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Quantifying Greenhouse Gas Emissions from Transit

Abstract: This *Recommended Practice* provides guidance to transit agencies for quantifying their greenhouse gas emissions, including both emissions generated by transit and the potential reduction of emissions through efficiency and displacement.

Keywords: carbon footprinting, climate change, greenhouse gas emission inventory/reporting, mode shift, land-use effect

Summary: This *Recommended Practice* provides guidance to transit agencies for quantifying their greenhouse gas emissions, including both emissions generated by transit and the potential reduction of emissions through efficiency and displacement. It lays out a standard methodology for transit agencies to report their greenhouse gas emissions in a transparent, consistent and cost-effective manner. It ensures that agencies can provide an accurate public record of their emissions, may help them comply with future state and federal legal requirements, and may help them gain credit for their "early actions" to reduce emissions.

Scope and purpose: This document lays out a standard methodology for transit agencies to report their greenhouse gas emissions in a transparent, consistent and cost-effective manner.

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Introduction

This introduction is not part of APTA SUDS CC-RP-001-09, Rev. 1, "Quantifying Greenhouse Gas Emissions from Transit."

Section 1 of this document provides an introduction to quantifying transit greenhouse gas emissions. Section 2 discusses quantification of emissions sources and reductions from transit operations and capital projects. This follows the requirements in *The Climate Registry General Reporting Protocol* but provides specific interpretation of these provisions for transit agencies. Section 3 provides guidance on quantifying avoided emissions—i.e., the greenhouse gas benefits of transit—from mode shift and the land-use effect. Section 4 provides guidance on quantifying Scope 3 emissions for capital projects and recycling. Section 5 provides guidance on emission offsets and quantifying carbon sinks. Section 6 summarizes the calculation method for demonstrating the net GHG emissions benefit.

APTA recommends the use of this document by:

- individuals or organizations that operate public transit systems;
- individuals or organizations that contract with others for the operation of public transit systems; and
- individuals or organizations that influence how public transit systems are operated (including but not limited to consultants, designers and contractors)

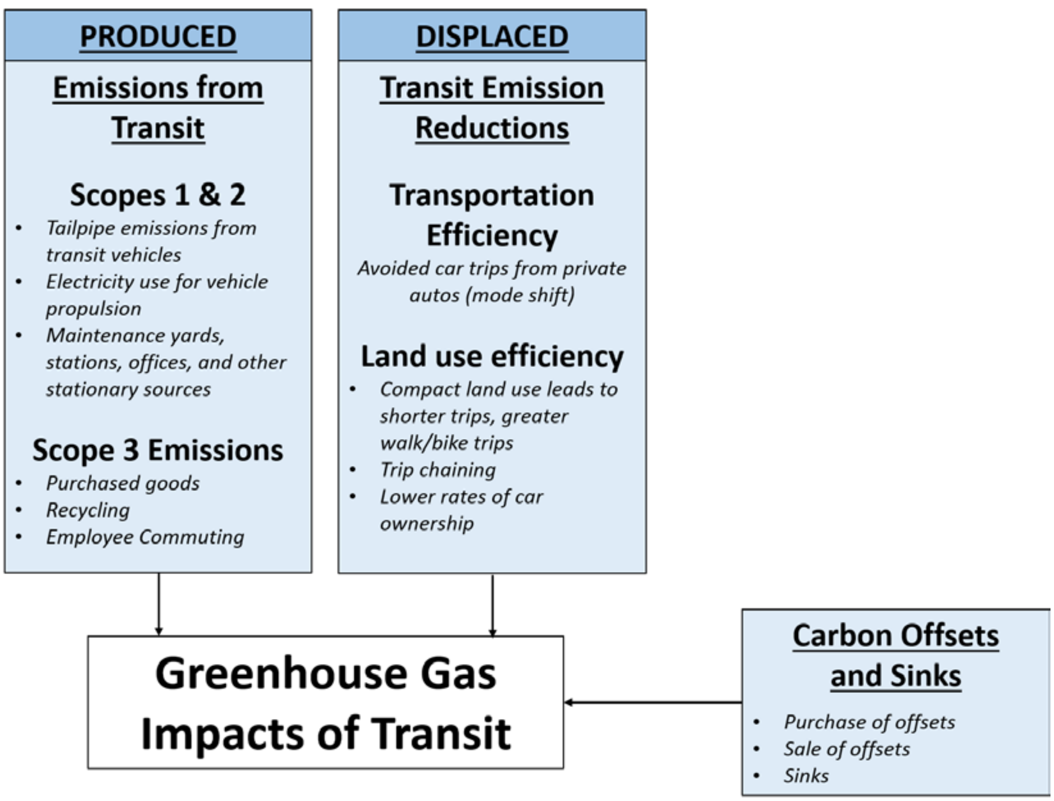
Quantifying Greenhouse Gas Emissions from Transit

1. Transit greenhouse gas emissions

1.1 Typology

Transit service and the practices of transit agencies influence greenhouse gas emissions in several ways. Previous guidance divided these influences into two categories: emissions produced by transit and emissions displaced by transit. This revised guidance adds carbon offsets and sinks as another key area that makes up the greenhouse gas emissions associated with a transit agency and its inventory (as shown in **Figure 1**).

FIGURE 1
Typology of Greenhouse Gas Impacts



Emissions from transit: Within transit agencies, the source of emissions is primarily mobile combustion; that is, the tailpipe or life-cycle emissions from fuel used in transit vehicles and electricity used by rail, agency fleet and revenue fleet vehicles. Sources also include stationary combustion, such as on-site furnaces, as well as indirect emissions from electricity generation, employee travel, purchased goods and services, and waste management. These sources are calculated at the agency level, except for emissions associated with new capital works, which are quantified on a project basis.

Emissions reductions: The main source of transit agency emissions reductions is the diversion of trips to transit and rail. These reductions can be calculated as a result of service provided, as well as at the regional or national level. These can be divided into two subcategories:

- Emissions avoided from displaced trips through mode shift from private modes to transit.
- Emissions avoided when transit enables denser land-use patterns that promote shorter trips, walking and cycling, and reduced car use and ownership. This is expressed through the land-use efficiency effect.

Carbon offsets and sinks: These are agency practices such as the purchase of emissions credits or the selling of such credits, attributed to agency practices such as emissions saved from additional diversions or fuel changes to a less carbon-intensive option. Agencies can also engage in practices such as landscaping or tree planting, which create carbon sinks that store carbon dioxide or remove it from the atmosphere.

1.2 Protocols consulted

Before the creation of the initial version of this Recommended Practice, transit agencies largely followed The Climate Registry protocols as the basis for greenhouse gas inventorying and reporting. Following common practice, the initial Recommended Practice based its recommendations on The Climate Registry's *General Reporting Protocol* (2008). Given precedent, this version largely follows the latest version of the *General Reporting Protocol for the Voluntary Reporting Program* (The Climate Registry 2016), and augments it through recommendations from the following protocols:

- *Local Government Operations Protocol* for the quantification and reporting of greenhouse gas emissions inventories (The Climate Registry 2010)
- *Corporate Value Chain (Scope 3) Accounting and Reporting Standard* (World Resources Institute 2012)
- *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (World Resources Institute 2014)
- *GHG Protocol Scope 2 Guidance* (World Resources Institute 2015)

While this Recommended Practice does not consult the following protocol, users are welcome to consult it for their own reference:

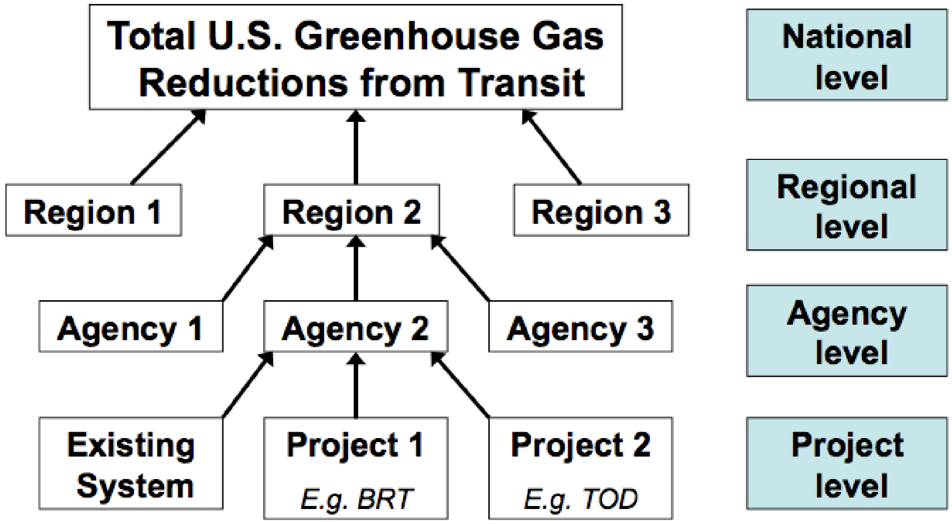
- *The Greenhouse Gas Protocol for the U.S. Public Sector* (World Resources Institute 2010)

1.3 Boundary setting

1.3.1 Scale

It is useful to make a distinction between *average* (i.e., ongoing or historical) impacts and *marginal* impacts from transit (**Figure 2**). Average impacts can be understood as the net impact of transit on present-day emissions. These are the benefits that have accrued from historical investments. Marginal impacts can be understood as the incremental change in emissions that result from a new project or policy change—for example from implementing a new light-rail or BRT line, or from changing fare levels.

FIGURE 2
Scale of Greenhouse Gas Reductions



1.3.2 National level

Several pieces of research focus on average impacts at the national level. The FTA estimates that, on a national level, the average transit system emits 0.45 lbs CO_2 per passenger mile compared with a single-occupancy private vehicle at 0.96 lbs CO_2 per passenger mile (FTA 2010). Two studies for APTA have quantified emissions avoided by transit through displaced car trips at 16 million metric tons (MMT) of CO_2 equivalent (CO_2e) per year, while producing only 12 MMT CO_2e of emissions (Bailey 2007; Davis and Hale 2007). An earlier study for APTA (Shapiro et al. 2002) arrived at a similar estimate of emissions from avoided car trips: 16.5 MMT of CO_2e emissions annually. Adding in the land-use, meanwhile, almost doubles these benefits, providing an additional 30 MMT of emission savings. An alternative estimate by the Public Interest Research Group puts the savings associated with transit at 26 MMT (Baxandall et al. 2008). In summary, the range of benefits from these studies is between 16 and 37 MMT per year.

1.3.3 Regional level

Research has also examined quantifying differences in transportation emissions among different metropolitan regions. UC Berkeley's Institute of Transportation Studies estimated life-cycle regional transportation greenhouse gas (GHG) emissions per passenger mile traveled (PMT) in three urban regions ranging from 480 g CO_2e/PMT in the Bay Area to 440 g CO_2e/PMT for Chicago and 410 g CO_2e/PMT in New York (Chester and Horvath 2009). A Brookings Institution report shows that transit-rich regions tend to have lower carbon footprints (Brown, Southworth et al. 2008). The greenhouse gas benefits of transit from congestion relief and the land-use effect are most appropriately quantified at the regional level. While transit service in most large regions is provided by multiple agencies, there often are synergies and geographic overlaps among these efforts. For example, in the San Francisco Bay Area, the land-use effect is difficult to ascribe to a single agency (such as BART) but is a result of the entire transit network, including agencies such as San Francisco MTA and AC Transit. For accounting purposes, however, APTA recommends allocating these regional benefits to individual agencies based on their share of unlinked passenger trips in a region. Agencies that operate in multiple metropolitan regions, such as New Jersey Transit, should take account of the benefits they provide in each region.

1.3.4 Agency level

This document focuses on produced emissions, displaced emissions, and offsets and sinks at the agency level. It provides guidance to transit agencies in quantifying their individual contribution to emissions and reductions and on allocating benefits calculated at the regional level to individual agencies.

In 2010, the FTA estimated emissions per PMT for transit systems in the U.S., including heavy rail, light rail, bus systems, commuter rail, van pool and other modes (FTA 2010). The estimated emissions are based on 2008 data from the National Transit Database, emissions factors from the Department of Energy, and sub-region electricity emission factors from EPA eGRID 2007 v1.1, published in April 2009.

Results from the report are summarized in **Table 1**.

TABLE 1

Summary of Estimated Carbon Emissions per Passenger Mile for U.S. Transit Systems, 2008

Mode	Range[1] (lbs CO_2/PMT)	National Average Weighted by PMT (lbs CO_2/PMT)
Heavy-rail systems	0.085–0.919	0.224
Light-rail systems	0.146–4.266	0.365
Bus systems	0.127–1.211	0.643
Commuter rail	0.013–1.524	0.326
Vanpool	0.099–0.646	0.223
Other modes[2]	0.234–8.934	n/a

1. Range for bus systems includes only the 50 largest in the U.S.
2. Other modes include automated guideway, Alaska Railroad, cable car, ferry boat, inclined plane, monorail, Publico and trolley bus.

Transit agencies small and large are self-reporting via the APTA Sustainability Commitment on their GHG inventories and benefits quantifications. Examples of large agencies with robust GHG reporting include the Utah Transit Authority, LA Metro and Sound Transit.

1.3.5 Project level, marginal benefits

At the project level (e.g., opening new bus rapid transit or rail lines, or improving service frequency), a variety of protocols and methodologies have been developed for specific project types in order to estimate the *marginal* change in emissions from transit expansion. For example:

- In 2016, the White House Council on Environmental Quality issued guidance for federal agencies on including greenhouse gas emissions impacts and effects of climate change on proposed projects through the National Environmental Policy Act (NEPA) framework.
- The California Emissions Estimator Model (CalEEMod) is a state-specific model for quantifying GHG and criteria pollutants associated with construction and operation of a variety of land-use projects.
- The FTA published the *Greenhouse Gas Emissions from Transit Projects: Programmatic Assessment* (FTA 2017). The assessment estimates partial life-cycle emissions for the construction, operation, and maintenance of sample transit projects, and provides a source of data and analysis to reference for future environmental assessments.
- LA Metro commissioned a cost-effectiveness study examining a variety of strategies for GHG reduction associated costs (Gallivan et al. 2010). The study includes a variety of projects including

energy efficiency improvements, vehicle technology upgrades, transit service expansions, and bike and transit pass programs.

