
AKGD	ASCC Alaska Grid	0.56	0.000012	0.000003
AKMS	ASCC Miscellaneous	0.23	0.000009	0.000002
AZNM	WECC Southwest	0.59	0.000008	0.000008
CAMX	WECC California	0.33	0.000014	0.000004
ERCT	ERCOT All	0.60	0.000008	0.000007
FRCC	FRCC All	0.60	0.000021	0.000008
HIMS	HICC Miscellaneous	0.69	0.000143	0.000021
HIOA	HICC Oahu	0.82	0.000050	0.000011
MROE	MRO East	0.83	0.000013	0.000014
MROW	MRO West	0.83	0.000013	0.000014
NEWE	NPCC New England	0.42	0.000039	0.000008
NWPP	WECC Northwest	0.41	0.000009	0.000007
NYCW	NPCC NYC/Westchester	0.37	0.000016	0.000002
NYLI	NPCC Long Island	0.70	0.000052	0.000008
NYUP	NPCC Upstate NY	0.33	0.000011	0.000005
RFCE	RFC East	0.52	0.000014	0.000008
RFCM	RFC Michigan	0.71	0.000015	0.000012
RFCW	RFC West	0.70	0.000008	0.000012
RMPA	WECC Rockies	0.85	0.000010	0.000013
SPNO	SPP North	0.89	0.000011	0.000015
SPSO	**SPP South**	0.75	0.000011	0.000010
SRMV	SERC Mississippi Valley	0.46	0.000011	0.000005
SRMW	**SERC Midwest**	0.83	0.000010	0.000014
SRSO	SERC South	0.68	0.000012	0.000012
SRTV	**SERC Tennessee Valley**	0.69	0.000009	0.000012
SRVC	SERC Virginia/Carolina	0.51	0.000011	0.000009

* Baseline Emission Factors are used to calculate GHGs from electricity purchases and T&D.

Table A- 6. Purchased Electricity GHG Emission Factors by eGRID Subregion (Non-Baseload)*[55]

eGRID Acronym	eGRID Subregion Name	MT CO_2/MWh	MT CH_4/GWh	MT N_2O/GWh
AKGD	ASCC Alaska Grid	0.67	0.000017	0.000004
AKMS	ASCC Miscellaneous	0.66	0.000027	0.000005
AZNM	WECC Southwest	0.54	0.000009	0.000004
CAMX	WECC California	0.49	0.000018	0.000003
ERCT	ERCOT All	0.51	0.000009	0.000003
FRCC	FRCC All	0.61	0.000022	0.000006
HIMS	HICC Miscellaneous	0.76	0.000154	0.000023
HIOA	HICC Oahu	0.84	0.000054	0.000009

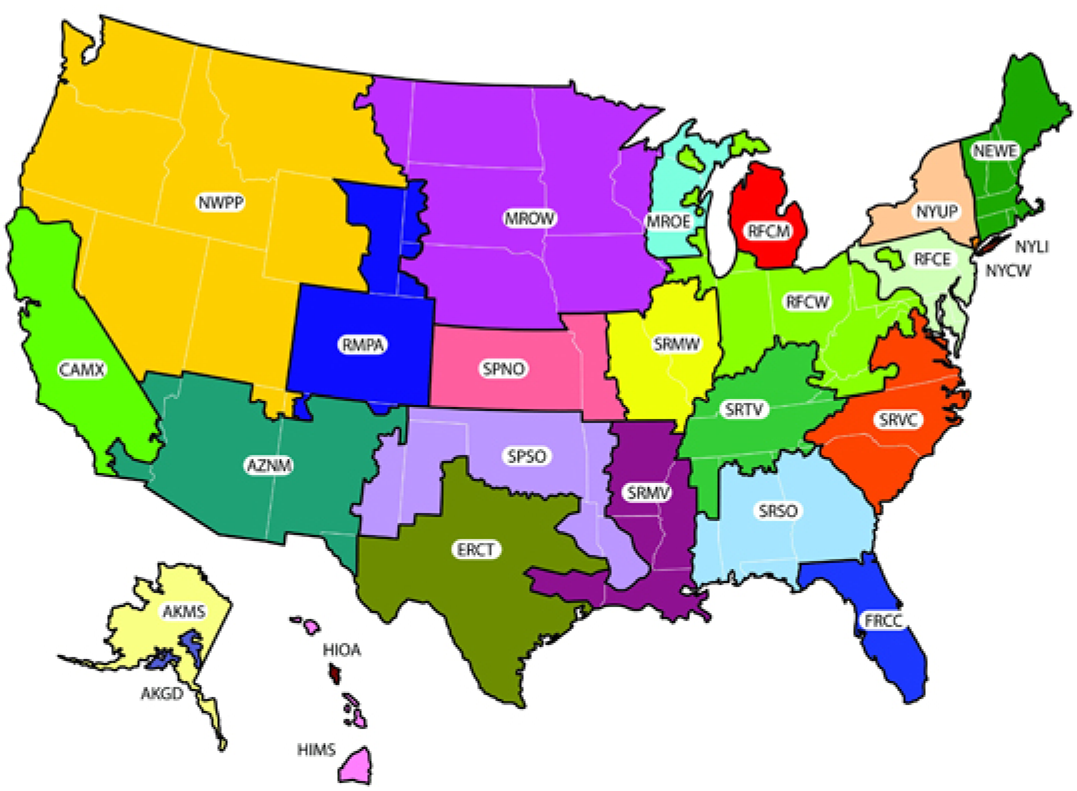
[54] http://cfpub.epa.gov/egridweb/ghg.cfm

[55] http://cfpub.epa.gov/egridweb/ghg.cfm

MROE	MRO East	0.83	0.000013	0.000011
MROW	MRO West	0.98	0.000021	0.000016
NEWE	NPCC New England	0.60	0.000035	0.000007
NWPP	WECC Northwest	0.60	0.000022	0.000008
NYCW	NPCC NYC/Westchester	0.69	0.000026	0.000004
NYLI	NPCC Long Island	0.68	0.000027	0.000005
NYUP	NPCC Upstate NY	0.69	0.000021	0.000008
RFCE	RFC East	0.81	0.000019	0.000011
RFCM	RFC Michigan	0.75	0.000013	0.000012
RFCW	RFC West	0.90	0.000011	0.000014
RMPA	WECC Rockies	0.73	0.000010	0.000009
SPNO	SPP North	0.98	0.000014	0.000015
SPSO	SPP South	0.63	0.000011	0.000005
SRMV	SERC Mississippi Valley	0.57	0.000013	0.000004
SRMW	SERC Midwest	0.95	0.000012	0.000015
SRSO	SERC South	0.77	0.000016	0.000012
SRTV	SERC Tennessee Valley	0.91	0.000013	0.000015
SRVC	SERC Virginia/Carolina	0.81	0.000018	0.000012

