

**U.S. Community Protocol
for Accounting and Reporting of Greenhouse Gas Emissions
Appendix D: Transportation and Other Mobile Emission
Activities and Sources**

Version 1.1

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**Developed by
ICLEI – Local Governments for Sustainability USA**

For the latest version of this Protocol, and other tools and resources that can help you report on community GHG emissions, visit www.icleiusa.org.

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Introduction

The transportation sector comprises emissions associated with the movement of people and goods, as well as service vehicles. This movement may be by road, rail, air, or water. Combustion of fuel in vehicle engines produces CO₂, N₂O, and CH₄ emissions. In some cases, particularly in transit, vehicles are powered by electricity and produce indirect emissions from electricity generation.

Transportation is one of the largest sources of greenhouse gas (GHG) emissions in most communities. Local governments have significant policy influence over some transportation emissions sources, for example, passenger vehicles and public transit, but less control over others, for example, air travel and marine vessels.

Table TR.1 below summarizes the sources of GHG emissions in the transportation sector. Paired with each source is a methodology explained later in this appendix.

➤ Note on calculating emissions for the on-road passenger and freight motor vehicle travel Basic Emissions Generating Activity: Depending on which recommended and alternate methods are used, you may need to use some combination of methods from TR.1 and TR.2 to calculate the required emissions from on-road vehicles. If you use TR.1.A, you will also need to do TR.2.A, TR.2.B, or TR.2.C. TR.1.B can also be combined with TR.2.A.

Uncertainties

Uncertainties are specific to individual sources and methods and are discussed in those sections.

Table TR.1 Summary of Transportation Greenhouse Gas Emission Sources

| GHG Source | GHG Types | Data Required | Available Methodologies |
|-------------------------------------|--|--|--------------------------------|
| Passenger vehicle operation | CO ₂ , CH ₄ , and N ₂ O | Output of a regional travel demand model | TR.1.A |
| | | OR | |
| | | -Vehicle distance traveled within the jurisdiction | TR.1.B |
| Freight and service truck operation | CO ₂ , CH ₄ , and N ₂ O | - State or county level truck VMT data from FHWA HPMS or other source - Jobs in truck-generating industries for municipality, county, and/or state | TR.2.A |
| | | OR | |
| | | - Travel demand model output – heavy duty VMT and speeds by network link (TR.2.B), or truck trip-ends and associated trip lengths (TR.2.C), in municipality - Speed-based CO ₂ , CH ₄ , and N ₂ O emission factors from MOVES or EMFAC model | TR.2.B TR.2.C |
| Freight rail operation | CO ₂ , CH ₄ and N ₂ O | - Line-haul freight movement (annual ton-miles moved by rail line, for all rail lines traversing the community) - Switching yard activity (number of locomotives and annual hours of operation per locomotive) - Line-haul and switching locomotive emission factors | TR.3 |
| Transit operation fuel combustion | CO ₂ | - Actual fuel use <i>or</i> -Fuel use estimated from vehicle miles traveled and vehicle fuel economy | TR.4.A |
| Transit operation fuel combustion | CH ₄ and N ₂ O | - Vehicle miles traveled by vehicle type <i>or</i> - Fuel use by vehicle type | TR.4.B |
| Transit traction power | CO ₂ , CH ₄ and N ₂ O | - Electricity use by mode | TR.4.C |
| Attribution of Transit emissions | | - Geographic data source of the transit agency's routes for each mode as well as the transit vehicle schedule (headways). - Number of ferry stops in each jurisdiction | TR.4.D, TR.4.E, TR.4.F |

| GHG Source | GHG Types | Data Required | Available Methodologies |
|--|--|--|-------------------------|
| Operation of inter-city passenger rail | CO ₂ , CH ₄ and N ₂ O | - Number of trains per day - Length of track within community - Energy intensity of passenger rail | TR.5 |
| Air travel-aircraft emissions | CO ₂ | Airport inventory | TR.6.A |
| | | OR - FAA's AEDT/SAGE emissions model output for airport in a calendar year or - ACRP Report 11 Airport Inventory Method 1 or 2 | TR.6.B |
| Air travel-ground support equipment and vehicles | CO ₂ , CH ₄ and N ₂ O | Airport inventory | TR.6.A |
| | | OR Fuel consumption of airport fleet vehicles and ground support equipment | TR.6.C |
| Attribution of Air travel emissions | | Airport passenger surveys that identify the number of passengers that are traveling to/from the community | TR.6.D |
| Marine vessels | CO ₂ , CH ₄ and N ₂ O | <ul style="list-style-type: none"> • Total number of vessels operating within community's waters by type • Activity hours of vessel within community's waters • Maximum power (kilowatt) rating of each vessel and average load factor • Power used by ships during hoteling | TR.7.A |
| Other off-road equipment | CO ₂ | - Number of building permits in county and jurisdiction Number of households in county and jurisdiction | TR.8.A |
| Fuel upstream lifecycle emissions | | - The same data required for TR.1 through TR.8 broken down by type of fuel - Scaling Factors for Full Fuel-Cycle Emissions in Table TR.9.1 | TR.9 |

TR.1 Emissions from Passenger Vehicles

Passenger vehicles make up a majority of U.S. GHG emissions from transportation. Passenger cars accounted for 43% and light duty trucks (including sport utility vehicles, pickup trucks, and minivans) accounted for 19% of U.S. transportation GHG emissions in 2010.¹ The proportion of a community's emissions that come from passenger vehicle transportation will differ from the national average based on local per capita driving and factors that influence emissions from other sectors, including climate and emission factors for electricity generation.