- The Clean Development Mechanism has approved a large-scale methodology for BRT (Grütter 2007) and more flexible, small-scale methodologies for projects such as regenerative braking on rail cars. (See Definitions for an explanation of the Clean Development Mechanism).

Ridership forecasts and other planning work for projects under FTA's Capital Investment Grant Program typically would quantify reductions in VMT, which can then be converted to CO_2e using standard emission factors.

1.4 Organizational boundaries and inventory

NOTE: Reference Chapter 4 of *The Climate Registry General Reporting Protocol*.

Agencies provide a greenhouse gas assertion that defines what emissions they measure and report. The assertion can be provided in a greenhouse gas report or project plan that results in emission reductions. An agency's boundaries and inventory of activities form the basis of this assertion.

The Climate Registry provides two options for defining the organizational boundary (based on World Resources Institute 2004) (for information on emission scopes, see Table 3 in Section 1.4.1):

- **Equity share approach.** This approach considers emissions from operations in which an organization has an economic interest in proportion to the equity share (usually defined by percentage ownership). If the equity share approach is used, then either financial or operational control also must be used.
- **Control approach.** The control approach is split into two categories:
  - **Financial control.** All emissions from operations over which the organization has control over financial policies and an interest in economic benefits, or for which it bears the financial risks. Financial control for transit agencies may be established by one or more of the following:
    - Wholly owning an operation, facility or source.
    - Governing the financial policies of a joint venture under a statute, agreement or contract.
    - Retaining the rights to the majority of the economic benefits and/or financial risks from an operation or facility that is part of a joint venture or partnership. This may be evident through casting the majority of votes at a meeting of the board of directors or having the right to appoint/remove a majority of the members of the board.
  - **Operational control.** All emissions from operations over which the organization has full authority to introduce and implement operating policies. In this instance, the agency must also provide a list of entities in which it has an ownership interest but does not have control. Operational control for transit agencies may be established through the following:
    - Wholly owning an operation, facility or source.
    - Having the full authority to introduce and implement operational and health, safety and environmental policies.

APTA strongly recommends that transit agencies use the operational control method to report their emissions. This provides the most appropriate match with their emissions and is also the regulatory approach being considered in some states, including California.

In many cases, organizational boundaries involve a gray area, and definitions of operational and financial control are subject to interpretation. In almost all cases, however, the following rule should apply: *If a transit agency reports data on a service to the National Transit Database (NTD), it should be considered to have operational control over those emissions.* For example:

- Directly operated services clearly fall under an agency's operational control.
- Purchased transportation services fall under an agency's operational control, as the agency specifies routes, service frequencies, vehicle and fuel types, and health and safety policies. This applies to services purchased from another transit agency or from a private contractor.
- Paratransit services provided under the Americans with Disabilities Act (ADA) fall under an agency's operational control, as the agency specifies service policies, eligibility (subject to federal law), vehicle standards, fuel types, and health and safety policies.
- Vanpool services reported to NTD—where the transit agency specifies destinations, vehicle standards, fuel types, and health and safety policies, and may also own or lease the vehicle—also fall under an agency's operational control.

Table 2 shows the sources of emissions that would be included and excluded based on operational control and financial control. For comparison, it also shows the types of services for which an agency reports to NTD. There is a precise match between NTD reporting and operational control. Note that any emissions excluded under NTD/operational control, and thus not considered Scope 1 or Scope 2, may still be reported under The Climate Registry protocol as Scope 3 (optional) emissions.

TABLE 2
Organizational Boundaries

	Required by Existing NTD Reporting?	**Included Under GHG Reporting?**	
		Operational Control (Recommended)	**Financial Control**
Revenue and nonrevenue service directly operated by the agency.	Yes	**Yes**	Yes
Service operated by the agency under contract to another organization. *Example: King County Metro operates Sound Transit service.*	Generally, no[1]	**Generally, no[1]**	No
Purchased transportation: Service offered by the agency but operated by another transit agency. *Example: Sound Transit contracts with King County Metro to provide bus service.*	Yes	**Yes**	Yes
Purchased transportation: Service offered by the agency but operated by a private contractor. *Example: Foothill Transit contracts with MV Transportation and First Transit to provide bus service.*	Yes	**Yes**	Yes
Paratransit service provided under a joint agreement. *Example: BART and AC Transit provide ADA paratransit through East Bay Paratransit.*	Generally, yes[1]	**Generally, yes[1]**	Varies
Paratransit service provided by taxis or another private contractor.	Yes	**Yes**	Varies; generally, no
Vanpools using transit agency-owned vehicles, or those under a finance or capital lease to the agency.	Yes	**Yes**	Yes
Vanpools and carpools using privately owned and leased vehicles.	Varies[1]	**Varies[1]**	No

TABLE 2
Organizational Boundaries

	Required by Existing NTD Reporting?	Included Under GHG Reporting?	
		Operational Control (Recommended)	Financial Control
Riders' transit access trips by private vehicle or via another transit agency.	n/a	**No**	No
Stations, parking, facilities and administrative buildings owned or leased by the agency under a finance or capital lease.	n/a	**Yes**	Yes
Stations, parking, facilities and administrative buildings under an operating lease.	n/a	**Yes**	No
Stations, parking and facilities owned and operated by another organization (e.g., a city, airport or shopping center).	n/a	**No**	No
Transit-oriented development (e.g., on land leased from the transit agency but with no financial or operational control).	n/a	**No**	No

1. Dependent on the agency under which these services are reported for NTD purposes.

Transit agencies will still need to provide additional, qualitative information on emissions from organizations in which they have an equity share if they select the equity share approach. (This might include service provided under a joint powers agreement.) Refer to Chapter 4 of The Climate Registry protocol for details of reporting requirements where an agency has an equity share in another organization.

Transit agencies that are part of a larger local government entity, such as a city, county or state, may also report their NTD emissions separately from the entire city operation. The transit agency may also report separately to The Climate Registry, provided that the larger entity (e.g., the city) is not also a TCR member. For example, if the City and County of San Francisco reports to The Climate Registry, then it should also include emissions from its MTA, but these should be disaggregated for purposes of comparison with other transit agencies. The guidance here still should be followed for purposes of determining emissions from transit vehicle fleets and operations, but it will generally form just one component of a larger report.

1.4.1 Emission sources (scopes)

Emission inventory protocols such as those developed by The Climate Registry (2016) and World Resources Institute (2004) make a key distinction between three "scopes" of emissions:

- **Scope 1: Direct emissions.** This scope includes:
  - stationary combustion from boilers and furnaces;
  - mobile combustion in vehicles owned and controlled by the organization;
  - physical or chemical processes; and
  - fugitive sources such as leakage of SF_6 from transformers or HFCs from air conditioning equipment.
- **Scope 2: Indirect emissions from purchased energy.** This scope includes purchased electricity, heating, cooling and steam.

- **Scope 3: Indirect emissions from corporate value chain.** This scope is required under the WRI protocol, but optional under The Climate Registry's. It includes 15 categories, but of relevance to transit agencies:
    - avoided emissions from mode shift to transit and from land-use effects;
    - transit access trips (e.g., to rail stations or park-and-ride facilities);
    - employee commuting and business travel;
    - emissions from vehicle manufacture and disposal;
    - upstream (well-to-tank) emissions from fuel extraction, refining and transportation; and
    - waste disposal.

For more details, refer to Chapter 5 of *The Climate Registry General Reporting Protocol*. The division into the three scopes is reflected throughout this guidance. At their heart, the scopes are a mechanism to avoid double counting, as follows:

- **Scope 1** emissions are reported under Scope 1 by only a single organization, based on direct emissions from its facilities and vehicles. Anything that is combusted (e.g., natural gas in furnaces) or emitted (e.g., fugitive emissions from air conditioning units) on the reporting organization's premises falls under Scope 1.
- **Scope 2** emissions are reported by both the organization that generates the electricity or steam (as Scope 1) and the purchaser of electricity and steam (as Scope 2).
- **Scope 3** emissions are reported as Scope 1 and possibly Scope 2 by other organizations (for example by the vehicle manufacturer). For purposes of providing a full picture of their emissions, an organization may report these Scope 3 emissions to understand their value chain. For example, the purchaser of cars and buses may report life-cycle emissions from manufacturing as Scope 3. For purposes of consistency among transit agencies and other reporters, these Scope 3 emissions must be clearly separated from Scope 1 and Scope 2 emissions, and the specific emission types under Scope 3 must be clearly itemized when reporting.

In practice, most emissions sources from transit operations fall under Scope 1, or Scope 2 in the case of agencies that use electric traction power for rail or trolley bus propulsion. Emissions associated with capital projects are under Scope 3 for most agencies, because these will be reported under Scope 1 by another organization, such as the contractor and steel manufacturer.

> **NOTE:** Agencies that are self-performing capital projects need to allocate emissions appropriately under Scope 1, 2 or 3.

Emissions reductions from mode shift and land use fall under Scope 3 since these activities reduce auto and/or air trip fuel consumption, which is largely a Scope 1 emission for their respective operators. *APTA encourages transit agencies to specify in purchased transportation and construction contracts the entity that will report specified emissions as Scope 1.*

Should an agency decide to register its emissions with The Climate Registry, *APTA strongly encourages the inclusion of avoided emissions from displaced trips.* While Scope 3 emissions are optional from a reporting standpoint under The Climate Registry's guidance, reporting avoided emissions from reduced private auto use or air trips provides the fullest picture of transit's net contribution to greenhouse gas reductions.

The types of emissions sources, reductions and removals associated with transit agency practices and service delivery are categorized in **Table 3**.

TABLE 3

Emissions Sources Associated with Transit Agency Service and Operation

Transit Service Delivery		**Scope**	
Mobile combustion	Emissions sources associated with combustion of fuels for transit vehicles	1	Purchased fuel
Electricity for traction power	Emissions sources attributable to the electricity purchased or produced to power transit vehicles	2	Purchased electricity
Fugitive emissions	Emissions from maintenance activities	1	
Trip diversions	Emissions reductions associated with the reduction of automobile and/or airplane trips[1] when riders use transit and rail	3	
Land use	Emission reductions associated with more compact development, more bike and walk trips, trip chaining, lower car ownership and other land-use effects associated with transit service	3	
Capital works	Indirect emissions (upstream) from materials associated with new capital works	3	Purchased goods and services Capital goods
Construction equipment	Direct emissions from on- and off-road vehicles and equipment	3	Services
Transit Maintenance and Operations		**Scope**	
Agency fleet	Direct emissions associated with agency fleet	1	Purchased fuel
Facilities	Electricity and fuel use at facilities, maintenance yards, offices, and other stationary sources	2	Purchased electricity Purchased steam Purchased heating and cooling
Waste management	Emissions associated with agency waste streams; can also include arisings from stations (recycling and reuse programs qualify as emissions reductions)	3	Waste generated in operations
Employee commuting	Emissions associated with commute vehicles for agency employees	3	
Agency purchased goods	Upstream emissions associated with purchased goods	3	Purchased goods and services Capital goods
Tree planting/ landscaping	Carbon sink associated with agency tree planting or landscaping activities	n/a	Carbon removal

1. This is applicable to agencies that have the capacity to displace air trips (e.g., Amtrak).

Quantifying emissions across all three scopes enables an agency to understand the emissions associated with its practices. This knowledge can drive decision making and strategies to improve discrete areas within an agency's inventory. As discussed in Section 6, APTA recommends that agencies quantify the benefit associated with transit service by calculating mobile combustion and electricity use to power transit vehicles and the emissions associated with avoided trips.

1.5 Why quantify emissions?

There are several reasons why a transit agency might want to comprehensively quantify its greenhouse gas emissions:

1. **Communicating the benefits of transit.** Reports have demonstrated the role of transit in addressing climate change and its related benefits on a national level (Bailey 2008, FTA 2010). By quantifying their emissions sources, reductions and offsets/removals in a standardized, rigorous manner, agencies can communicate the contribution of transit toward wider emissions reduction targets to elected officials and to the wider community, especially as local, state and federal policy seeks to address transportation's role in contributing to climate change.
2. **Ensuring eligibility for new funding sources.** Climate change policy opens up sources of funding for transit and vehicle trip reduction programs. Examples include developer-funded transit improvements to mitigate GHG impacts of new projects under state environmental legislation; grant programs for emission reduction such as FTA's TIGGER program under ARRA; grant programs developed as a result of California's AB32, such as California's Low Carbon Transit Operations Program (LCTOP) and California's Transit and Intercity Rail Capital Program (TIRCP); and the sale of emission reductions (offsets) on carbon markets. All of these require the quantification of emission savings, and completing this protocol will allow transit agencies to have readily accessible data for these funding sources.
3. **Reporting to carbon accounting organizations, such as The Climate Registry.** Organizations such as The Climate Registry maintain inventories of greenhouse gas emissions based on standardized protocols. In most cases, reporting is voluntary. However, some states have passed or are considering regulations that would mandate reporting to The Climate Registry for large emitters, and there may be benefits for organizations that can demonstrate that they have taken early action to reduce emissions.
4. **Setting emissions targets in local/regional climate action plans.** Many localities and regions are creating climate action plans that identify strategies for reducing emissions. This *Recommended Practice* will assist agencies in evaluating and demonstrating the regional emission reductions they can contribute. This in turn can result in additional policy, programmatic and/or financial support for the provision of transit and supporting activities.
5. **Support environmental planning.** Quantifying an agency's greenhouse gas emissions and reductions can provide valuable baseline information to support project environmental assessments. Some states require GHG assessment in environmental reviews. Through Senate Bill 97 (SB 97), California requires as part of the environmental review process an investigation of project-related sources and GHG emissions. At the federal level, assessing GHGs is not legally required under NEPA. However, in 2016, the White House Council of Environmental Quality (CEQ) published guidance to federal agencies requiring the consideration of GHG and climate change impacts under NEPA reviews.
6. **Supporting internal efforts to reduce emissions.** Many transit agencies have goals to reduce greenhouse gas emissions, both from their own operations and from the wider community. This guidance can help ensure that emissions are reported in a standardized way, allowing agencies to track their efforts and benchmark themselves against other agencies. Reduced emissions can also provide reductions in operating costs, resulting in greater efficiencies that promote more effective use of funding and lower operating expenses. In particular, this methodology is the basis for GHG measurement in the APTA Sustainability Commitment.