* Non-baseload eGRID factors are used to calculate GHG emissions from RECs

Figure 8. Map of eGRID Subregions



Source: http://cfpub.epa.gov/egridweb/ghg.cfm

Table A- 7. Default Fuel Economy of Vehicles[56]

Vehicle Type	Default MPG
General Vehicle Class	
Passenger Car	22.5
SUV or Truck (gasoline)	18.1
SUV or Truck (diesel)	18.1
Motorcycle	50
Specific Vehicle Sizes (Gasoline)	
Economy	27.9
Compact	30.5
Midsize	27.9
Full Size	22.4
Luxury	19.7
Minivan/Wagon	20.2
Small SUV	19.9
Medium SUV	16.6
Large SUV	15.8
Passenger Van	15.0
½ Ton Pickup	16.1

[56] FEMP GHG and Sustainability Workbook, http://www.fedcenter.gov/Documents/index.cfm?id=16387

APPENDIX B: GLOBAL WARMING POTENTIALS

Table B- 1. GWPs of Major Greenhouse Gases

Chemical formula	Name	Global warming potential (100 yr.)
CO_2	Carbon dioxide	1
CH_4	Methane	21
N_2O	Nitrous oxide	310
CHF_3	HFC–23	11,700
CH_2F_2	HFC–32	650
CH_3F	HFC–41	150
C_2HF_5	HFC–125	2,800
$C_2H_2F_4$	HFC–134	1,000
CH_2FCF_3	HFC–134a	1,300
$C_2H_3F_3$	HFC–143	300
$C_2H_3F_3$	HFC–143a	3,800
CH_2FCH_2F	HFC–152	53
CH_3CHF_2	HFC–152a	140
CH_3CH_2F	HFC–161	12
C_3HF_7	HFC–227ea	2,900
$CH_2FCF_2CF_3$	HFC–236cb	1,340
CHF_2CHFCF_3	HFC–236ea	1,370
$C_3H_2F_6$	HFC–236fa	6,300
$C_3H_3F_5$	HFC–245ca	560
$CHF_2CH_2CF_3$	HFC–245fa	1,030
$CH_3CF_2CH_2CF_3$	HFC–365mfc	794
SF_6	Sulfur hexafluoride	23,900
CF_4	PFC–14 (Perfluoromethane)	6,500
C_2F_6	PFC–116 (Perfluoroethane)	9,200
C_4F_{10}	PFC–3–1–10 (Perfluorobutane)	7,000
C_6F_{14}	PFC–5–1–14 (Perfluorohexane)	7,400

* For a complete list of GWPs, please refer to:
EPA Mandatory Reporting Rule, Federal Register, Friday, October 30, 2009, Table A-1 to Subpart A of Part 98. See www.epa.gov/climatechange/emissions/downloads09/GHG-MRR-Full%20Version.pdf.

APPENDIX C: ABBREVIATIONS

ACS	American Community Survey
ACUPCC	American Colleges and Universities Presidents Climate Commitment
APTA	American Public Transportation Association
BOD	Biological oxygen demand
BTS	Bureau of Transportation Statistics
CARROT	Climate Action Registry Reporting Online Tool
CBECS	Commercial Building Energy Consumption Survey
CCAR	California Climate Action Registry
CH_4	Methane
CNG	Compressed natural gas
CO_2	Carbon dioxide
DOT	Department of Transportation
EMIS	Environmental (or Energy) Management Information System
EPA	Environmental Protection Agency
F-GHG	Fluorinated greenhouse gas
FEMP	Federal Energy Management Program
ft^2	square feet
GHG	Greenhouse gas
Gpf	Gallons per flush
GRP	General Reporting Protocol
GWP	Global warming potential
HFC	Hydrofluorocarbon
HHV	High heat value
HVAC	Heating, ventilation and air conditioning
IPCC	Intergovernmental Panel on Climate Change
kg	kilograms
kWh	Kilowatt hour
LFG	Landfill gas
LGO	Local Government Operations (Protocol)
LOE	Level of effort
LPG	Liquefied petroleum gas
lb	pound
MCF	Thousand cubic feet
mi	Mile

MT	Metric tons
MMBtu	Million British Thermal Units
$MMTCO_2E$	Million metric tons of CO_2 equivalent
MPO	Metropolitan Planning Organization
$MTCO_2E$	Metric tons of CO_2 equivalent
MWh	Megawatt hour
N_2O	Nitrous oxide
NCHRP	National Cooperative Highway Research Program
NHTS	National Household Travel Survey
PFC	Perfluorocarbon
PNR	Passenger Name Record
POV	Personally-owned vehicle
QA	Quality assurance
QC	Quality control
RECs	Renewable Energy Credits
RGGI	Regional Greenhouse Gas Initiative
scf	Standard cubic feet
SF_6	Sulfur hexafluoride
SOP	Standard Operating Procedure
T&D	Transmission and distribution
TCR	The Climate Registry
TSD	Technical Support Document
VMT	Vehicle miles traveled
WBCSD	World Business Council for Sustainable Development
WCI	Western Climate Initiative
WRI	World Resources Institute
WWT	Wastewater treatment
WWTP	Wastewater treatment plant

APPENDIX D: SCOPE 3 EVALUATION APPROACH

As noted in the *Scope 3* section of these Guidelines, state DOTs will have the option to (1) not include scope 3 emission sources in their inventory, (2) include the scope 3 emission sources recommended by these Guidelines , or (3) include their own preferred set of scope 3 emission sources. , A state-specific methodology is presented in this sections so that state DOTs can individually evaluate which scope 3 emission sources are relevant for their GHG inventory.

The general approach for selecting appropriate scope 3 emission sources is based on the *WRI Scope 3 Standard* and is summarized below.

1. Identify potential scope 3 emission sources
2. Establish first- and second-order metrics to evaluate the emission sources
3. Weight the first-order metrics based on relative importance to stakeholders
4. Rank the emission sources for each second-order metric
5. Calculate a weighted score for each first-order metric by each emission source
6. Sum weighted scores for all first-order metrics to determine a total score for each emission source
7. Select recommended scope 3 emission sources based on total weighted score

The table below provides an example of the structure that can be used to determine the scope 3 emission sources that will be included in a state DOT GHG inventory.

Note that the table is pre-populated with values the authors used to determine the scope 3 sources recommended by these Guidelines, where appropriate. A state DOT, when evaluating their own circumstances, may choose to value these parameters differently. The remainder of this section details the approach and provides definitions for the first and second order metrics provided.