Depending on the purpose, different categories of emissions may be included. For example, inventories such as The Climate Registry consider only direct and indirect emissions from transit agencies and would not include avoided emissions from mode shift or land-use changes (although these could still be reported as optional information).

2. Transit emission sources

This section provides guidance on how to quantify emissions sources associated with transit agency operations and delivery of transit service. These include emissions from transit, including direct emissions from mobile source combustion (Scope 1) and indirect emissions from electricity purchases (Scope 2).

This guidance is designed to be applicable for all transit agencies, whether or not they register their emissions with The Climate Registry or a similar body. However, some agencies may want, or may be required through state regulations, to join The Climate Registry. For that reason, this guidance is compatible with *The Climate Registry General Reporting Protocol* v2.1, and the more recent version of the protocol is incorporated into this guidance by reference. The principles of developing an emissions inventory are already well-established; this section aims to provide a high-level overview for transit agencies and to interpret the guidance in terms of specific challenges faced by the transit industry.

Transit agencies should distinguish their emissions sources between Scope 1 and 2 emissions and Scope 3 emissions. In general, operational emissions will fall under Scopes 1 and 2 and capital emissions. Because most construction and manufacturing activities are contracted out, they fall under Scope 3. This avoids double counting, since these emissions will be reported as Scope 1 or Scope 2 by contractors and other organizations. Agencies that are self-performing capital projects need to allocate emissions appropriately under Scope 1, 2 or 3. Table 4 shows where these emissions will be reported. Note that the reporting of emissions by another organization (e.g., a steel manufacturer) does not preclude reporting of these same emissions by a transit agency, but a transit agency must report them as Scope 3 if it does so at all.

TABLE 4
Reporting of Emissions (Examples)

Source	Reported as Scope 1 or 2 By
Steel manufacture for rail construction	Steel manufacturer
Cement production (fuel combustion and calcification)	Cement manufacturer
Transportation of materials	Transportation provider
Construction equipment (earthmoving, tunnel boring, etc.)	Construction contractor
Rail and bus vehicle manufacture	Manufacturer
Landfill of construction waste	Landfill operator

2.1 Simplified quantification methods for emissions sources

NOTE: Reference Chapter 11 of *The Climate Registry General Reporting Protocol*.

All emissions must be quantified. However, up to 5 percent of emissions may be reported using simplified methods that provide an upper-bound (i.e., conservative) estimate. This may be appropriate where the costs of data collection are disproportionate to the quantity of emissions. *For most transit agencies, some types of nonmobile source emissions are likely to fall under this 5 percent threshold and be eligible for simplified methods.* **Table 5** provides examples of emissions reported by agencies to the California Climate Action Registry, when it was active. For example, emissions from mobile sources and purchased electricity account for 97 percent or more of emissions in these two cases.

Transit agencies are encouraged to provide as complete and accurate an inventory as possible. However, as long as mobile source emissions from revenue vehicles are quantified accurately and precisely, agencies have a significant amount of leeway in using simplified methods to quantify stationary and other mobile emissions from sources such as the following:

- steam heating for office buildings
- nonrevenue vehicles where fuel purchase and mileage records are unavailable
- fugitive emissions from air conditioning units and transformers

The Climate Registry allows for reporting at the Entity level. An agency could report total greenhouse emissions by category:

- mobile emissions (CNG, electricity, gasoline, diesel, etc.) for both revenue and nonrevenue vehicles.
- stationary emissions (natural gas; forklift propane, acetylene and CO_2 welding; used oil for heat; generators; etc.)
- indirect emissions (electricity, utility)
- fugitive emissions (refrigerants for facility and vehicles, fire suppression that uses HFCs)

While this is possible, APTA does not recommend reporting at the Entity level since The Climate Registry encourages facility-level reporting. This level of reporting also provides agencies with another indicator for measuring and improving the performance of their facilities.

TABLE 5
Illustration of Transit Emissions by Source

Source	Scope	Santa Barbara MTD		AC Transit (California)	
		Metric Tons CO_2e	Percentage	Metric Tons CO_2e	Percentage
Mobile combustion	1	5,687	95%	64,379	93%
Stationary combustion	1	27	0.5%	1,965	3%
Fugitive emissions	1	1	0%	0	0%
Purchased electricity	2	264	4%	2,568	4%
Purchased steam	2	0	0%	0	0%
Purchased heating and cooling	2	0	0%	0	0%
Total		5,979	100%	68,912	100%

Source: Public reports submitted to the California Climate Action Registry

2.2 Categorizing emissions data by facility

NOTE: Reference Chapter 6 of *The Climate Registry General Reporting Protocol*.

Facility-level reporting details emissions for each facility on an individual basis.

In general, the registry defines a facility as “a single physical premises”—i.e., “any stationary installation or establishment located on a single site or on contiguous or adjacent sites that are owned or operated by an entity.” However, certain facilities may be aggregated for reporting purposes as follows (note that nothing precludes reporting on a more disaggregated basis should a transit agency have available data):

- **Commercial buildings.** Offices, sales outlets, customer service facilities, maintenance yards and administrative facilities may be aggregated and reported as a single facility. This will capture most of an agency's emissions from stationary sources, except for stations. Ideally, maintenance yards should be disaggregated, but this is not required.

NOTE: The Climate Registry protocol allows aggregation for commercial buildings but not for industrial buildings. However, the precise definition of "commercial buildings" is unclear. Examples of commercial buildings include "office buildings, retail stores, storage facilities, etc.," while examples of industrial buildings include factories, mills and power plants.

- **Stations and rights-of-way.** Stations and other emissions on a contiguous right-of-way (e.g., signals that draw power from the electrified rail, if these are not counted under traction power) may be reported as a single facility, analogous to a pipeline. If data are available on individual stations, agencies are encouraged to disaggregate emissions further.

NOTE: According to The Climate Registry protocol (2016, 41): "TCR understands that some emission sources, such as pipelines and electricity transmission and distribution (T&D) systems, do not easily conform to this traditional definition of a facility." As a result, The Climate Registry permits transit rights-of-way to qualify as a single facility under this provision.

- **Mobile sources.** Mobile source emissions should be disaggregated into NTD categories. Each NTD category plus nonrevenue vehicles will comprise a separate facility.

The Climate Registry allows aggregation of the following greenhouse gas emission sources:

- commercial buildings (office, residential, platforms, line and signal, park-and-ride facilities, etc.)
- mobile sources (fleets, including off-road and on-road, both revenue and nonrevenue) by:
  - geographic location (e.g., state/province, national or North American); or,
  - vehicle type (e.g., bus, train) within each geographic location.

Note that emissions also must be disaggregated by state for purposes of reporting to The Climate Registry. This applies only to transit agencies that report stationary emissions sources (such as a maintenance yard) in more than one state. Agencies that operate across state lines and have mobile source emissions or right-of-way in more than one state (e.g., New Jersey Transit running service into New York) may choose to disaggregate these types of emissions by state or to simply report them as a single "United States" category.

Industrial facility (e.g., maintenance garages) emissions must be reported separately, which include the following:

- stationary combustion (natural gas) from utilities, forklifts (e.g., propane), welding (e.g., acetylene and CO_2)
- indirect emissions from electricity (e.g., from utilities)
- fugitive emissions from refrigerants (e.g., HVAC on buildings and vehicles)

The required disaggregation of emissions data for a typical transit agency is shown in **Table 6**.

TABLE 6

Typical Disaggregation of Emissions Data

Physical Premises	NTD Revenue Vehicles (per NTD Categories)
• Maintenance facilities (industrial, individually reported) • Commercial and residential buildings (may be aggregated) • Park-and-ride, stations, right-of-way emissions (may be aggregated) • All nonrevenue vehicles (may be aggregated)	• Bus • Trolleybus • Publico • Jitney • Heavy rail • Commuter rail • Light rail • Monorail • Alaska Railroad • Automated guideway • Cable car • Inclined plane • Aerial tramway • Demand response (e.g., paratransit) • Vanpool • Ferry • Other NTD revenue vehicle

APTA also advises agencies to use discernment when interpreting TCR guidance on special facilities. TCR indicates that "transit systems" are a kind of "Other Special [Facility]." Agencies should not confuse their entire operations with other kinds of transit systems (e.g., a passenger transport system within a greater entity, such as a people mover within an airport).

2.3 Performance metrics

NOTE: Reference Chapter 17 of *The Climate Registry General Reporting Protocol*.

Performance metrics are optional under The Climate Registry protocol. However, in order to facilitate benchmarking of transit agencies, this standard requires the following metrics to be reported for both National Transit Database modal category and for the agency as a whole:

- **Emissions per vehicle mile (revenue service plus deadhead segments).** This primarily measures vehicle efficiency and will be sensitive to efforts to purchase lower-emission vehicles or to switch to lower-carbon fuels.
- **Emissions per revenue vehicle hour.** This is another measure of operational efficiency but will take into account efforts to reduce deadheading. It also takes into account congestion, which will depress performance on emissions per vehicle mile.
- **Emissions per passenger mile.** This takes into account service productivity and will reward increases in ridership and load factors.

Data on vehicle miles, revenue vehicle hours and passenger miles by mode for an agency can be found on National Transit Database Form S-10. The reporting structure is shown in **Table 7**. These metrics form part of the APTA Sustainability Commitment for Transit Agencies.

Note that alternative comparisons based on different metrics (e.g., emissions per revenue vehicle hour or unlinked trip) can easily be backed out using NTD data. Absolute values will be reported in addition to these performance metrics. When interpreting the data, bear in mind that, in some cases, performance metrics may go in the "wrong" direction even though the absolute quantity of net emissions savings (including avoided emissions) increases. For example, a rail extension with less productive service may increase the quantity of emission savings but reduce them on a passenger-mile or vehicle-mile basis.

TABLE 7
Required Performance Metrics

Mode	Emissions (E)	Vehicle Miles (VM)		Revenue Hours (RH)		Passenger Miles (PM)	
		Total	E/VM	Total	E/RH	Total	E/PM
Bus	E_b	VM_b	E_b/VM_b	RH_b	E_b/RH_b	PM_b	E_b/PM_b
Light rail	E_{LR}	VM_{LR}	E_{LR}/VM_{LR}	RH_{LR}	E_{LR}/RH_{LR}	PM_{LR}	E_{LR}/PM_{LR}
[repeat for other NTD modes]							
Nonrevenue	E_{NR}						
Stationary sources	$E_{stationary}$						
Total[1]	E_{tot}	VM_{tot}	E_{tot}/VM_{tot}	RH_{tot}	E_{tot}/RH_{tot}	PM_{tot}	E_{tot}/P_{tot}

1. Including emissions from stationary sources.

2.4 Quantifying emissions sources

This section provides guidance on quantifying emissions from five types of sources:

- Direct emissions:
  - from stationary combustion (e.g., on-site furnaces)
  - from mobile combustion
  - fugitive emissions (e.g., refrigerant leaks)
- Indirect emissions:
  - from purchased electricity (e.g., steam purchases)
  - from other indirect emissions (e.g. value-chain accounting and reporting)

In most cases, data will be available for all transit agencies through NTD reporting, fuel purchases and similar records. However, should this not be the case, simplified methods may be used, provided that the emissions total 5 percent or less of the agency's total emissions. For more details, see Chapter 11 of The Climate Registry protocol.

The Climate Registry requires separate reporting of CO_2 emissions from fossil fuel combustion and biomass combustion. CO_2 emissions from fossil fuel combustion are reported in Scope 1, while CO_2 emissions from biomass combustion are reported separately from the scopes. The same step-by-step procedure for determining GHG emissions from fossil fuels applies to non–fossil fuels. Note that emissions of CH_4 and N_2O from biomass combustion are included in Scope 1 and are not treated differently from CH_4 and N_2O emissions from fossil fuel combustion. This principle also applies to the combustion of liquid biofuels that are received as blends. For more details, see Chapter 12 of The Climate Registry protocol.

2.4.1 Direct emissions (Scope 1)

2.4.1.1 Stationary combustion

NOTE: Reference Chapter 12 of *The Climate Registry General Reporting Protocol*.

The following are typical stationary combustion sources for transit agencies:

- boilers
- furnaces
- on-site generation

The Climate Registry provides several options ("methods") for quantifying direct emissions from stationary combustion. Given the small share of emissions from stationary sources, most transit agencies will find it appropriate to use method GRP ST-04-CO_2 for CO_2, using default emission factors for each fuel type.

> **NOTE:** In general, ST-01 provides the most precise estimates but is most demanding in terms of data. ST-04 is less data-intensive and relies on default factors.

In general, data on direct emissions from stationary combustion will not be available through NTD reporting. Agencies have most of the data necessary for calculating greenhouse gas emissions available from their utility bills (natural gas usage and electricity usage) and monthly or annual reports from fleet managers (mobile fuel use). Agencies should determine annual fuel use by reading individual meters or by using fuel receipts or purchase records, together with data on changes in stocks. Emissions must be calculated separately for each facility, as described previously. Refer to Chapter 12 of The Climate Registry protocol for detailed directions, and the most recent version of the TCR Default Emission Factors document for factors to use. Agencies may also refer to the most recent version of the EPA Emission Factors for Greenhouse Gas Inventories document.

TABLE 8
Example: Emission Factors by Fuel Type

Fuel Type	CO_2[1]	CH_4[2]	N_2O[2]	MMBTU/gal[1]
Natural gas[3]	53.06 kg/MMBTU	1.0 g/MMBTU	0.1 g/MMBTU	—
Fuel oil No. 1	10.26 kg/gal	3.0 g/MMBTU	0.6 g/MMBTU	0.14
Fuel oil No. 2	10.35 kg/gal	3.0 g/MMBTU	0.6 g/MMBTU	0.14
LPG	5.68 kg/gal	3.0 g/MMBTU	0.6 g/MMBTU	0.092
Propane	5.66 kg/gal	3.0 g/MMBTU	0.6 g/MMBTU	0.09

1. Sourced from 2017 TCR Default Emission Factors
2. Sourced from EPA Emission Factors for Greenhouse Gas Inventories (last modified in 2014)
3. U.S. weighted average

Consumption for each fuel type (e.g., natural gas) is calculated using the following formula:

$$\textit{Total Annual Natural Gas Consumption} = \textit{Annual Fuel Purchases} - \textit{Annual Fuel Sales} + \textit{Fuel Stock at Beginning of Year} - \textit{Fuel Stock at End of Year}$$

Each fuel type's GHG emissions are calculated using the following formulas:

$$\textit{Natural gas: } CO_2 \textit{ Emissions} = \textit{Fuel Consumed (in Decatherms)} \times 53.06\ (CO_2 \textit{ Emission Factor}) / 1000$$
$$\textit{Natural gas: } N_2O \textit{ Emissions} = \textit{Fuel Consumed (in Decatherms)} \times 0.1\ (N_2O \textit{ Emission Factor}) / 1{,}000{,}000$$
$$\textit{Natural gas: } CH_4 \textit{ Emissions} = \textit{Fuel Consumed (in Decatherms)} \times 1.0\ (CH_4 \textit{ Emission Factor}) / 1{,}000{,}000$$

> **NOTE:** Natural gas utility bills are reported in decatherms. A decatherm = 1.0 MMBTU.

NOTE: Throughout this part of the report, the denominators (1000, 1,000,000, etc.) simply normalize CO_2 emissions into standard units (metric tons of CO_2), depending on the units of the original data and emission factors.

NOTE: Agencies should always refer to the most recent version of The Climate Registry's Default Emission Factors document when calculating emissions.

As described in Climate Registry guidance, information on fuel use in facilities will be available from a range of potential sources internal and external to the agency, including:

- accounts payable;
- departmental records;
- engineering department;
- facility engineer;
- fuel vendors/suppliers;
- insurance company;
- real estate department; and
- utility provider.

2.4.1.2 Mobile combustion

NOTE: Reference Chapter 13 of *The Climate Registry General Reporting Protocol.*

Typical sources of mobile combustion emissions for transit agencies include the following:

- revenue vehicles
- nonrevenue vehicles

This category includes vehicles fueled by natural gas and biofuels, but *not* electric traction where the electricity is generated off-site (and is thus classified as Scope 2).

Note that biogenic (e.g., biodiesel) emissions must be reported separately. For blended fuels (e.g., B20), fossil and biogenic emissions must be disaggregated. Under The Climate Registry protocol, emissions are measured on an organizational basis, and transit agencies must report actual emissions at the point of combustion. No account is taken of reduced life-cycle emissions from biogenic sources, such as carbon sequestered during the growing of the crop.

Also note that well-to-tank emissions from fuel extraction, refining and transportation are not considered. If an agency wishes to estimate these emissions, for example using GREET or a similar model, they would be considered Scope 3 and must be reported separately. The utility of reporting well-to-tank emissions comes as more electric vehicles come into the market and replace existing automobile and bus vehicle fleets.

The Climate Registry provides several methods for quantifying direct emissions from mobile combustion, described in the **Figure 3** and **Figure 4** decision trees. **Table 9** shows data sources and National Transit Database references.

When actual fuel use, fuel carbon content and heat content data are available, emissions for each fuel type are calculated using the following formulas:

$$\textit{Total Annual Fuel Type (e.g., Natural Gas) Consumption} = \textit{Annual Fuel Purchases} + \textit{Fuel Stock at Beginning of Year} - \textit{Fuel Stock at End of Year}$$

$$\textit{Fuel Type } CO_2 \textit{ Emissions} = \textit{Heat Content} \times \textit{Carbon Content} \times \%\ \textit{Oxidized} \times 44 / 12 / 1000$$

$$\textit{Fuel Type } N_2O \textit{ Emissions} = \textit{Annual Distance Driven} \times N_2O \textit{ Emission Factor} / 1{,}000{,}000$$

$$\textit{Fuel Type } CH_4 \textit{ Emissions} = \textit{Annual Distance Driven} \times CH_4 \textit{ Emission Factor} / 1{,}000{,}000$$

NOTE: 44 / 12 converts from carbon into CO_2, based on their relative molecular weights (C = 12, O = 16).

Note that N_2O and CH_4 emission factors must be included for all mobile sources. For diesel vehicles, these will be negligible, but for compressed natural gas vehicles, CH_4 emissions may be significant due to incomplete combustion.

For locomotives, N_2O and CH_4 emissions are calculated based on fuel consumption rather than distance driven.

For purchased transportation services, transit agencies must obtain the relevant data from the contract operator.

Refer to Chapter 13 of The Climate Registry protocol for detailed directions and default emissions factors.

FIGURE 3
Decision Tree for Selecting a Methodology for Direct CO_2 Mobile Emissions

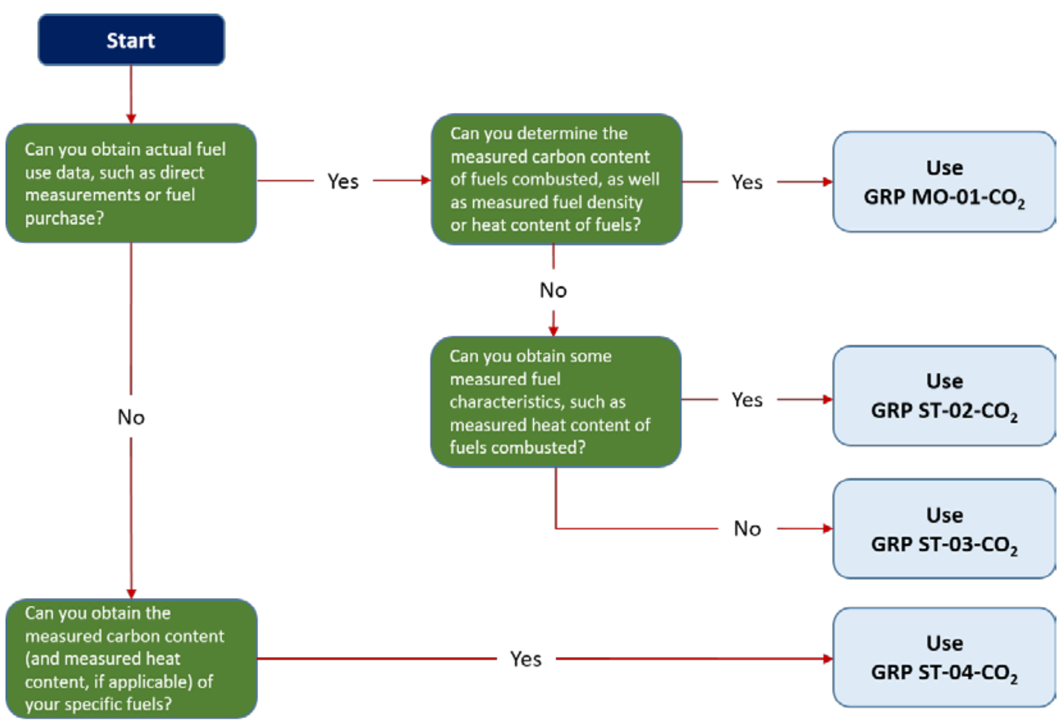


FIGURE 4

Decision Tree for Selecting a Methodology for Direct CH_4 and N_2O Mobile Emissions

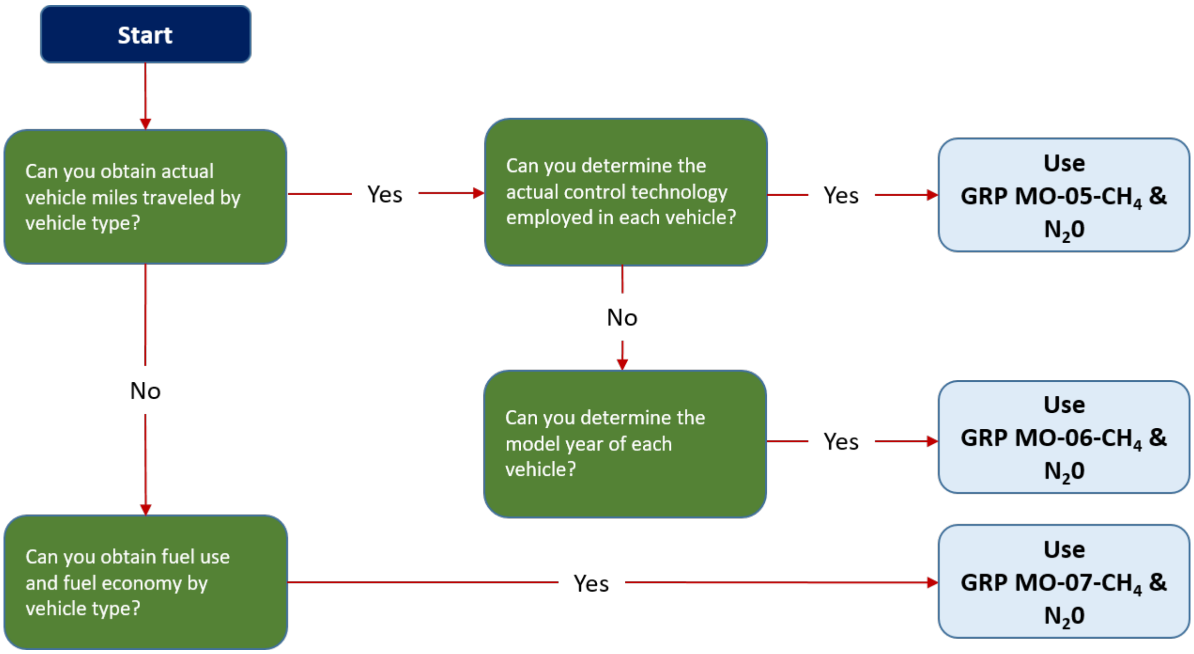


TABLE 9

Mobile Source Inputs Required

Input	Data Source
Annual fuel consumption by NTD category by fuel type	NTD Form R-30[1]
Annual fuel consumption from purchased transportation	Obtain from service contractor
Carbon content of fuels by type	Obtain from fuel supplier (preferred), or use default values in TCR protocol Chapter 13
Heat content of fuels by type	Obtain from fuel supplier (preferred), or use default values in TCR protocol Chapter 13
Percentage of fuel oxidized	Assume 100 percent
Annual mileage by NTD category; not required for nonroad vehicles (e.g., locomotives)	NTD Form S-10
Annual mileage for nonrevenue vehicles (if fuel consumption data is not available)	Odometer readings; if unavailable, simplified estimation methods may be used[2]
Fuel economy for nonrevenue vehicles (if fuel consumption data not available)	Sticker value or https://www.fueleconomy.gov/

1. Form R-30 is required for NTD reporters serving urbanized areas and directly operating their services. Agencies serving nonurbanized areas will need to refer to fuel purchase records or to estimate fuel consumption through mileage and fuel economy (Tier C). For agencies that use CNG, note that The Climate Registry default emission factors are expressed in terms of cubic feet or BTUs, but fuel use is reported on NTD Form R-30 as “gallon equivalents.” Most agencies will have calculated these gallon equivalents based on original fuel use data in BTUs or therms. For purposes of emissions reporting, the agency should refer back to these original data. If this is not possible, then use the NTD defaults (BTUs = 138,000 × diesel gallon equivalents, or 114,000 × gasoline gallon equivalents) or the agency-specific conversion factors that are used for NTD reporting purposes.
2. Provided that total emissions estimated using simplified methods do not exceed 5 percent.

2.4.1.3 Fugitive emissions

> **NOTE:** Reference Chapter 16 of *The Climate Registry General Reporting Protocol*.

Typical sources of fugitive emissions for transit agencies include the following:

- leakage from air conditioning systems in buildings and stations (note that not all refrigerants are greenhouse gases; refer to Appendix B of The Climate Registry protocol)
- leakage from vehicle air conditioning systems (note that not all refrigerants are greenhouse gases; refer to Appendix B of The Climate Registry protocol)
- leakage from fire extinguishers
- leakage from electrical systems such as transformers (SF_6)

The Climate Registry protocol provides guidance on estimating fugitive emissions of HFCs and PFCs from air conditioning and refrigeration systems—e.g., air conditioning units on transit vehicles. Agencies that service their own units should have data on the quantity of refrigerants purchased and/or used. Others can use simplified estimation methods, provided that total emissions estimated using simplified methods do not exceed 5 percent of an organization's inventory. Data still will be required on the capacity of each unit and the types of refrigerants used.

2.4.2 Electricity indirect emissions (Scope 2)

2.4.2.1 Electricity use

> **NOTE:** Reference Chapter 14 of *The Climate Registry General Reporting Protocol*. Additionally, reference the *Greenhouse Gas Protocol Scope 2 Guidance* (2015).

These types of emissions include electricity, steam, heating or cooling purchases from a cogeneration plant or a conventional boiler not owned by the agency. Refer to Chapter 15 of The Climate Registry protocol.

Electricity use must be quantified for each NTD mode and for each facility. Electricity use for traction is reported on NTD Form R-30. Non-traction electricity use (such as for office buildings) is not reported to NTD, and monthly electric bills or meter records should be the primary source.

The Climate Registry provides different methods for calculating emissions from electricity use. Agencies that have meter records or bills should follow TCR's GRP-IE-01-CO_2, CH_4 and N_2O. For leased premises where meter records or bills may not be available, electricity use can be estimated through information on total building area, space used by the agency, total building electricity use and building occupancy rate, per TCR's GRP-IE-02-CO_2, CH_4 and N_2O.

For transit agencies using electric traction that purchase power directly from a specific source, generator-specific emission factors may be used. Other transit agencies should use eGRID region-specific emission factors, provided in The Climate Registry protocol Chapter 14.

2.4.2.2 Dual reporting

> **NOTE:** Reference the *World Resource Institute's Greenhouse Gas Protocol Scope 2 Guidance* and *The Climate Registry General Reporting Protocol,* chapters 5 and 14.

In 2015, the World Resource Institute and World Business Council for Sustainable Development released the GHG Protocol Scope 2 guidance (World Resources Institute 2015), an amendment to the *GHG Protocol Corporate Standard*. The Climate Registry also follows this updated guidance.

The most significant change introduced by the guidance is the requirement that companies must quantify and report Scope 2 emissions totals using a location-based method and a market-based method:

- **Location-based method:** A method to quantify Scope 2 GHG emission based on average energy generation emission factors for defined locations, including local, subnational or national boundaries (per GRP-IE-04-CO_2, CH_4 and N_2O in TCR).
- **Market-based method:** A method to quantify Scope 2 GHG emissions based on GHG emissions emitted by the generation from which the reporter contractually purchases electricity bundled with instruments, or unbundled instruments on their own (per GRP-IE-05-CO_2, CH_4 and N_2O in TCR).