Table D- 1. Scope 3 Emission Source Determination Approach

Evaluation Criteria			Scope 3 Emission Sources							
Weight	**First-Order Metric**	**Second-Order Metric**	**Vendor/Contractor Emissions**	**Contracted Solid Waste**	**T&D**	**Employee Commutes**	**Business Air Travel**	**Business Ground Travel**	**Contracted WWT**	**Supply Chain Emissions**
1.0	**Magnitude of Emissions**	Relative Size of Emission Source	3	2	2	2	2	1	1	3
		Contribution to State DOT's GHG Emissions								
		Average								

		Weighted Score								
0.8	**Mitigation Potential**	Ease of Implementation	1	3	3	2	2	2	1	1
		DOT Influence	3	3	3	2	2	2	1	1
		Net Cost to State DOT								
		Average								
		Weighted Score								
0.6	**LOE of Estimating Emissions**	Methodology	2	3	3	3	3	3	3	2
		Proxy Data Estimation	1	2	3	3	3	3	2	1
		Calculation Tool	1	3	3	3	3	3	3	1
		Data Availability and Quality								
		Average								
		Weighted Score								
0.4	**Consistency with Other Inventories and Programs**	Required by Federal GHG Guidance	2	3	3	3	3	3	3	1
		Included in Other Public Sector Inventories	1	3	1	3	2	2	1	1
		Required by State or Regional Reporting Program								
		Overlap with Other State Regulations or Initiatives								
		Average								
		Weighted Score								
0. 2	**Importance to Agency Decision-Makers**	Importance to Agency Decision-Makers	3	2	2	2	2	2	2	1
		Relevance to state DOT's inventory								
		Average								
		Weighted Score								
	TOTAL SCORE									

1) *Identify potential scope 3 emission sources*

There are many potential scope 3 emission sources, several primary ones include: Transmission and Distribution, Employee Commutes, Business Air Travel, Business Ground Travel, Contracted Solid Waste, Contracted Wastewater Treatment, Vendor and Contractor Emissions, and Supply Chain Emissions. This list is not exhaustive, but rather represents the major scope 3 emission sources that state DOTs will likely encounter.

2) *Establish first- and second-order metrics to evaluate the emission sources*

The following five first-order metrics have been identified to help evaluate which scope 3 emission sources are relevant to state DOTs based on an understanding of State DOT operations and a review of common criteria used by other organizations:

- magnitude of emissions,
- GHG mitigation potential,
- level of effort (LOE) required to estimate emissions,
- consistency with other inventories and programs and
- importance to agency decision-makers.

Additional “second-order metrics” were identified that further define the first-order metrics and help to quantify them. State DOTs will have additional second-order metrics—beyond those introduced in Table D-1—that can help them evaluate which scope 3 emission sources to include in their GHG inventory (described below).

3) Weight the first-order metrics based on relative importance to stakeholders

Weights are assigned to the first-order metrics based on their relative importance for determining relevance to a state DOT’s GHG inventory on a scale of 0 to 1, where 1 represents the highest-valued evaluation criteria.

4) Rank the emission sources for each second-order metric

Second order metrics are assigned values of 3, 2, or 1, which indicate the degree to which the scope 3 emission source meets the requirements of that metric. The second-order metrics and proposed definitions of each rank are described in more detail below.

5) Calculate a weighted score for each first-order metric by each emission source

An average of the values assigned to the second-order metrics should be used to determine the first-order metric’s rank.

As an example, in Table D-1, the first-order metric, *LOE of Estimating Emissions*, has three second-order metrics—*Methodology, Proxy Data Estimation*, and *Calculation Tool*. For one of the potential scope 3 emission sources, business air travel, these second-order metrics receive values of 3, 1, and 3, respectively. The average, 2.33, is assigned to *LOE of Estimating Emissions* for business air travel.

Next, the average score for each first-order metric is multiplied by the metric’s assigned weight (1 to 0.2) to determine the weighted score for each first-order metric.

6) Sum weighted scores for all first-order metrics to determine a total score for each emission source

After all the scope 3 emission sources have been assigned a weighted score for each first-order metric, the weighted scores should be summed for each emission source to obtain a total score for that emission source.

7) Select recommended scope 3 emission sources based on total weighted score

The emission sources with the highest scores should be considered the most relevant scope 3 emission source for the state DOT.

STATE-SPECIFIC SCOPE 3 SOURCE DETERMINATION APPROACH

This section defines the first and second order metrics available to the scope 3 determination approach.

1: FIRST ORDER METRIC: MAGNITUDE OF EMISSIONS

Second Order Metric: Relative Size of a GHG emission source

The relative magnitude of scope 3 emission sources can be approximated by looking at emission inventories that have included scope 3 emission sources. This metric will be most valuable if the state DOT has not estimated emissions for any scope 3 emission sources and is seeking to leverage other GHG inventories that have been completed by other entities.

The table below defines the parameters used to establish a rank of 3, 2, and 1 for the *Magnitude of Emissions* metric.

Table D- 2. Parameters for Ranking Magnitude of Emissions Metric[57]

Rank	Parameter
3	Emission source contributes, on average, more than 25% of an organization's scope 3 emissions
2	Emission source contributes, on average, between 5 and 25% of an organization's scope 3 emissions
1	Emission source contributes less than 5% of an organization's scope 3 emissions

Second Order Metric: Contribution to State DOT's GHG Emissions

The absolute contribution of a scope 3 emission source to a state DOT's overall emissions will be an important consideration for prioritizing scope 3 emission sources.

Table D- 3 defines the recommended parameters state DOTs can use to establish a rank of 3, 2, and 1 for the *Contribution to State DOT's GHG Emissions* metric. This metric will be most valuable if the state DOT has already performed some scoping estimates to determine which scope 3 emission sources are most appropriate for their operations.

Table D- 3. Parameters for Contribution to State DOT's GHG Emissions Rankings

Rank	Parameter
3	Emission source contributes more than 25% of DOT's scope 3 emissions
2	Emission source contributes between 5 and 25% of DOT's scope 3 emissions
1	Emission source contributes less than 5% of DOT's scope 3 emissions

[57] There are some scope 3 emission sources that are not included in publicly available GHG emission inventories, such as vendor and contractor emissions. While emissions from vendors and contractors are likely a significant source of GHG emissions, as indicated by a recent study, *Life-cycle Environmental Inventory of Passenger Transportation in the United States*, their approximate contribution to an organization's scope 3 emissions in comparison with other scope 3 emission sources is unavailable.

2: FIRST ORDER METRIC: MITIGATION POTENTIAL

Scope 3 sources such as vendor and contractor emissions contribute a large amount to an organization's GHG footprint. One reason for including scope 3 emissions in a GHG inventory is that they often present an opportunity for creative GHG emission reduction strategies. Several scope 3 emission sources present an opportunity for cost-effective mitigation.

Second Order Metric: Ease of Implementation

If there are low- to no-cost mitigation options available for a particular emission source, a state DOT may choose to include that source in their inventory as it will present a cost-effective way to reduce emissions and meet their GHG reduction goals. Low- to no-cost measures include use of low-cost technological solutions that provide quick payback periods—such as installing energy efficient light bulbs—as well as simple behavioral changes—such as using more daylighting—that can reduce consumption or support sustainable use of resources.

The table below defines the parameters used to establish a rank of 3, 2, and 1 for the *Ease of Implementation* metric.

Table D- 4. Parameters for Ease of Implementation Metric Rankings

Rank	Parameter
3	Many low-cost technological solutions and behavioral change opportunities are available for this source.
2	Several low-cost technological solutions and/or behavioral change opportunities are available for this source.
1	There are few to no known low-cost technological solutions or behavioral change solutions available for this source.

Second Order Metric: DOT Influence

Another metric that contributes to the mitigation potential of an emission source is whether the DOT has influence or control over the emission source. A DOT's influence over the emission source can be categorized in 4 ways:

1) State DOT has direct influence over the emission source (e.g., the amount of solid waste generated),
2) State DOT has influence over the emission source through management decisions (e.g., the amount of business travel allocated),
3) State DOT has influence over the emission source through contracts (e.g., the activities of vendors and contractors), or
4) State DOT has no influence over the emission source

The table below defines the parameters used to establish a rank of 3, 2, and 1 for the *DOT Influence* metric.

Table D- 5. Parameters for DOT Influence Metric Rankings

Rank	Parameter
3	DOT has direct or widespread influence over emission source
2	Emission source can be influenced through DOT management decisions or contracts
1	DOT cannot influence emission source

Second Order Metric: Net cost or savings to state DOT

If the mitigation potential of a scope 3 emission source will present a net savings to state DOTs (i.e., allow them to save on energy or fuel costs), then it may be more advantageous to include the emission source in a state DOT's inventory. However, if the cost savings from mitigation of that emission source are less than the capital costs to implement mitigation measures, mitigating the emission source would be a net cost to state DOTs. The rankings associated with the cost of mitigation are described below.

The determination of dollar costs or savings associated with a mitigation activity will depend on a state DOT's existing infrastructure and their billing practices. The table below defines the recommended parameters state DOTs use to establish a rank of 3, 2, and 1 for the *Net Cost or Savings to State DOT* metric.

Table D- 6. Parameters for Net Cost Metric Rankings

Rank	Parameter
3	Mitigating this emission source could save DOTs money
2	Mitigation will likely have a low cost or low level of savings
1	Mitigation of this emission source will cost DOTs money

3: FIRST ORDER METRIC: LEVEL OF EFFORT FOR ESTIMATING EMISSIONS

Second order metric: Methodology

State DOTs will be better positioned to estimate emissions from a scope 3 emission source if a standardized methodology is available. Until recently, methods to estimate scope 3 emissions were not readily available. This is changing, however. Of particular note is the *Federal GHG Guidance*, which provides methods to estimate emissions from six scope 3 emission sources. The parameters used to establish rankings for the *Methodology* metric are driven by whether or not a methodology is available (mostly from the *Federal GHG Guidance*) as shown in the table below.

Table D- 7. Parameters for Methodology Rankings

Rank	Parameter
3	Methodology is available
2	Methodology is under development
1	No methodology is available

Second Order Metric: Proxy Data Estimation

For many scope 3 emission sources, data will not be readily available, may be of poor quality, or may be too cost- or labor-intensive to obtain. In these cases, a proxy methodology can be used to estimate activity data in the absence of actual data (see the Methodologies to Calculate Scope 3 Emissions section of these Guidelines).

At this time, no major GHG guidance document has provided proxy data estimation techniques for scope 3 emission sources; however, for certain sources such as employee commuting, data can be estimated using regional datasets and adapting scope 1 calculations for sources such as mobile combustion. The table below defines the parameters used to determine a rank of 3, 2, and 1 for the *Proxy Data Estimation* metric.

Table D- 8. Parameters for Proxy Data Estimation Rankings

Rank	Parameter
3	Proxy data estimation methodology is available
2	Proxy data estimation methodology has been developed internally, but is not standardized
1	No proxy data estimation methodology is available

Second Order Metric: Calculation Tools

A third metric that can help determine LOE is the existence of a calculation tool to help DOTs estimate emissions from scope 3 sources. The table below defines the parameters used to define a rank of 3, 2, and 1 for the *Calculation Tool* metric.

Table D- 9. Parameters for Calculation Tool Metric Rankings

Rank	Parameter
3	Standard calculation tool is readily available to state DOTs
2	Internal calculation tool has been created or can be developed
1	No standard calculation tools are available to state DOTs

Second Order Metric: Data Availability and Quality

A major factor in determining whether an emission source can be included in a GHG inventory is whether or not the DOT collects the data. If not, is it possible for the DOT to begin collecting the data? In addition to whether the data are collected, the completeness or accuracy of the data will be a factor in determining whether or not to include the emission source. In general, scope 3 activity data are often less accurate than scope 1 and scope 2 activity data. Therefore, whether data entry is standardized, manual (subject to human error), or automated (i.e., automatically pulled from billing/invoice data) may determine the quality of the data and therefore whether the scope 3 emission source should be included in a GHG inventory. Table D- 10defines the recommended parameters state DOTs can use to establish a rank of 3, 2, and 1 for the *Data Availability and Quality Rankings* metric.

Table D- 10. Parameters for Data Availability and Quality Rankings

Rank	Parameter
3	Data are currently collected by DOT, and data quality is acceptable
2	Data are not currently collected but could be collected in the future; data quality could be improved
1	Data are not available, is too resource-intensive to gain, and will likely not be attainable in the future; data quality is poor

4: FIRST ORDER METRIC: CONSISTENCY WITH OTHER INVENTORY PROGRAMS

Ideally, state DOTs' GHG inventories will be comparable to inventories from other states and public sector organizations. In order for a DOT's GHG inventory to be easily comparable with other GHG inventories, it will need to include the same types of emission sources that other inventories are including. Four second-order metrics help define consistency with other inventory programs.

Second Order Metric: Required by Federal GHG Guidance

The *Federal GHG Guidance* requires that federal agencies account for scope 3 emissions from six scope 3 sources: business air travel, business ground travel, employee commuting, transmission and distribution (T&D) losses associated with purchased electricity, contracted solid waste, and contracted wastewater treatment. While state DOTs are not subject to the requirements of the *Federal GHG Guidance,* state DOTs may choose to design their emissions inventories to be consistent with those of federal agencies. The table below defines the parameters used to establish a rank of 3, 2, and 1 for the Required by *Federal GHG Guidance* metric.

Table D- 11. Parameters for Required by Federal GHG Guidance Metric Rankings

Rank	Parameter
3	Required by Federal GHG Guidance
2	Not currently required by Federal GHG Guidance; Will be required in future years
1	Not required by Federal GHG Guidance

Second Order Metric: Included in other public sector inventories

State DOTs will likely want to compare their GHG inventories to those of other public sector organizations. Therefore, it is helpful to determine which scope 3 emission sources are being included in other organizational GHG inventories to determine if an emission source will be a useful addition to a state DOT's inventory.