This new method changes the common practice that organizations would use in the past of calculating gross Scope 2 emissions based on the location-based method. If an organization was including green power purchases in its inventory, then net Scope 2 emissions were calculated. With the new guidance, these power purchases will be accounted for in the market-based method.

For more information, please consult the *Greenhouse Gas Protocol Scope 2 Guidance*.

3. Emissions reductions

This section provides guidance on methodologies to calculate transit's impact on reducing regional greenhouse gas emissions through mode shift and the land-use effect.

3.1 What's changed in this version

The prior version of this *Recommended Practice* considered three benefits from public transportation: mode shift, congestion reduction and the land-use multiplier. This version is not only renaming those benefits but also altering how they are quantified and reported. The first two—mode shift and congestion reduction—are now called "transportation efficiency gains." Land use is now called "land-use efficiency" and its impacts are the "land-use effect."

Beyond changes in nomenclature, the congestion section has been significantly modified. There are a number of reasons for this, including:

- the lack of data for measurement of congestion benefits; and
- the lack of agreement in academic literature about whether public transportation reduces congestion.

Since the publication of the previous version of this document, there have been many publications that have addressed these issues. Of particular note is FTA's *Greenhouse Gas Emissions from Transit Projects: Programmatic Assessment* (FTA 2017). This report describes calculation methods and constants for emissions associated with construction, operation and maintenance of many types of transit modes. It also includes avoided emissions from private vehicle mode shift (VMT). It does not include benefits from congestion or land use. The Federal Highway Administration has published the Energy and Emissions Reduction Policy Analysis Tool (EERPAT) (www.planning.dot.gov/fhwa_tool/default.aspx), which presents calculation tools to estimate the impact of transportation strategies on greenhouse gas reductions. APTA recommends referring to these documents for additional information.

3.2 Transportation efficiency

Transportation efficiency greenhouse gas benefits from transit occur when the roadway network operates more efficiently. Efficiency is the increased movement of people and goods on the limited roadway network. Transit benefits occur as drivers switch to less-polluting modes, and modes with better reliability or in some cases reduced travel time. The movement from private vehicles to transit is called mode shift and is one of the known greenhouse gas benefits of transit.

There are two major methodological approaches to estimating the mode shift effect on an agency level: the use of regional travel demand models and applying a mode shift factor to data on transit passenger mileage. This guidance recommends the second approach. However, the first approach is also discussed briefly for the sake of completeness.

3.2.1 Regional models

This approach uses county or regional travel demand models, typically maintained by metropolitan planning organizations (MPOs). The principle is simple: Remove the transit system from the model and calculate vehicle miles traveled and greenhouse gas emissions.

This approach is recommended when the MPO can provide this service; however, for most transit agencies this source may not be available.

3.2.2 Calculate mode shift factor

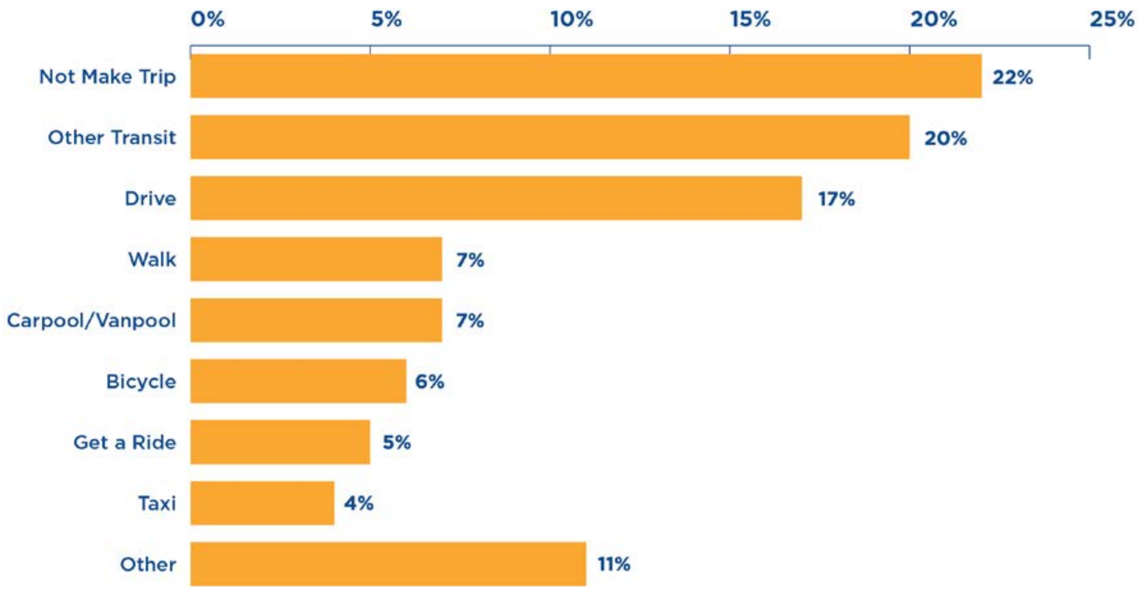
The recommended approach is to apply a mode shift factor—the ratio of transit passenger miles to displaced private auto miles—to data on passenger mileage. For example, if an agency reports 1 million passenger miles in a given year to the National Transit Database and calculates a mode shift factor of 0.6, then it would estimate displaced mileage at 600,000. This can then be converted to CO_2e using a suitable emissions factor. The mode shift factor does not include changes to trip lengths or transit-induced shifts to walking and biking; these are considered in the land-use effect.

This approach is relatively robust, does not require sophisticated modeling and draws on readily available data. A precedent can be found in the bus rapid transit methodology approved under the Clean Development Mechanism.

An estimate of the mode shift factor can be derived from logical inference. For example, it might be assumed that individuals without a driver's license will not shift to private autos. However, there are few clear-cut cases (e.g., these individuals might obtain a ride from a friend or household member). This suggests that stated choice surveys are the most appropriate measure.

In many cases, transit agencies already ask this question as part of regular rider surveys. **Figure 5** shows the results from the APTA publication *Who Rides Public Transportation* ("Who Rides") (APTA 2017, 69).

FIGURE 5
Alternate Mode—All Transit Users



The following are the main challenges with interpreting such data:

- Long-term responses may differ from short-term (e.g., people might eventually move or purchase a vehicle). An additional question on auto ownership can be used to factor in these longer-term adjustments.
- Methods used to estimate transit passenger miles have some variability among transit agencies. King County Metro Transit estimates transit ridership using automatic passenger counting (APC) technologies on a large, stratified sample to estimate unlinked trips and annual passenger miles. Other transit agencies may use other technologies and methods to estimate passenger miles.
- Roadway infrastructure may not be able to accommodate all trips that would shift to private autos, suggesting either that trips may be suppressed or that infrastructure would respond (i.e., highways would be expanded).
- Trip lengths may differ between transit and auto (e.g., if an auto route provides a more direct path). Since individuals generally choose destination and mode simultaneously, trip lengths likely would lengthen in the absence of transit. However, this effect is calculated as part of the land-use effect. For purposes of calculating mode shift impacts, equal trip lengths by transit and auto can be assumed.

3.2.2.1 Methodological procedure

This section provides detailed guidance for a transit agency to calculate its mode shift factor and to estimate its mode shift impact on emissions. It provides different “tiers” to enable agencies to select the most appropriate way to determine a mode shift parameter, based on available data, staff resources and the degree of precision required.

The following procedure should be used.

Step 1: Quantify passenger miles

Passenger miles by mode can be found on National Transit Database Form S-10. The assumption is that one passenger mile on transit is equivalent to one passenger mile in a private auto—i.e., that the distances are comparable. Note that while transit may create land-use patterns with overall shorter trip distances, this effect is captured in the land-use effect.

Step 2: Calculate mode shift factor
Alternative methods for estimating the mode shift factor are described in the next section.

Step 3: Calculate VMT displacement
For each mode, multiply passenger miles by the mode shift factor.

Step 4: Estimate average fuel economy for displaced VMT
Fuel economy will vary among regions depending on the composition of the vehicle fleet and degree of congestion in each region.

This document presents three methodological approaches to accounting for these regional differences, presented as tiers in decreasing order of specificity and sophistication:

- **Tier A:** Use a regionally specific factor published by the region's MPO. MPOs sometimes estimate and publish average speeds for their regions. If it is available from your MPO, use a regionally specific emission factor that accounts for vehicle fleet composition and vehicle speeds. This should be derived from the EPA's MOVES model.
- **Tier B:** Use the speed adjustment formula from the Urban Mobility Report. Vehicle speed data for many large urban areas are published in the Texas Transportation Institute's *Urban Mobility Report* Appendix A. If using this source, use the weighted average freeway and arterial speed, weighted by VMT. Convert speed to fuel economy with the following formula:

$$\text{Average Fuel Economy} = 8.8 + (0.25 \times \text{Average Speed})$$

  NOTE: This relationship is used in the Texas Transportation Institute's *Urban Mobility Report*, and credited originally to Raus, J.A., "Method for Estimating Fuel Consumption and Vehicle Emissions on Urban Arterials and Networks," Report No. FHWA-TS-81-210, April 1981.

- **Tier C:** Use the national default value for fleet fuel economy from the U.S. DOT. If average speed is unavailable, then use the conservative 21.4 miles per gallon. Fuel economy data for light-duty vehicles is available from the Bureau of Transportation Statistics, DOT (https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles).

Step 5: Convert to CO_2 equivalent
If regional or state-specific data are available on emission factors, these may be used. Otherwise, use the following default values:

- **CO_2 emissions:** 8.81 kg CO_2/gal of gasoline
- **N_2O emissions:** 0.0079 g N_2O/mi and 1 metric ton N_2O to 265 metric tons CO_2e (GWP)
- **CH_4 emissions:** 0.0147 g CH_4/mi and 1 metric ton CH_4 to 28 metric tons CO_2e (GWP)

Emission factors are from *The Climate Registry General Reporting Protocol – 2017 Default Emission Factors*, Tables 13.5 and B1.

3.2.2.2 Estimating the mode shift factor

One of three alternative tiers, in decreasing levels of specificity, may be used to estimate the mode shift factor, which is the ratio between transit passenger miles and displaced private vehicle miles. A mode shift factor of 1.0 indicates that each transit passenger mile displaced one private vehicle mile. In most cases, data will be available in terms of trips rather than miles, but the default assumption is that transit and displaced private vehicle trips are of equal length.

Tier A: Model-based

Some larger agencies may have a travel demand model that can be used to estimate the mode shift factor. Note that this is *not* the same as using a travel demand model to estimate avoided emissions through removing the transit system altogether.

Tier B: Survey-based

Transit agencies often undertake rider or travel surveys that include a question on alternative modes of travel were transit unavailable for that trip. Transit and other public agencies may also conduct origin-destination surveys that provide similar information. These may be used to estimate the mode shift factor as follows:

Mode Shift Factor = *% stating they would drive alone*
+ % stating that someone else would drive them
+ % shifting to taxi/TNCs
+ % stating they would carpool / average carpool occupancy

If local estimates of average carpool occupancy are unavailable, then use a default of 2.5. This is a conservative estimate, assuming a mix of two- and three-person carpools.

A survey must adhere to the following requirements:

- It must include an option for respondents to indicate that they would not make the trip if transit were unavailable, in order to capture induced demand.
- It must be representative of all transit riders and include a maximum 5 percent margin of error with 95 percent confidence (generally this requires about 375 responses, depending on total ridership). This *Recommended Practice* does not prescribe specific sampling techniques. For further information, refer to TCRP Synthesis 63, *On-Board and Intercept Transit Survey Techniques* (2005).
- The survey must have been conducted within the past five years in order to capture current land-use and demographic patterns.

Agencies that offer distinct types of service that serve different markets (e.g., bus and commuter rail) may wish to develop specific mode shift factors by mode or market.

The recommended question wording is as follows:

If transit service were not available, how would you make this kind of trip?

- □ *Drive alone*
- □ *Walk*
- □ *Get a ride*
- □ *Carpool*
- □ *Taxi*
- □ *Bicycle*
- □ *Other transit*
- □ *I would not make this trip*

Long-run responses may differ from the short-run responses that the question elicits. For this reason, an optional supplemental question may be used to discern likely impacts on vehicle ownership that would increase the mode shift factor. The recommended question wording is:

If transit service were to stop permanently, would your household change the number of vehicles it owns?

- □ *Yes—purchase at least one vehicle*
- □ *Yes—give up at least one vehicle*
- □ *No—not change the number of vehicles*

The results would be used in conjunction with a third question (which is almost universal on existing transit rider surveys) on vehicle ownership. For example, the Transit Performance Monitoring System question asks:

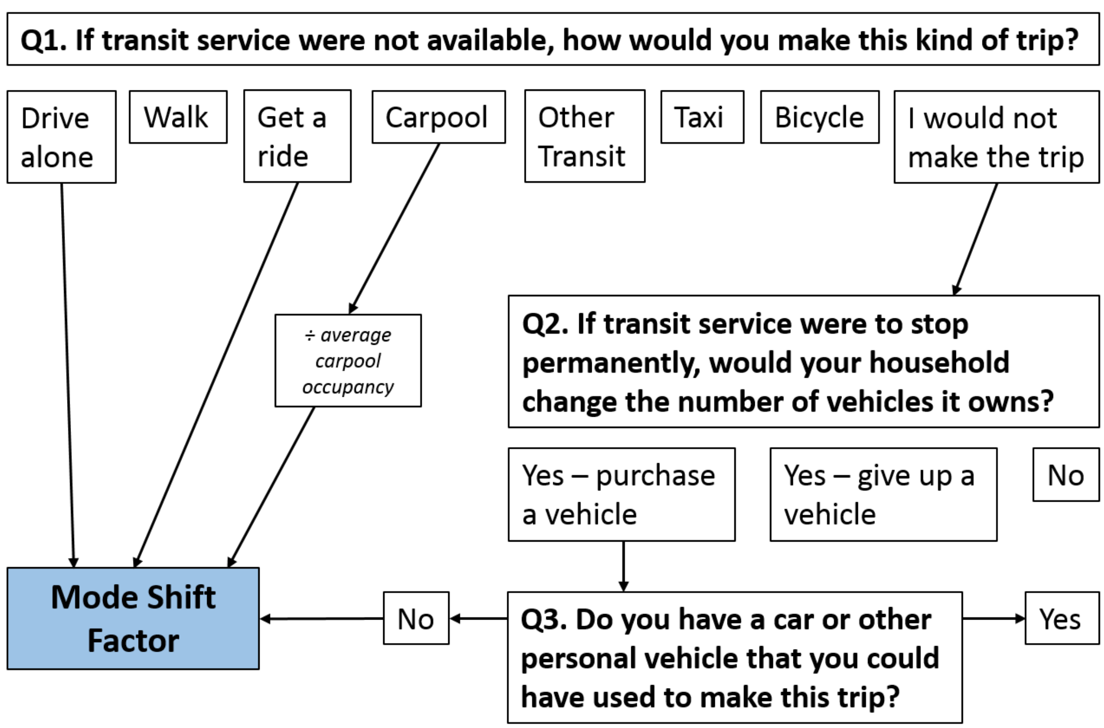
Do you have a car or other personal vehicle that you could have used to make this trip?