In the survey of state DOTs conducted to support these Guidelines, eight respondents identified scope 3 emission sources they included or planned to include in their GHG emissions inventory. A table presenting these results is shown below.

Table D- 12. Summary of Task 2 Survey Responses on Scope 3 Emission Sources

Emission Source	Number of Affirmative Responses	% of Total Respondents
Employee Commuting	6	75%
Business Air Travel	4	50%
Business Ground Travel	4	50%
Contracted Solid Waste Disposal	1	12.5%
Transmission & Distribution Losses	1	12.5%
Contracted Wastewater Treatment	0	0%

The table below defines the parameters used to establish a rank of 3, 2, and 1 for the *Inclusion in Other Public Sector Inventories* metric based on the above findings.

Table D- 13. Parameters for Inclusion in Other Public Sector Inventories Metric Rankings

Rank	Parameter
3	Emission source is included in more than 50% of inventories surveyed
2	Emission source is included in 25-49% of inventories surveyed
1	Emission source is included in less than 25% of inventories

Second Order Metric: Required for state GHG reporting program

If a scope 3 emission source is required by a state or regional GHG reporting program, then it will need to be included in a state DOT's emission inventory. At this time, most regional GHG reporting programs may encourage the inclusion of scope 3 emission sources, but do not require them.

Whether or not an emission source is required for a state GHG reporting program will be state-specific.

defines the recommended parameters that state DOTs can use to establish a rank of 3, 2, and 1 for the *Required for State GHG Reporting Program* metric.

Table D- 14. Parameter for Required for State GHG Reporting Program Metric Rankings

Rank	Parameter
3	Emission source is required by a state or regional GHG reporting program
2	Emission source is not currently required but is either encouraged through voluntary reporting, or may be required in future years
1	Emission source is not required or recommended by state or regional GHG reporting program

Second Order Metric: Overlap with other state regulations or initiatives

If data for a scope 3 emission source is already collected for another state program, regulatory requirement, or environmental initiative, then including it in a GHG inventory will be relatively straightforward. In addition, there may be co-benefits with other regulatory initiatives such as air or water quality programs. Collecting data for a GHG inventory may help a DOT meet other regulatory data collection requirements.

As with the *Required for State GHG Reporting Program* metric, co-benefits associated with other state regulatory initiatives will be state-specific. Table D- 15 defines the recommended parameters that the state DOTs can use to establish a rank of 3, 2, and 1 for the *Required for State GHG Reporting Program* metric.

Table D- 15. Parameter for Overlap Metric Rankings

Rank	Parameter
3	Data required for this emission source is already collected for a mandatory regulatory program or initiative
2	Data required for this emission source is already collected for a voluntary regulatory program or initiative
1	Data for this emission source is not currently collected for another program or initiative

5: FIRST ORDER METRIC: IMPORTANCE TO AGENCY DECISION-MAKERS

Agency decision-makers may have specific justification for including select scope 3 emission sources in their inventory. These justifications may be hard to broadly define, but may be of significance for reasons pertinent to the state DOT.

Second order metric: Importance to Agency Decision-Makers

A consideration for determining whether or not to include an emission source is whether it is important to agency decision-makers that the emission source be included in *a* DOT inventory. State DOTs could hold internal discussions to identify the most relevant emission sources, and thereby determine the rank of each emission source.

The table below defines the parameters used to establish a rank of 3, 2, and 1 for the *Importance to Agency Decision-Makers* metric.

Table D- 16. Definition of Importance to Agency Decision-Makers Metric Rankings

Rank	Parameters
3	Emission source is deemed important by major decision makers
2	Emission source is relevant to some decision makers
1	Emission source is deemed unimportant to decision makers

Second Order Metric: Relevance to State DOT's Inventory

Similar to the *Importance to Agency Decision-Makers* metric discussed above, it is important to determine if decision-makers deem a particular emission source relevant to *their* state DOT's emissions inventory. Table D- 17 defines the parameters used to establish a rank of 3, 2, and 1 for the *Relevance to State DOT's Inventory* metric.

Table D- 17. Parameters for Relevance to State DOT's Inventory Metric Rankings

Rank	Parameters
3	Emission source is deemed important by major decision makers
2	Emission source is relevant to some decision makers
1	Emission source is deemed unimportant to decision makers

APPENDIX E: RELEVANT GHG GUIDANCE MATERIALS

While there are many GHG inventory guidance documents available, state DOTs do not fall solely under any one guidance document or protocol and therefore have the flexibility to apply the best inventory procedures available from each as well as to develop state DOT-specific procedures where appropriate.

This appendix details the GHG guidance materials introduced in the *Relevant GHG Guidance Materials* section of these Guidelines to help state DOTs better understand the resources available to them. The GHG guidance materials are grouped into GHG Protocols, GHG Methodologies and Combined GHG Guidance Materials.

GHG PROTOCOLS

WRI/WBCSD: The GHG Protocol- A Corporate Accounting and Reporting Standard

The WRI/WBCSD developed the GHG Protocol Initiative in 1998 to establish international standards for organizations to use in conducting GHG emissions inventories. The *Corporate Accounting and Reporting Standard* details accounting and reporting standards for conducting GHG emissions inventories, and provides the basis for the ISO and Climate Registry protocols. The *Corporate Standard* was developed primarily for businesses, but its principles can be applied to other types of organizations, and it is designed to be program and policy neutral. The *Corporate Standard* was developed through a multi-stakeholder peer review process.

Like most other protocols, reporting of scope 3 emissions is optional under the *Corporate Standard*, but reporting is recommended because scope 3 sources may exhibit cost-effective emissions reduction potential. Scope 1 emissions are divided into: generation of heat, electricity or steam from stationary combustion; transportation of materials, products, waste, and employees in company owned or controlled mobile combustion sources, process emissions from physical or chemical processing (i.e. materials manufacture), and fugitive emissions (i.e. refrigerant leaks). Scope 2 emissions include purchased electricity, heat or steam, and chilled water. Possible scope 3 emission sources include: extraction and production of purchased materials and fuels; transport-related activities such as business travel and commuting; upstream electricity-related activities; leased assets, franchises and outsourced activities; use of sold products and services; and waste disposal. The Corporate *Standard* recommends prioritizing scope 3 sources that are relevant to the organization and likely to have a large impact compared to scope 1 and 2 sources, have emissions reduction potential, and that have reasonably available data and reliability. Whichever emission sources are included under scope 3, it is important to thoroughly document the extent to which each source is covered.

The general steps for conducting an inventory based on the *Corporate Standard* are: (1) identify emissions sources, (2) select a GHG emissions calculation approach; (3) collect activity data and choose emission factors; (4) apply calculation tools, and (5) roll up GHG emissions data to a the highest organizational level. Step 1 involves identifying scope 1, 2, and 3 emission sources. The calculation approach in step 2 is usually to apply documented emission factors to activity data. For step 5, an organization may choose to gather facility-level emissions data either by centrally collecting all data and calculating emissions, or by requiring each facility to calculate its emissions and then report to the highest organization level.

In order for a DOT GHG emissions inventory to be consistent with the *Corporate Standard*, it must report the following: the organizational and operational boundaries and consolidation approach used; which scope 3 emission sources are included, if any; the reporting period; total scope 1 and scope 2 emissions, reported separately for each scope and including emissions of CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6 in metric tonnes and metric tonnes of CO_2 equivalent; base year emissions profile and outline of base year recalculation procedure; context for significant emission changes from base year emissions; direct CO_2 emissions data from biologically sequestered carbon (for example, from burning biomass and biofuels), reported separately from scopes 1 and 2; methodologies and calculation tools used; and any specific source, facility, or operational exclusions. Optional information to report includes: reliable scope 3 emissions data from relevant activities; further subdivisions of emissions data by facilities and activity type, if available; emissions performance benchmarking against internal and external benchmarks; non-Kyoto GHG emissions (for example, Montreal Protocol gases); an outline of any GHG management or reduction programs or strategies; the quality of the inventory; a list of facilities included in the inventory; and an agency contact.

http://www.ghgprotocol.org/standards/corporate-standard

WRI: The GHG Protocol for the U.S. Public Sector

In 2010, the WRI published *The GHG Protocol for the U.S. Public Sector: Interpreting the Corporate Standard for U.S. Public Sector Organizations* (hereby referred to as *"Public Sector Standard"*). This document draws on the design principles of the *Corporate Standard*, but is tailored specifically for public sector organizations. The *Public Sector Standard* recommends the operational control consolidation approach because this is more relevant to agencies than the equity share approach, and agencies do not always have financial control over their operations.

Similar to the *Corporate Standard*, the *Public Sector Standard* requires inclusion of direct scope 1 and indirect scope 2 emissions in a GHG emissions inventory, as well as biogenic CO_2 emissions from the combustion of biofuels and biomass, reported separately.

The emission sources required by the *Public Sector Standard* are the same as above, although they are tailored to more government-specific conditions. For example, most public sector agencies are unlikely to have process emissions from physical or chemical manufacturing. In addition, the *Public Sector Standard* mentions other direct emissions sources, including on-site landfills, composting, wastewater treatment plants and incinerators, laboratory activities, munitions firing, and organization-specific activities (for example, space shuttle launches for NASA). The *Public Sector Standard* recognizes that scope 2 emissions from purchased electricity, steam, and district heating or cooling will likely be some of the largest emission sources for public sector organizations. While reporting of scope 3 emissions is optional, the *Public Sector Standard* states that scope 3 emissions from public sector organizations may be substantial due to contractor emissions, and therefore may represent an opportunity for innovation in GHG reductions through the use of procurement policies, for example.

The scope 3 emission sources common to government organizations consist of the following: transport-related activities in vehicles not owned or controlled by the agency may include employee business travel, employee commutes to and from work, transportation of purchased materials or goods, upstream transportation of purchased fuels, and transportation of waste by a contracted service. Leased assets and outsourced activities are also reported under scope 3 if their reporting is not required under the chosen consolidation approach. Third-party waste treatment and disposal include wastewater treatment, solid waste disposal from operations and the production of purchased materials and fuels, and end-of-life disposal of purchased or sold products. Non-scope 2 electricity-related emissions include extraction, production, and transportation of fuels consumed in the generation of electricity, purchase of electricity sold to an end-user, and transportation and distribution losses for purchased electricity. Finally, extraction and production associated with purchased materials and fuels are scope 3 emissions.

Leased assets present another unique challenge for the public sector as many facilities used by government agencies are not owned, but rather leased. The most common type of lease for government is an operating lease, wherein the tenant agency does not own or have financial control of the facility but does maintain operational control. For assets under an operating lease, therefore, emissions from energy combustion or electricity consumption would be categorized as scope 1 and 2 emissions, respectively, under the operational control approach, but would be classified as scope 3 emissions under the financial control approach. In addition, the *Public Sector Standard* recommends that centralized heating/cooling system emissions (i.e. refrigerant leakage and combustion of natural gas in a boiler unit) be classified as scope 1 emissions if the operational control approach is used. If the lessee has no control over the operation of these units (for example, there is a central temperature control system that cannot be influenced by the tenant), then these emissions may be reported under scope 3.

In selecting a base year for an emissions inventory, agencies should choose the earliest relevant year for which there is reliable data. In addition, base years may be mandated externally through state or regional reporting requirements. Another consideration in selecting a base year is whether to report by calendar year or by fiscal year. Calendar year reporting is consistent with the UNFCCC and several voluntary reporting programs, but fiscal years may make more sense for agencies if utility and other activity data are reported on a fiscal year basis. Recalculation of base year emissions may also be required if emissions change by a set amount such as 5%, due to discovery of error, structural change of the agency, or outsourcing of activities; a protocol for recalculating emissions must be developed and applied consistently.

The *Public Sector Standard* outlines 5 steps to account for scope 3 emissions. First, describe and map the value chain of the organization, which represents all of the upstream and downstream activities that contribute to or are a consequence of the agency's operations. This will identify the full range of possible scope 3 categories. Example value chain components could be listing all of the organization's suppliers, inputs, and outputs. Secondly, the agency should determine which scope 3 emission categories are relevant, due to their large contribution to total emissions, significant potential for emissions reductions, or if they are deemed critical by key stakeholders. Third, identify and engage partners along the value chain. Fourth, quantify scope 3 emissions, clearly documenting any estimation methods used and the quality of data collected. Finally, sum all scope 3 emissions to the relevant organizational level, such as district offices or headquarters.