- □ *Yes*
- □ *No*

This calculation is shown graphically in **Figure 6**. The mode shift factor would be increased by the percentage of respondents who would be expected to shift to driving in the long term through changes in vehicle ownership. This increment would be calculated as:

- people who do not have access to a vehicle at present; *and*
- people who report that they would purchase a vehicle if transit service were not available; *and*
- people who report that they would not make the trip if transit service were not available.

FIGURE 6
Mode Shift Factor with Short- and Long-Run Effects



Tier C: Default by agency type

This option is for use by transit agencies that do not have a suitable rider survey or model. It provides estimates of the mode shift factor by agency type (i.e., mode, the size of population served), based on Who Rides (APTA 2017, 70-71). Who Rides provides two sets of data that have been combined in **Table 10**. One is for bus versus rail systems, the other for systems with less than 1 million population (smaller), and those with more than 1 million (larger). Who Rides provides several options for making the trip.

TABLE 10
Alternative Mode from APTA Who Rides Public Transportation Report

"What alternative mode might you use if transit service were not available?" All alternative mode responses reported as percentages									
Service Area Type and Population	**Drive Alone**	**Walk**	**Ride with Someone**	**Taxi**	**Bicycle**	**Not Make Trip**	**Other Transit**	**Get a Ride**	**Mode Shift Factor (A + D + (C/2.5) + H)/100**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
Bus	12	10	6	6	6	23	18	8	**0.284**
Rail	25	3	8	2	5	21	24	0	**0.302**
Smaller (<1 million)	20	25	2	6		17	4	24	**0.508**
Larger (>1 million)	18	7	8	5		24	23	4	**0.302**

The mode shift benefits include only those modes that have greenhouse gas emissions, and as such include drive alone, ride with someone, taxi, and get a ride. The emissions from each of these sources can be estimated based on the methodology described in Step 4 of Section 3.2.2.1 above.

APTA recommends use of population-based mode shift factors. To ensure they work with the most accurate default factors possible, agencies should select the population-based mode shift factor that best reflects their urbanized area's size. About 96 percent of Who Rides ridership (measured in unlinked passenger trips) comes from larger service areas (APTA 2017, 13), indicating that the modal data more closely reflects larger urbanized area ridership. Were smaller urbanized area agencies to use modal data, they would employ factors that less accurately reflect their ridership.

3.3 Congestion benefits

Congestion on U.S. roadways has increased significantly in recent years with the recovering economy. Several private companies publish data on congestion, including TomTom (www.tomtom.com/en_gb/trafficindex/) and INRIX (inrix.com/press-releases/scorecard-us/). These sources indicate that drivers waste significant time on congested roadways. Public transportation is often viewed as a solution to congestion issues, as it frees up roadway space for additional private vehicles.

The prior version of this document agreed with this general precept and recommended using the Texas Transportation Institute (TTI) Urban Mobility Scorecard to estimate transit benefits from congestion reduction. TTI estimated significant congestion benefits from public transportation. As part of this report, TTI estimated the congestion benefits of public transportation—i.e., the increased travel time and fuel consumption that would occur if public transportation did not exist. Recently, TTI has ceased publication of this transit data and has changed the Urban Mobility Scorecard as well. There is no longer a readily available nationally accepted publication that provides estimates of public transportation benefits.

There are numerous methodologies for measuring and valuing congestion. These are discussed in some detail in "Smart Congestion Relief" (Litman 2017), which describes various approaches to the measurement of congestion. Litman and others have criticized TTI for basing congestion benefits on free flow speeds and failing to adequately account for induced demand.

Beyond the lack of TTI data, there is disagreement in the literature concerning the congestion benefits of public transit. Some authors argue that induced traffic negates all benefits from public transit. For example, Duranton and Turner (2011) argue about the "fundamental law of road congestion," that public transit does not reduce vehicle miles traveled and that new roadways fill with new traffic to reproduce prevailing congestion levels.

Others argue that public transit provides significant benefits due to user travel choices. Anderson (2014) argues that data from the LA Metro strike in 2003 shows large benefits from public transit on congestion levels, writing that "average highway delay increases 47 percent when transit service ceases." Lo and Hall (2006) reached similar findings in their study of the transit strike, noting that traffic speeds declined by as much as 20 percent and the rush hour period increased in average length by as much as 200 percent. From his findings, Anderson asserts that without public transportation, there would be significant economic losses from the dispersal of economic activity.

Due to the lack of consensus on congestion benefits, this document no longer provides a methodology to measure congestion benefits. Transit agencies can still quantify their own congestion benefit if they so choose.

3.4 The land-use efficiency effect

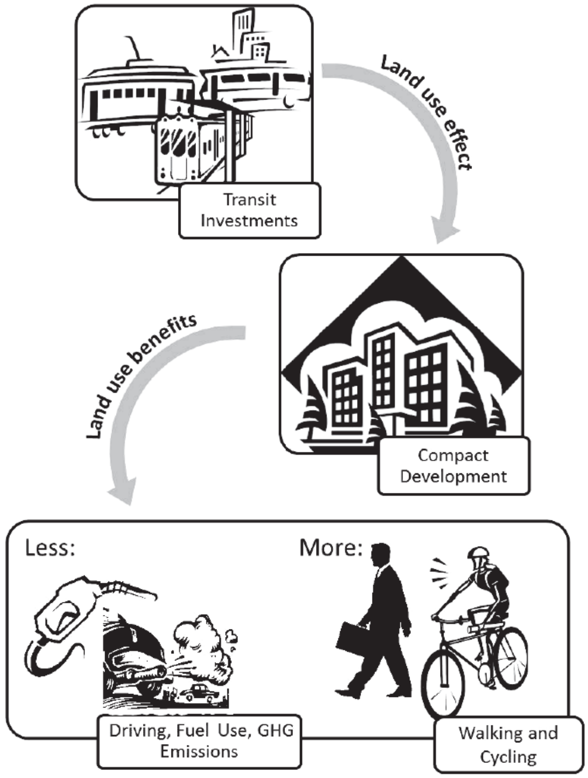
This section provides guidance on methodologies to calculate the land-use efficiency benefits of transit on greenhouse gas emissions. Together with transportation efficiency (discussed in the previous section), land-use efficiency leads to emission reductions as private automobile travel is reduced, albeit in a less direct though often significantly greater way than transportation efficiency. The discussion, analytic approach and associated tools presented in this section draw heavily upon TCRP 176 (TCRP 2015).

Members of APTA's Climate Change Standards Working Group, including present and previous authors of this guidance document, contributed to the original research question and served on the oversight panel for the TCRP H-46 research project that produced Report 176 with the intent of extending the knowledge base and refining the analytic techniques for calculating the land-use effect of transit on vehicle miles traveled, energy use and greenhouse gas emissions.

3.4.1 What is the land-use efficiency effect?

The land-use efficiency effect accounts for the indirect impacts of transit on reducing vehicle travel through changes in land use resulting from the provision of transit service. As discussed in TCRP Report 176, "A growing body of research analyzes the extent to which public transportation systems beget land use changes in the form of more compact development. The evidence is mixed, but favors the theory that public transportation investments can, under the right circumstances, promote more compact development." The TCRP Project H-46 research team calls this phenomenon the *land-use effect of transit* (or simply the *land-use effect*). See **Figure 7**.

FIGURE 7
The Land-Use Effect of Public Transportation



An extensive literature demonstrates that people living in compact developments, even people who do not use transit, tend to drive less and walk and bike more. In *Growing Cooler*, the authors find that for every 1 percent increase in density, VMT is reduced by 0.3 percent. In other words, the elasticity of VMT with respect to density is −0.3 (Ewing et al. 2008). This lower rate of driving saves fuel and thereby reduces greenhouse gas emissions. Compact development in turn provides a host of environmental and social benefits, including helping to reduce vehicle miles traveled, fuel use and greenhouse gas emissions. These are called the *land-use benefits*. Since land-use effects lead to land-use benefits, these terms are sometimes used interchangeably.

The land-use effect of transit is complementary to, but completely separate from, the "ridership effect of transit" (sometimes referred to as the "direct effect of transit" or, in the nomenclature of this document, the "transportation efficiency effect"), whereby people ride buses and trains instead of driving private vehicles. There is evidence that the land-use efficiency benefits of transit are often greater than the benefits generated directly by transit ridership.

Land-use efficiency reduces the VMT of non-transit riders by fostering communities where trip distances are shorter, trip chaining is more common, private vehicle ownership is lower, and walking and cycling are more attractive options. In greater detail, these pathways function in the following way (Neff 1996; Newman and Kenworthy 1999; Litman 2006):

- **Reduced trip lengths.** Higher-density development would in many cases not be possible without the existence of transit—for example, due to the need to provide more parking. By facilitating compact development, transit can shrink the footprint of the urban area and reduce overall travel distances. In addition, residents often adjust to the availability of transit by moving closer to bus and rail corridors.

This may be partly offset when the transit route structure forces travel by an indirect route, particularly when a suburb-to-suburb trip requires a transfer downtown.

- **Facilitation of bicycle and pedestrian travel.** As well as reducing trip lengths, the higher densities and mix of uses supported by transit enable mode shift from the private auto to walking and cycling, which requires less energy and generates lower emissions per unit of travel. For example, pedestrian-oriented shops and services may not be economically viable without the density and foot traffic that transit supports.
- **Trip chaining.** Transit can facilitate the combination of trips into a single tour, which also reduces VMT by eliminating duplicative travel among multiple two-way trips. For example, a commuter may pick up groceries or dry cleaning on the way home from the station.
- **Impacts through vehicle ownership.** Households living close to transit tend to own fewer vehicles, partly because a vehicle may not be needed for commuting, and partly because of the reduced availability and higher cost of parking. In turn, reduced vehicle availability tends to lead to reduced auto use, and the private car may cease to become the habitual choice for every trip.

3.4.2 TCRP 176 research methodology

The research conducted under TCRP Project H-46 and published as TCRP Report 176 is one of only a handful of research efforts to date to use statistical modeling techniques to determine the size of the land-use effect. It is the only research effort to use multiple datasets to analyze and cross-validate the land-use effect at multiple geographic scales. Most other research has started with assumptions about the strength of the land-use effect in order to quantify land-use benefits. Statistical modeling has the advantage of quantifying the magnitude of the land-use effect itself, before quantifying land-use benefits. In fact, the bulk of this research effort was devoted to analyzing the land-use effect.

Using statistical models allowed the research team to isolate particular transit variables that determine the land-use effect (such as transit supply and frequency), while controlling for other factors that are correlated with urban land-use patterns (such as urban area population size and road supply), which distinguishes it from the ICF's 2008 study "The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction." Two different datasets were used to conduct statistical analyses at different scales.

3.4.2.1 Urbanized area dataset

The *urbanized area dataset* contains data at a macro scale on more than 300 federal-aid urbanized areas, with boundaries defined by the FHWA. Data incorporated include urbanized area size in square miles, demographic characteristics such as population size and average income, transit variables such as route miles by mode and transit revenue miles, and control variables such as local fuel prices. Each variable in this dataset is a single aggregate value for the urbanized area. Data are from 2010.

The urbanized area dataset was used to conduct a cross-sectional analysis to examine differences in travel behavior between urbanized regions that have experienced different levels and types of transit investment.

The urbanized area models enable the research team to answer the following questions:

- What is the total land-use effect of an urban area's existing transit system?
- What is the likely additional land-use effect within the urban area of incremental improvements in the transit system?

3.4.2.2 Neighborhood dataset

A *neighborhood dataset* was used to model the land-use effect of transit at a finer scale. Whereas the urban area model was constructed by comparing whole regions with one another, the neighborhood model incorporates small-scale variations in land-use patterns and travel patterns, including both population and employment densities. It also explicitly considers more land-use characteristics: land-use mixing, pedestrian environment and job accessibility. The neighborhood dataset allows the research team to compare the characteristics of transit-rich neighborhoods with those of transit-poor neighborhoods within regions in order to study the land-use effect. The neighborhood dataset was also used to conduct a longitudinal analysis of observed land-use changes in Portland, Oregon, between 1994 and 2011, in order to compare results with the cross-sectional analyses.

The neighborhood dataset contains data at a micro scale for nine diverse regions in the United States (using Metropolitan Planning Organization–defined boundaries): Austin, Texas; Boston, Massachusetts; Eugene, Oregon; Houston, Texas; Kansas City (Missouri and Kansas); Portland, Oregon; Sacramento, California; Salt Lake City, Utah; and Seattle, Washington. Data incorporated include land-use variables such as urban density and level of land-use mixing, demographic variables such as household size, transit variables such as availability of a rail station, and data on household travel behavior including driving (VMT) and transit use (PMT). Most variables in the dataset are calculated as averages within a small area: approximately one-quarter mile squared. Data are from different years, ranging from 1991 to 2011, depending on the region.

These research questions addressing effects at the agency-wide or regional scale are the most pertinent to the scale of this *Recommended Practice*, and so the method and the associated elements of the calculator tool are the focus of the guidance provided in this document.

3.4.3 Methodological procedure

As part of TCRP Report 176, the research team created the Land Use Benefit Calculator (“the calculator”), an Excel-based sketch-modeling tool, to apply the research findings. The calculator (available at www.TRB.org/main/blurbs/172110.aspx) is designed to allow transit agencies, metropolitan planning organizations, and other interested parties to estimate the land-use benefits of their existing or planned transit projects with a minimum amount of input data required.