Finally, the *Public Sector Guidance* recommends that agencies develop an inventory quality management system that describes the steps taken to develop a GHG inventory including GHG accounting procedures, data collection, reporting, and a data correction and checking system. An inventory program framework should include: methods, data, inventory processes and systems, and documentation.

http://www.ghgprotocol.org/the-public-sector-works-with-ghg-protocol-to-develop-a-new-protocol

WRI: The GHG Protocol – Corporate Value Chain (Scope 3) Accounting and Reporting Standard

In November of 2010, WRI published a draft standard for accounting for and reporting scope 3 emissions. Accounting and reporting standards for scope 3 emission sources will be very helpful as there is a lot of variability in the way scope 3 emissions are defined and quantified across inventories. The *Scope 3 Protocol* includes guidance for: purchased goods and services; direct (tier 1) supplier and cradle-to-gate emissions; energy-related emissions not included in scope 2; capital equipment; transportation and distribution (upstream and downstream); business travel; waste generated in operations; franchises not included in scopes 1 and 2 (upstream and downstream); leased assets not included in scopes 1 and 2 (upstream and downstream), investments not included in scopes 1 and 2; use of sold products; end-of-life disposal of sold products; and employee commuting. Final guidance will be published in 2011.

http://www.ghgprotocol.org/standards/product-and-supply-chain-standard

GHG METHODOLOGIES

Most GHG guidance documents provide similar methodologies for calculating GHG emissions—particularly for scope 1 and scope 2 emissions. However, guidance documents sometimes vary in the activity data they use to calculate GHG emissions, the preferred units for recording the activity data, the depth of emission source descriptions, the number of available calculation approaches, and the detail of the calculation approach depending on the targeted audience of the guidance document.

In this section, guidance documents that contain methodology descriptions and data sources most relevant to state DOTs are listed, along with a brief explanation of why they are recommended for state DOTs.

2006 IPCC Guidelines for National Greenhouse Gas Inventories

The Intergovernmental Panel on Climate Change (IPCC) *2006 Guidelines for National Greenhouse Gas Inventories* (hereafter referred to as *IPCC Guidelines*) provides methodologies for estimating national inventories of anthropogenic (human-induced) emissions by sources and removals by sinks of greenhouse gases. The 2006 *IPCC Guidelines* consist of five volumes. Volume 1: General Guidance and Reporting describes the basic steps in inventory development and offers general guidance in GHG and removals estimates. Volume 2: Energy provides guidance for estimates in the energy sector of the economy and includes sections on stationary combustion, mobile combustion, fugitive emissions, and carbon dioxide transport, injection, and geological storage. Volume 3: Industrial Processes provides guidance for estimates in the industrial processing sector of the economy, and includes sections for mineral industry emissions (e.g., cement production), chemical industry emissions (e.g., ammonia production), metal industry emissions (e.g., iron and steel production), non-energy products from fuels and solvents use (e.g., lubricant use), electronics industry emissions (e.g., etching and CVD cleaning for semiconductors), emissions of fluorinated substitutes for ozone depleting substances (e.g., refrigeration and air conditioning applications), and other product manufacture and use (e.g., emissions of SF_6 and PFCs from electrical equipment). Volume 4: Agriculture, Forestry, and Other Land Use provides guidance for estimates in the agriculture, forestry and other land use sectors of the economy. This includes sections for forest land, cropland, grassland, wetlands, settlements, and other land. Finally, Volume 5: Waste provides guidance for estimates in the waste sector of the economy. This volume includes sections for waste generation, composition, and management data, solid waste disposal, biological treatment of solid waste, incineration and open burning of waste, and wastewater treatment and discharge.

The methodologies presented by the *IPCC Guidelines* are designed for national-level GHG Inventories. However, they provide a useful reference for standard GHG accounting methods.
http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Inventory of U.S. Greenhouse Gas Emissions and Sinks

The EPA's annual *Inventory of U.S. Greenhouse Gas Emissions Sources and Sinks* is the official nationwide greenhouse gas emissions inventory of the United States submitted to the UNFCCC. Although emissions are calculated at the national level in this inventory, the methodologies used are helpful for inform emissions estimations at lower organizational levels as well. For example, the transportation methodology may be applicable to state DOTs if fleet-specific information is not available. To calculate CO_2 emissions from fossil fuel combustion, total fuel consumption by fuel type and sector is required, which is used to determine the total carbon content of consumed fuels and estimate CO_2emissions. Emissions are then allocated by vehicle type based on average vehicle fleet composition statistics. For CH_4 and N_2O, distance traveled (VMT) and the GREET transportation fuel cycle model's emission factors are used to calculate emissions.

http://epa.gov/climatechange/emissions/usinventoryreport.html

COMBINED GHG GUIDANCE MATERIALS

ICLEI/The Climate Registry/California Air Resources Board: Local Government Operations (LGO) Protocol

The *LGO Protocol* is a joint collaboration between the California Air Resources Board (CARB), the California Climate Action Registry, ICLEI – Local Governments for Sustainability, and The Climate Registry. The purpose of the *LGO Protocol* is to provide guidance tailored to local governments for conducting GHG emissions inventories consistent with international inventory design standards. The *LGO Protocol* is based on the *GHG Protocol Corporate Standard*, various CARB publications, the California Climate Action Registry's *General Reporting Protocol*, The Climate Registry's *General Reporting Protocol*, ICLEI's *International Local Government GHG Emissions Analysis Protocol*, the International Organization for Standardization (ISO) 14064-1 *Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*, EPA's Climate Leaders *GHG Inventory Guidance*, and the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007*.

The *LGO Protocol* requires reporting for emissions of all 6 Kyoto GHGs calculated for calendar years, rather than fiscal years, in accordance with UNFCCC, the Kyoto Protocol, European Union Emissions Trading Scheme, The Climate Registry, the California Climate Action Registry, and the State of California's mandatory reporting regime.

In addition to categorizing emissions by scope, the *LGO Protocol* identifies local government sector categories for emissions sources. These are: buildings and other facilities; streetlights and traffic signals; water delivery facilities; port facilities; airport facilities; vehicle fleet; transit fleet; power generation facilities; solid waste facilities; wastewater facilities; and other process and fugitive emissions. The categorization of emissions into sectors may be more relevant to local government policy than is categorization into scopes alone. Below is a description of the sources and scopes included under each of the sectors that are relevant to state DOTs.

- Buildings and Other Facilities – includes stationary and fugitive scope 1 emissions and scope 2 emissions from purchased energy. This includes administrative facilities, public venues, recreational facilities, storm water pumping, and storage facilities.
- Streetlights and Traffic Signals – includes scope 2 emissions from purchased electricity for lighting and traffic services such as crosswalk signals and amber flashers.

- Port Facilities – includes stationary and fugitive scope 1 and scope 2 emissions from purchased energy related to port facilities, including marinas, ferry stations, and administrative facilities. This does not include mobile sources.
- Airport Facilities – stationary and fugitive scope 2 emissions and scope 2 emissions from airports, including terminals, hangers, runway lighting, and administrative facilities; does not include mobile sources.
- Vehicle Fleet – includes all scope 1 mobile combustion and fugitive emissions and scope 2 emissions for all mobile equipment operated by the state DOT. This includes cars, trucks, vans, heavy machinery, boats, aircraft, tractors, etc.
- Transit Fleet – includes all scope 1 mobile combustion and fugitive emissions, and scope 2 emissions from mass transit equipment operated by the DOT. This may include vans, buses, and light rail, among others.
- Power Generation Facilities – includes all stationary combustion and fugitive emissions (scope 1) and scope 2 purchased energy and transmission and distribution loss emissions of facilities used to generate or distribute power.
- Solid Waste Facilities – stationary and fugitive scope 1 emissions and scope 2 emissions from DOT-owned and operated disposal facilities
- Other Process and Fugitive Emissions – other scope 1 process or fugitive emission sources.

The *LGO Protocol* identifies scope 3 sources that are relevant to and have been quantified by many local governments. These include: emissions from waste generated by government operations, but disposed of outside organizational boundaries; emissions from employee commuting; and emissions from employee business travel. As scope 3 emissions data are typically less available and accurate, the LGO Protocol states that estimation methods may be used in place of actual data as long as the estimation process is thoroughly documented.

The third section of the *LGO Protocol* details methodologies for quantifying emissions from local government operations. The *Protocol* uses calculation-based methodologies using activity data and established emission factors. Recognizing that agencies have varying levels of time and resources to expend in conducting a GHG inventory, the *LGO Protocol* has two levels of calculation methods, depending on level of effort required.

The *Local Government Operations Protocol* provides two levels of calculation methods for all scope 1 and scope 2 emission sources. The first level of methodology relies on activity data and results in the most accurate calculation of emission sources. The "alternate" methodologies are less accurate but require less intensive data collection and can be used in the absence of available or complete data. For example, an alternate approach for estimating fugitive fluorinated GHG emissions involves national average equipment leakage rates, whereas the preferred methodology requires an inventory of fluorinated GHGs used in refrigeration or air conditioning equipment. The alternate methodologies are appropriate for state DOTs that do not keep central records of certain data sources and who will need alternative, yet standardized, methodologies to calculate emissions.

In addition, the *LGO Protocol* is a useful source of methodologies for state DOTs because the recommended data sources are specific to local government operations, including state DOTs (for example, fuel receipts and reimbursement records for fuel usage data).

http://www.theclimateregistry.org/resources/protocols/local-government-operations-protocol/

White House Council on Environmental Quality: Federal GHG Accounting and Reporting Guidance

The *Federal GHG Guidance* establishes requirements and provides procedures for Federal agencies to prepare GHG emission inventories. The *Federal GHG Guidance* relies on the protocols set forth by the Public Sector Standard; however, it also makes modifications to accommodate Federal agencies specifically.

Technical Support Document

The *Federal GHG Guidance* Technical Support Document ("TSD") provides default and advanced methodologies for the major scope 1 and scope 2 emission sources as well as six scope 3 emission sources—employee commuting, business air travel, business ground travel, T&D losses, contracted solid waste, and contracted wastewater treatment. The default methodologies provide relatively less intensive data collection, and often use default national averages in estimating emissions. The advanced methodologies are more accurate, but often require a higher level of effort for data collection and calculations.

The TSD provides methodologies and calculations for scope 1 and scope 2 emission sources that are very similar to those in the *LGO Protocol* and may be useful to state DOTs. However, the data sources described in the *Federal GHG Guidance* are tailored to federal reporting and are not necessarily applicable to state DOTs, so the *LGO Protocol*'s recommended activity sources will likely be more useful for state DOTs.

The *Federal GHG Guidance TSD* is currently the only major guidance document that provides detailed methodologies for estimating six scope 3 GHG emission sources—employee commuting, business air travel, business ground travel, electricity losses from transmission and distribution (T&D), contracted solid waste, and contracted wastewater treatment. The activity data sources provided in the *Federal GHG Guidance* are tailored for federal agencies (i.e., GSA travel records), but the calculation methodologies and required activity data for scope 3 GHG emissions are relevant to state DOTs.

http://www.whitehouse.gov/administration/eop/ceq/sustainability/fed-ghg

Climate Leaders Greenhouse Gas Inventory Guidance

Climate Leaders was developed as a voluntary GHG reporting program by the EPA. In 2010, EPA announced that it would phase out the Climate Leaders program, encouraging members to participate instead in other existing reporting programs such as the Climate Registry. The *Climate Leaders Greenhouse Gas Inventory Guidance* is based on the WRI/WBCSD *Corporate Standard*. Climate Leaders Partners are required to document emissions of the six major GHGs six major GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) on a company-wide basis (including at least all domestic facilities) associated with the following emission sources: (i) on-site fuel consumption and energy use; (ii) industrial process-related emissions, as applicable; (iii) on-site waste disposal, (iv) on-site air conditioning and refrigeration use; (v) indirect emissions from electricity and steam purchases; and (vi) mobile sources.

The components of the Climate Leaders GHG Inventory Guidance are Design Principles, Cross-Sector Core Modules, Sector-Specific Core Modules, and Optional Modules. The Design Principles Guidance contains information on defining inventory boundaries, identifying GHG emission sources, defining and adjusting a base year, determining the minimum level of data to be reported, and more. The Cross-Sector Core Modules Guidance includes direct sources and indirect emissions from electricity purchased by the reporting entity. The Sector-Specific Core Modules Guidance pertains to process emissions for specific industry sectors. Finally, the Optional Modules

Guidance provides GHG accounting guidance and reporting forms pertaining to other indirect emissions sources that the Partner may wish to include in the inventory.

The Climate Registry: General Reporting Protocol

The Climate Registry provides standard reporting guidance for voluntary reporting of emissions in their *General Reporting Protocol,* published in 2008. Updates to the Protocol have been published separately, but are not yet incorporated into a new revised reporting protocol. The Climate Registry also offers sector-specific guidance for the Electric Power Sector and Oil and Gas Production Sector.

The *General Reporting Protocol* provides guidance on inventory design, accounting, and reporting principles; geographical, organizational, and operational boundaries; and facility-level reporting, including how to define facility boundaries and categorizing mobile source emissions. The second portion of the *GRP* provides methodology for quantifying emissions. The last part of the *GRP* provides detailed instructions on reporting emissions to the Climate Registry, including verification requirements.

http://www.theclimateregistry.org/resources/protocols/general-reporting-protocol/

California Climate Action Registry: General Reporting Protocol

The California Climate Action Registry provides many resources to aid in the development of GHG emissions inventories. These include the *General Reporting & Verification Protocols* as well as industry-specific protocols for the cement sector, power/utility sector, forest sector, and local government operations (described above). In addition, CCAR developed the *Climate Action Registry Reporting Online Tool (CARROT)* to aid members in reporting emissions. The *General Reporting Protocol* is based on the principles of the WRI/WBCSD *Corporate Standard*.

The California Climate Action Registry's General Reporting Protocol is similar to TCR GRP, but is tailored specifically to California-based entities. Because these methodologies and data sources are tailored for GHG inventories at the state level, they may be useful for state DOTs to use in determining relevant data sources for their activity data. Like the TCR GRP, the CCAR GRP does not provide methodologies for estimating scope 3 emissions.

http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html