Specifically, the calculator allows the user to estimate the following:

- the land-use benefits of the existing regional transit system
- the land-use benefits of a regional transit plan
- the land-use benefits of a new transit route or improved transit service along an existing corridor
- the land-use benefits of a new transit station or stop or improved transit service to an existing station or stop

All land-use benefits are estimated in terms of the following metrics:

- VMT reduction
- gasoline consumption reduced
- GHG emissions saved

For the purposes of this guidance, the benefits of the existing regional system make it the most directly relevant function, though the others may prove useful in other planning and development applications. The tool contains instructions within the spreadsheet itself, which should be understood prior to use.

3.4.4 Caveats and next steps

For an urbanized area with only a single transit provider where the transit provider's service area matches that of the urbanized area, the transit provider can claim 100 percent of the estimated benefits. However, it's not uncommon for there to be multiple transit providers in the same urbanized area. Therefore, an additional calculation step is necessary to apportion that benefit among those providers using a contribution factor. Because the land-use effect is regionally specific rather than agency-specific, and given the complex modeling interactions and data limitations, it is difficult to perfectly attribute land-use impacts to a particular agency where two or more operate in the same service area. This guidance recommends using the Custom Base module in the tool to help address this issue to some degree by enabling an agency to enter its own specific data parameters to inform the model, which helps scale the benefits calculation accordingly, though it may not fully account for the extent of overlap between multiple service providers operating in the same geography. If an agency chooses to do this in a region with multiple providers, it is recommended that it coordinate with other providers on messaging around what the shared regional benefit is likely to be.

As a next step, TCRP 176 notes that the following future research on this topic would be useful:

> Different approaches to measuring density. Gross population densities, the primary measure used in this research, have a clear relationship to travel patterns. But population-weighted densities may be a better predictor of travel patterns as it better captures the range and intensity of land use within a region. For example, the New York City and Los Angeles Metropolitan Statistical Areas have very similar gross population densities at 2,826 and 2,646 people per square mile, respectively (U.S. Census Bureau 2012). But the New York City region has a super dense core with sprawling suburbs. The Los Angeles region has little distinct core, but moderate uniform density throughout. In New York, many people are living at much higher local densities than almost anyone in Los Angeles. Population-weighted density is an emerging alternative way to measure regional densities accounting for local variations. Densities are first calculated at the local scale, for example population per square mile in each census tract. Regional density is then calculated as the average of local densities, with each census tract's density weighted by its population. In this way, census tracts where more people live (which tend to be more densely populated tracts), are given more weight in the calculation. Population-weighted density is a better regional measure of the typical local density experience of residents. The population-weighted density of New York at 31,251 people per square mile compares with that of Los Angeles at 12,114 (U.S. Census Bureau 2012). However, calculating population-weighted densities for all urban regions will require a substantial data collection effort.

4. Scope 3 emissions

Agencies can follow the guidance provided here to better understand and identify methods for measuring emissions in their value chain. For purposes of consistency among transit agencies and other reporters, these Scope 3 emissions must be clearly separated from Scope 1 and Scope 2 emissions, and specific emission types under Scope 3 must be clearly itemized. Scope 3 emissions are optional to report under The Climate Registry protocol, as they will generally fall under Scope 1 of another organization (e.g., the contractor). However, Scope 3 emissions are required by the World Resources Institute protocol since a complete report across an entity's value chain reveals areas of impact and opportunities to focus efforts for greater effect, especially for agencies undertaking significant capital improvement programs.

Other helpful protocols or resources for preference purchasing, and checklists or requirements for disclosure include the Carbon Disclosure Project (https://www.cdp.net/en), GreenSource (https://www.greensourceconstructioninc.com/), and the World Business Council on Sustainable Development (https://www.wbcsd.org/).

4.1 Value chain accounting and reporting

The GHG Protocol launched the corporate value chain (Scope 3) Accounting and Reporting Standard in 2011. This provides a detailed approach to identifying and measuring significant Scope 3 emissions and identifies 15 categories of Scope 3 emissions to assess:

Upstream

1. Purchased goods and services
2. Capital goods
3. Fuel- and energy-related activities (not included in Scope 1 or Scope 2)
4. Upstream transportation and distribution
5. Waste generated in operations
6. Business travel
7. Employee commuting (outside of employees commuting by the agency’s own service)
8. Upstream leased assets

Downstream

9. Downstream transportation and distribution
10. Processing of sold products
11. Use of sold products
12. End-of-life treatment of sold products
13. Downstream leased assets
14. Franchises
15. Investments

Per the GHG Protocol, agencies should report Scope 3 emissions in the year that the activities occurred (e.g., emissions related to product purchased or sold in the reporting year).

Agencies can conduct a materiality assessment (not to be confused with materiality in emission report verification) to determine the relevance of various Scope 3 elements to their operations. Upon making this determination, agencies can decide which elements form Scope 3 reporting in their greenhouse gas assertion (as discussed in Section 1.4). For many agencies, working with their major vendors and suppliers will enable them to exercise influence and source products that align with their agency values (reduced carbon or water intensity in products, recycled content, regional sourcing, etc.).

Emissions from transit capital projects carried out by contractors fall under Scope 3 (agencies that are self-performing capital projects need to allocate emissions appropriately under Scope 1, 2 or 3). The APTA guidance aims to provide a simple method to calculate emissions from capital projects that will be suitable for agencies of all types, regardless of size or types of capital investment pursued. It is not intended as required reporting, nor as a guide to conducting full life-cycle analysis of transit capital projects. Stripple and Uppenberg (2010), Chang and Kendall (2011), and Chester and Horvath (2008) provide examples of the variation and effort required for that type of analysis.

Note that Scope 3 emissions should not be included when making modal comparisons, such as comparing transit emissions to private auto emissions per passenger mile. This is because auto emissions calculations generally do not include emissions such as highway construction and vehicle manufacture, and because Scope 3 emissions are the direct emissions of other entities.

4.1.1 Recommended procedure for quantifying value chain emissions

APTA recommends that transit agencies develop estimates for the following Scope 3 categories:

- **Categories 1 and 2:** Purchased Goods and Services, Capital Goods (Capital Improvements and Construction)

Transit agencies can report estimates of emissions from the major materials used to construct capital projects and the emissions from construction activities (purchased goods and services). Recent FTA guidance for programmatic assessments has included default quantities for these emissions, while several states and local municipalities require an estimate of the emissions associated with construction activities as part of environmental documentation. It is important to note that these emissions would not be included in a baseline calculation of transit benefits. What the analysis of emissions from purchased goods and services enables is greater information on materials and construction practices to better inform appropriate policy or contract requirements that could positively influence the environmental profile of materials selected.

Analyses can vary from detailed whole-life greenhouse gas inventories to simpler calculations using emissions factors applied to a quantity of material. APTA advises that transit agencies always rely on region- or agency-specific available emissions factors. However, as emissions factors are still an emerging area, APTA has provided default emissions factors, in **Table 11**, associated with the materials and goods of significance in GHG terms and relevance to a transit agency. This guidance provides emissions factors as an aid to agencies that wish to undertake the analysis but who do not have staff expertise or time to develop or research more region- or agency-specific factors. These can provide a high-level estimate of the emissions associated with purchased goods for capital projects. Both the metric tonnage of each material and the emission factor should be reported, along with total estimated emissions.

TABLE 11
Embodied CO_2 Metrics for Transit Capital Projects

Input	Default Emission Factor	Emissions Factor Source and Notes
Steel products used in the reporting year	1.7 metric tons of CO_2e per metric ton of steel used	https://eta.lbl.gov/publications/international-comparison-co2-emission Note: This is an emissions factor for crude steel, not for a specific steel product.
Cement used in the reporting year	0.92 metric tons of CO_2e per metric ton of cement used	http://www.nrmca.org/sustainability/CONCRETE%20CO2%20FACT%20SHEET%20FEB%202012.pdf Note: This is an aggregate number reflecting a survey of Portland cement manufacturers carried out by the Portland Cement Association.
Concrete (ready mix) used in the reporting year	Consult the Environmental Product Declaration Tables 6 to 14 for an emissions factor associated with the relevant ready mix concrete strength.	https://www.nrmca.org/sustainability/EPDProgram/Down-loads/EPD10080.pdf Note: Emissions factors vary significantly depending on strength of concrete.
Asphalt used in the reporting year	0.7 kilograms CO_2 per square meter of hot mix asphalt 0.08 kilograms CO_2 per square meter of warm mix asphalt	https://www.fhwa.dot.gov/pavement/sustainability/hif15002/hif15002.pdf Table 7-5 Note: This emissions factor is in the form of a kilogram per meter squared of material. Total emissions can be converted in to metric tons using a density factor for the type of asphalt used.

TABLE 11
Embodied CO_2 Metrics for Transit Capital Projects

Input	Default Emission Factor	Emissions Factor Source and Notes
Copper wire used in the reporting year	2.04 metric tons of CO_2e per metric ton of virgin copper wire used 1.64 metric tons of CO_2e per metric ton of recycled copper wire used	https://www3.epa.gov/warm/pdfs/Copperreport6-2.pdf Note: This is a report from 2005. The national average energy coefficients will have changed in the interim. However, these factors can provide a rough figure for estimating emissions.

Another source for emissions factors comes from an emerging practice among manufacturers (steel, asphalt paving, concrete) that have developed an environmental product declaration, or EPD. This is a verified and registered document that discloses information about the life-cycle environmental impact of a product, including the global warming potential in terms of carbon dioxide equivalent embodied per given unit of material. This type of document provides specific information about the product purchased by a transit agency, rather than general emission factors. Both the metric tonnage of each material and the emission factor should be reported, along with total estimated emissions. If suppliers have not yet developed EPDs, transit agencies can also require this as part of bids for new capital projects. Several national associations (National Ready Mix Association, National Asphalt Pavement Association, World Steel Association, American Institute of Steel Construction) have worked with their industries to develop product category rules (PCRs), as well as nationally applicable EPDs. Individual manufacturers and suppliers can either use the national EPD or rely on the necessary PCR that specifies what to include in a more tailored EPD.

Alternatively, reporting agencies can use databases attached to software to identify more emissions factors specific to their geographic region or for a wider set of materials. These databases are often linked directly to design software and can provide an estimate of embodied emissions based on the specific infrastructure design for a capital project.

Detailed emissions can be aggregated into a whole-life carbon inventory for a project. Hanson et al. (2014) and Stripple et al. (2010) are examples of project life-cycle analysis studies that looked at construction, operation and materials upstream emissions for facilities, track, track foundation (concrete), bridges (steel girders and concrete) and tunnels, and electric power and control systems (copper and aluminum cable, steel). Considering the list of materials reviewed in these and other whole-project rail and transit analyses, the recommended list of materials for capital projects to analyze is provided in **Table 11**. Agencies should always consider unique factors in their supply chain, such as local regulation or primary energy supply, to determine the appropriateness of these generic factors for their major materials.

Emissions associated with construction activities and materials, including those listed in **Table 11**, should be reported as Scope 3 for agencies that decide to report to The Climate Registry. In general, emissions from capital projects should be disaggregated to the project level.

Other emissions from construction that APTA recommends be estimated, collected and reported by the agency include the following:

- **Mobile source emissions from construction equipment.** The agency will need to estimate the types of vehicles in the fleet of off- and on-road equipment that will be used, as well as their hours and miles used. Actual site data should be collected to verify the estimate and should include equipment type, manufacturer, engine model year, rated horsepower, hours and miles of operation, and fuel used, in addition to other information required by local air quality districts for compliance with construction permits.

- **Waste transportation and disposal.** Diverting waste from landfills through required recycling or reusing materials avoids GHG emissions. Agencies should calculate volume or weight of materials diverted and can use data from the U.S. EPA Waste Reduction Model (WARM) to calculate potential avoided emissions (after subtracting transportation emissions).
- **Waste generated in operation.** The APTA *Recommended Practice* "Quantifying and Reporting Transit Sustainability Metrics" (APTA SUDS-CC-RP-003-12) provides a methodology for transit agencies to quantify the weight of waste generated in operation. Agencies can then input this data in WARM, which provides more granular detail on the emissions associated with various waste streams and the effect of disposal choice on the emissions profile. The waste calculation should include such major waste streams as vehicle and tire disposal.
- **Employee commuting.** Transit agencies can elect to account for employee commutes by surveying staff and employees through an anonymous online survey. The survey should capture mode (walking, biking, bus provided by another agency, rail vehicle provided by another agency, carpool and vanpool, and automobile, and include a subsection for class of automobiles [zero or low-emissions vehicle, medium and heavy duty]) and distance traveled.

4.1.2 Physical scope

Emissions should be reported for dedicated transit facilities only, such as stations, intermodal facilities and physically separated rights-of-way (including resurfacing of a separated right-of-way for exclusive use by bus rapid transit). Emissions from general roadway resurfacing projects, street lighting, etc. should be accounted for in the inventory of the respective local government entity (e.g., a county streets department), based on operational control.

4.2 Emission reduction from recycling

Transit agencies recycle materials from both internal activities and from customer-related activities. Recycling reduces emissions due to both emissions not generated by landfilling or combustion, and from lower emissions from products that use recycled materials. Reduced emissions can be included in an agency's inventory as Scope 3 emissions. Among agencies contacted during preparation of this document, very few included waste generation and recycling in their greenhouse gas inventories.

The EPA has developed a model that evaluates the emission savings from recycling and reuse compared to alternative methods. The EPA describes WARM as "a tool designed to help managers and policy-makers understand and compare the life-cycle GHG and energy implications of materials management options (recycling, source reduction, landfilling, combustion with energy recovery, anaerobic digestion, and composting) for materials commonly found in the waste stream. By comparing a baseline scenario (e.g., landfilling) to an alternate scenario (e.g., recycling), WARM can assess the energy and GHG implications that would occur throughout the material life cycle."

To use the model, agencies need to know the quantity of each material under consideration (aluminum, glass, organic materials, etc.) and how much of this material was managed in each of many specific methods (reused, recycled, landfilled, combusted, digested). With this information, the model produces estimates of GHG emissions for baseline and alternative management scenarios. The model can be used for both internally and externally generated waste.

In some cases, agencies may not know the composition of their internal or externally generated waste streams; this information may be available from local disposal agencies or other transit agencies.

5. Emission offsets

There are two aspects of carbon offsets to be discussed. First is the creation and sale of carbon offsets by a transit agency. Second is the purchase of carbon offsets. This section also addresses carbon sinks.

A carbon offset represents the reduction, removal or avoidance of greenhouse gas emissions achieved through the implementation of a specific project according to a GHG accounting protocol that establishes how to determine the baseline level of emissions, project monitoring and additionality. Offsets are measured in metric tons of carbon dioxide equivalent ($MTCO_2e$) and are used to compensate for GHG emissions that occur elsewhere. A carbon sink represents the removal of greenhouse gas emissions from the atmosphere.

A carbon offset and/or sink can be generated from a wide range of project types such as activities that displace fossil fuel use with wind or solar energy, energy conservation, afforestation and reforestation, waste handling and disposal, agricultural activities, transportation sector measures, and other actions that deploy technologies or implement practices that reduce, remove or avoid GHGs.

Entities, including transit agencies, normally consider the sale or purchase of offsets within the context of emission reduction strategies such as cap-and-trade programs (e.g., RGGI), Clean Development Mechanisms, and other programs (e.g., net-zero emission programs).

5.1 Creation and sale of carbon offsets

Many types of transit projects can reduce greenhouse gas emissions, either by shifting travelers from personal vehicles to transit vehicles or by reducing emissions produced by transit vehicles and associated infrastructure. Transit GHG reducing projects are briefly summarized in four broad categories:

- **Expanding or improving transit capacity:** Projects in this strategy group accommodate and attract new ridership to transit. Increased ridership results in decreased GHG emissions from reduced trips in personal vehicles. GHG emission reductions are generally quantified by estimating the change in passenger miles traveled and resulting reduction in personal VMT. Additional emissions generated by increased transit operations must also be accounted for.
- **Transit rider outreach and incentives:** Higher ridership can be achieved through outreach programs and incentives. GHG emission reductions for transit rider outreach and incentives are also generally quantified by estimating the change in PMT and resulting reduction in personal VMT. However, many projects in this category cannot be reliably quantified using existing tools.
- **Active transportation and land use:** Project types listed under this strategy category move beyond the traditional purview of transit agencies—operating transit vehicles—into the built environment and other modes of transportation. VMT and emission impacts of some project types have been estimated by using travel demand models and/or observed relationships from empirical research. However, there are no widely accepted, standardized quantification methodologies for these types of projects.
- **Improving the efficiency of transit energy use:** Unlike the previous three strategy categories, this category reduces GHG emissions produced by transit assets. Emission reductions from most vehicle or fuel-switching projects can be reasonably estimated by using pre- and post-project fuel amounts consumed. Renewable energy projects require an estimation of generation capacity and facility use. Facility energy efficiency improvements can be quantified by comparing energy consumption rates for facility equipment changes or by modeling the energy use of a whole building or facility.

Transit agencies have participated in the carbon offset markets by creating and selling offsets through the Clean Development Mechanism. Based on information available to APTA, no U.S. agency has sold offsets; only King County Metro Transit has purchased offsets. If offsets were sold, then the amount of carbon sold would need to be added back to the agency's carbon inventory.

5.2 Purchase of carbon offsets

Many organizations meet their emission-reduction goals by purchasing offsets from verified GHG projects that reduce emissions from sources not used by the organization. Projects that sell offsets are readily available from many locations. These could include projects such as:

- substitution of low-carbon fuels, such as solar panels, biodiesel or other products;
- aerobic composting of local food and yard waste;
- methane recapture and destruction at dairy farms and landfills; and
- reforestation.

A transit agency could procure offsets to reduce its emissions. This could help it achieve climate or energy goals. Few transit agencies have pursued this option, but it could assist in meeting other goals. However, purchasing carbon offsets may not have an impact on the long-term operations of the organization and may reduce funding for service, which can reduce overall emissions.

5.3 Carbon sinks

Many transit projects include the addition or removal of biomass. Transit agencies can choose to include these changes in carbon sinks as part of their carbon accounting. The California Air Resources Board (ARB) provides a methodology by which to compute these changes in carbon storage: the Greenhouse Gas Quantification Methodology for the Department of Forestry & Fire Protection (CAL FIRE) Urban and Community Forestry Program (www.arb.ca.gov/cc/capandtrade/auctionproceeds/calfire_ucf_16-17.pdf). Reproduced below, agencies should use the following approaches per the ARB methodology:

Tree Planting

Net GHG Benefit = Carbon Storage in Planted Trees − Carbon in Planted Trees Not Assumed to Survive + GHG Reductions from Energy Savings from Shade − GHG Emissions from Tree Planting and Maintenance

Biomass Utilization for Wood Products

Net GHG Benefit = Carbon Stores Long-Term in Wood Products + Avoided GHG Emissions from Landfills − GHG Emissions from Mill

Biomass Utilization for Electricity Generation

Net GHG Benefit = Avoided GHG Emissions from Displaced Fossil Fuel Energy + Avoided GHG Emissions from Landfills − GHG Emissions from Biomass Facility

APTA encourages referring to the ARB manual for further information.

6. Benefits calculation

APTA recommends that transit agencies express the GHG emissions benefits associated with transit service as a net GHG emissions benefit. The net GHG emissions benefit accounts for GHG emissions avoided from reductions in vehicle miles traveled and other mode shift, as well as GHG emissions generated by agency activities to directly deliver service (mobile combustion and/or electricity use for traction power).

Total GHG Emissions Avoided = GHG Emissions of Displaced Autos

Net GHG Emission Benefit =
Total GHG Emissions Avoided − GHG Emissions of Service Vehicles

NOTE: If an agency has a large enough service area to potentially displace passenger air trips, then it can use the following avoided emissions calculation:

Total GHG Emissions Avoided =
GHG Emissions of Displaced Autos + GHG Emissions of Displaced Passenger Air Trips

This calculation relies on quantifying comparable activities: fuels combusted or electricity used to deliver a unit of transportation. Agencies may use the quantification methods proposed for other activities to calculate agency emission sources, reductions, removals and offsets. However, the GHG benefit of transit service delivered should reflect the calculation above.

In the accompanying calculator tool, agencies have the option of selecting both tailpipe and well-to-wheels fuel energy density factors. Providing well-to-wheels enables agencies to account for emissions from the production and distribution of different fuel types including hydrogen and electricity, as well as exhaust (tailpipe) emissions.

Related APTA standards

APTA SUDS-CC-RP-003-12, "Quantifying and Reporting Transit Sustainability Metrics"

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Definitions

AB32: California's Global Warming Solutions Act of 2006, which includes a binding target to reduce greenhouse gas emissions to 1990 levels by 2020—a reduction of about 25 percent. AB32 also allows the California Air Resources Board to implement a cap-and-trade program to help achieve this goal.

additionality: A measure of whether an offset would have been implemented in the normal course of business. Refers to reductions that are "additional" to the baseline scenario and thus would not have happened *but for* the offset program. The offset-crediting mechanism does not need to be the only reason for a project to go forward, but it should be a decisive reason.

allowance (or permit): The right to emit 1 metric ton of CO_2 equivalent under a cap-and-trade program. Allowances are traded on carbon markets. Electricity generators and other entities covered under a cap-and-trade program must surrender one allowance for each unit of emissions.

cap-and-trade program: A program that limits the amount of a given pollutant that can be emitted into the environment. It is characterized by a fixed number of allowances (the cap, which ensures that a given emissions target is met) and a trading mechanism that allows polluters to buy and sell permits.

carbon "credit": See *offset.*

carbon trading: Can refer to a cap-and-trade program for greenhouse gases, or the sale and purchase of greenhouse gas offsets.

Certified Emission Reduction (CER): One unit of greenhouse gas reductions (1 metric ton of CO_2 equivalent) certified under the Clean Development Mechanism.

Clean Development Mechanism (CDM): An offset program established under the Kyoto Protocol. It allows developing countries to participate in greenhouse gas reduction efforts and reduces the costs of Kyoto compliance to industrialized countries. These industrialized countries can achieve their mandated Kyoto targets through a combination of domestic reductions and purchase of Certified Emission Reductions (CERs) from projects in developing nations. CERs also can be purchased by electricity generators and other emitters in Europe, as a way to fulfill their obligations under the European Emissions Trading Scheme. In other words, the two types of allowances are fungible on the European market.

CO_2 equivalent (CO_2e): One unit of greenhouse gas emissions standardized by relative global warming potential (usually measured over a 100-year period). Methane, for example, is 28 times more powerful than carbon dioxide, and so one-twenty-eighth of a metric ton of methane is one metric ton of CO_2e. ICLEI defines this concept using the term *global warming potential* (GWP).

global warming potential (GWP): A relative scale that measures how much a given mass of gas is expected to contribute to global warming. Methane, for example, is 28 times more powerful than carbon dioxide and has a GWP of 28.

greenhouse gas assertion: Declaration or factual and objective statement of greenhouse gas emissions made by the responsible party.

ICLEI: An international clearinghouse on sustainable development and environmental protection policies, programs, and techniques being implemented at the local level, which has developed its own greenhouse gas inventory protocols for local governments.

leakage: Changes in emissions that occur outside of the boundary of the cap-and-trade program or offset project. Leakage can be either positive or negative. Examples might include a reduction in gasoline life-cycle emissions from extracting, transporting and refining oil; induced traffic from a reduction in congestion; or construction emissions.

materiality: In greenhouse gas emission report verification, the concept that individual or the aggregation of errors, omissions and misrepresentations could affect the greenhouse gas assertion and could influence the intended users' decisions.

materiality assessment: In sustainability reporting, a process that identifies and prioritizes aspects of an organization's significant economic, environmental, and social impacts, used to substantively influence the assessments and decisions of stakeholders.

mode shift factor: The ratio of transit passenger miles to displaced private auto miles.

National Transit Database: A database on transit ridership, energy use, finances and other information, based on data provided by transit agencies and compiled and validated by the Federal Transit Administration. See www.transit.dot.gov/ntd.

offset: A voluntary reduction in emissions from a source that is not covered by a cap-and-trade program. Offsets can include transportation projects (e.g., fuel switching or bus rapid transit); forestry and other biological carbon "sinks"; or destruction of non-CO_2 greenhouse gases such as methane or hydrofluorocarbons. Offsets under the Clean Development Mechanism can be used by nations to meet their obligations under the Kyoto Protocol, and by firms under the European Emissions Trading Scheme. Other offsets are voluntary, generating Verified Emission Reductions, and are purchased by organizations for purposes of marketing or corporate social responsibility, or by individuals wishing to reduce their carbon footprint.

permanence: The concept of whether an emissions reduction is permanent—i.e., whether carbon sequestered in soils, forests or underground storage is re-released into the atmosphere. Any emissions reduction in the transportation sector will be permanent (the emissions are not stored, but simply not released), although the years of effectiveness of a project may vary.

protocol (or methodology): The procedure for calculating emission reductions from a specific type of project (e.g., bus rapid transit) or quantifying emissions from a specific type of organization.

Regional Greenhouse Gas Initiative (RGGI): A cap-and-trade program in the Northeastern states.

The Climate Registry: A nonprofit organization that sets guidelines for the measurement, verification and public reporting of greenhouse gas emissions. The Climate Registry is similar to what was the California Climate Action Registry, but operates throughout North America.

Western Climate Initiative: A collaboration of states and provinces in the Western United States and Canada that works together on ways to reduce greenhouse gases in the region.

Abbreviations and acronyms

AC Transit	Alameda-Contra Costa Transit District
ADA	Americans with Disabilities Act
APC	automatic passenger counting
ARB	Air Resources Board
ARRA	American Recovery & Reinvestment Act
BART	San Francisco Bay Area Rapid Transit District
BRT	bus rapid transit
BTU	British thermal unit
CalEEMod	California Emissions Estimator Model
CARTA	Chattanooga Area Regional Transportation Authority
CCAR	California Climate Action Registry
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CEQ	Council of Environmental Quality
CER	Certified Emissions Reductions
CH_4	methane
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DRL	detailed review letter
EERPAT	Energy and Emissions Reduction Policy Analysis Tool
eGRID	Emissions & Generation Resource Integrated Database
EPA	Environmental Protection Agency
EPD	environmental product declaration
ETS	(European) Emissions Trading Scheme
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	greenhouse gas
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
GWP	Global Warming Potential
HFC	hydrofluorocarbon
HMPS	Highway Performance Monitoring System
ICLEI	Local Governments for Sustainability (formerly International Council for Local Environmental Initiatives)
IPCC	Intergovernmental Panel on Climate Change
LCTOP	Low Carbon Transit Operations Program
MMBTU	million British thermal units
MMT	million metric tons
MOVES	Motor Vehicle Emission Simulator
MPO	metropolitan planning organization
MTA	Metropolitan Transportation Authority (State of New York)
MTA	Municipal Transportation Agency (San Francisco)
MTCO2e	metric tons of carbon dioxide equivalent
MTD	Metropolitan Transit District (Santa Barbara, California)
N_2O	nitrous oxide
NATSA	North American Transportation Services Association
NEPA	National Environmental Policy Act
NTD	National Transit Database
PCR	product category rule

PFC perfluorocarbon
PMT passenger miles traveled
RGGI Regional Greenhouse Gas Initiative
SEM structural equations modeling
SF_6 sulfur hexafluoride
T&D transmission and distribution
TIRCP Transit and Intercity Rail Capital Program
TCR The Climate Registry
TCRP Transit Cooperative Research Program
TIGGER Transit Investment for Greenhouse Gas and Energy Reduction
TNC transportation network company
TPMS Transit Performance Monitoring System
TTI Texas Transportation Institute
UNFCCC United Nations Framework Convention on Climate Change
VMT vehicle miles traveled
VMT vehicle mode shift
WARM EPA Waste Reduction Model
WRI World Resources Institute

Summary of document changes

- Updated emission factors and other guidance based upon newest versions of reference greenhouse gas emission reporting protocols
- Inclusion of emissions from fixed facilities and right-of-ways sources
- Expanded discussion and refinement on Scope 3 emissions
- The document no longer provides a methodology for measuring the congestion benefit as an emission reduction
- Update to mode shift figures based on updated APTA demographic analysis
- Update to land use efficiency (formerly land use multiplier) section based upon TCRP 176 research
- Inclusion of discussion on recycling, emission offsets, and carbon sinks
- Deletion of appendixes, as they were no longer relevant

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