Passenger vehicle GHG emissions consist of direct emissions from the combustion of petroleum-based fuel by internal combustion engine passenger cars and light duty trucks. This includes emissions from combustion of liquid fuels, like gasoline, diesel, and liquefied gases, compressed fuels such as natural gas, and the anthropogenic share of emissions from biofuel blends. The guidance contained in this section can be used to estimate the total CO₂, N₂O, and CH₄ emissions from transportation fuels and attribute these emissions to a local government. The guidance does not include methods to estimate fugitive fluorocarbon refrigerant emissions from vehicle air conditioners. For guidance on vehicle refrigerant emissions, consult Section 7.4 of the Local Government Operations Protocol.

Local Government Influence over Passenger Vehicle Activity and Origin-Destination versus In-Boundary Attribution

Local governments have control over several policy areas that can influence individual travel choices and GHG emissions.² First, unlike other economic sectors where the point of emission typically occurs on private property, greenhouse gases from passenger vehicles are primarily emitted on publicly owned transportation rights-of-way. State and local governments own, configure, maintain, and set policies that govern the use of these rights-of-way and influence travel behavior. Secondly, local government authority over land use controls the density, type of activity, and distribution of certain activities within a community. A passenger vehicle trip is one of the transportation modes individuals can use to connect between these activities and local governments can influence the total number and length of passenger vehicle trips. Third, as an extension of their land use authority, local governments have regulatory control over privately provided off-street parking in new developments. This allows local governments to exert considerable influence over vehicle activity, as each passenger vehicle trip segment begins and ends in a parking space.

The combination of authority over transportation and the built environment means that local governments arguably have a larger influence over passenger vehicle GHG emissions than any other level of government, although state governments and the U.S. Federal Government have considerably

¹ U.S. EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*. 2-20.

² For an in-depth discussion of the local regulatory authority over GHG emissions from all sectors, see Trisolini, Katherine. "All Hands on Deck: Local Governments and the Potential for Bidirectional Climate Change Regulation." *Stanford Law Review* 62 (669). 2010. Available at <http://ssrn.com/abstract=1578470>. For an in-depth discussion of local government's regulatory authority over transportation GHG emissions within the context of measurement and attribution, see DeShazo, JR and Juan Matute. "The Local Regulation of Climate Change." In *The Oxford Handbook of Urban Planning*. 2012. Rachel Weber and Randall Crane, Eds. 455-476.

more authority over vehicle efficiency and fuel carbon intensity. This phenomenon is best expressed in the differences in per capita driving, walking, biking, and transit use of U.S. cities.

A local government's ability to affect passenger vehicle emissions through its authority does not mean that unilateral local action is the most effective strategy to create real emissions reductions. In fact, cities that aggressively pursue unilateral emissions reductions may cause inadvertent increases in regional emission. A city with low per capita VMT and a good transit and bicycle network might reject new growth in order to achieve its own targets. If this growth instead occurs in an area with more driving and fewer alternative transportation options, GHG emissions resulting from this new growth would be higher. Thus, coordinated local transportation and land use policies within a travel-shed or regional planning area can be most effective in achieving real reductions in GHG emissions. Under an effective coordinated regional transportation and land use plan, some cities with above-average regional accessibility, walk-ability, and transit access may experience absolute increases in VMT and GHG emissions even while regional per-capita emissions fall. In fact, planned increases in absolute emissions in such areas or areas with lower heating and cooling energy demand may be viable strategies in an effective and efficient statewide or regional strategy to reduce emissions.

The recommended method (TR.1.A) presented in this guidance recognizes that local governments possess the authority to influence GHG emissions from passenger vehicle trips both inside and outside of a community's geographic boundaries. This method also recognizes that local governments cannot influence all passenger vehicle GHG emissions within their boundaries. As such, the recommended origin-destination method (using a demand-based model) better captures a local government's ability to affect passenger vehicle emissions than the alternate method (TR.1.B) to calculate in-boundary emissions, which ICLEI USA has included in past guidance, including Clean Air and Climate Protection (CACP) Software.

Uncertainty inherent in estimating emissions from passenger vehicles

Local government accounting for GHG emissions from passenger vehicles differs from state-level and national-level accounting because of the high proportion of cross-boundary travel, and the unique authority and influence local governments possess over transportation and land use. State and national methods are based on amount of fuel dispensed. This method does not serve local governments well as vehicles typically travel between multiple jurisdictions on a single tank of fuel and attributing emissions based on fueling locations would be both inaccurate and useless for local government emissions management purposes. However, data on the amount of fuel dispensed can be useful in validating model results for regions or states with a low proportion of trans-boundary travel.

Likewise, methods based solely on the amount of vehicle travel within the community's geographic boundaries also produce inaccurate results. One reason is because of a high proportion of pass-through traffic in some communities, which occurs within the geographic boundaries, but the community cannot influence. An example is an interstate highway that passes through a small city. Another reason is that, for some communities a low proportion of vehicle miles from trips that terminate or originate in the community occur within the community's geographic boundaries.

Local variations in vehicle fuel efficiency and fuel type may result in discrepancies between actual and estimated emissions for a community. Communities with a younger-than-average vehicle fleet may have a higher proportion of hybrid and high-mileage vehicles in their fleets than the regional, state, or national averages. These local variations should be accounted for in an integrated regional travel and

emissions model, but this is not often the case. Adjustments based on known local data will improve the inventory's accuracy, but many communities do not have this data as state departments that manage the registration of motor vehicles do not produce it.

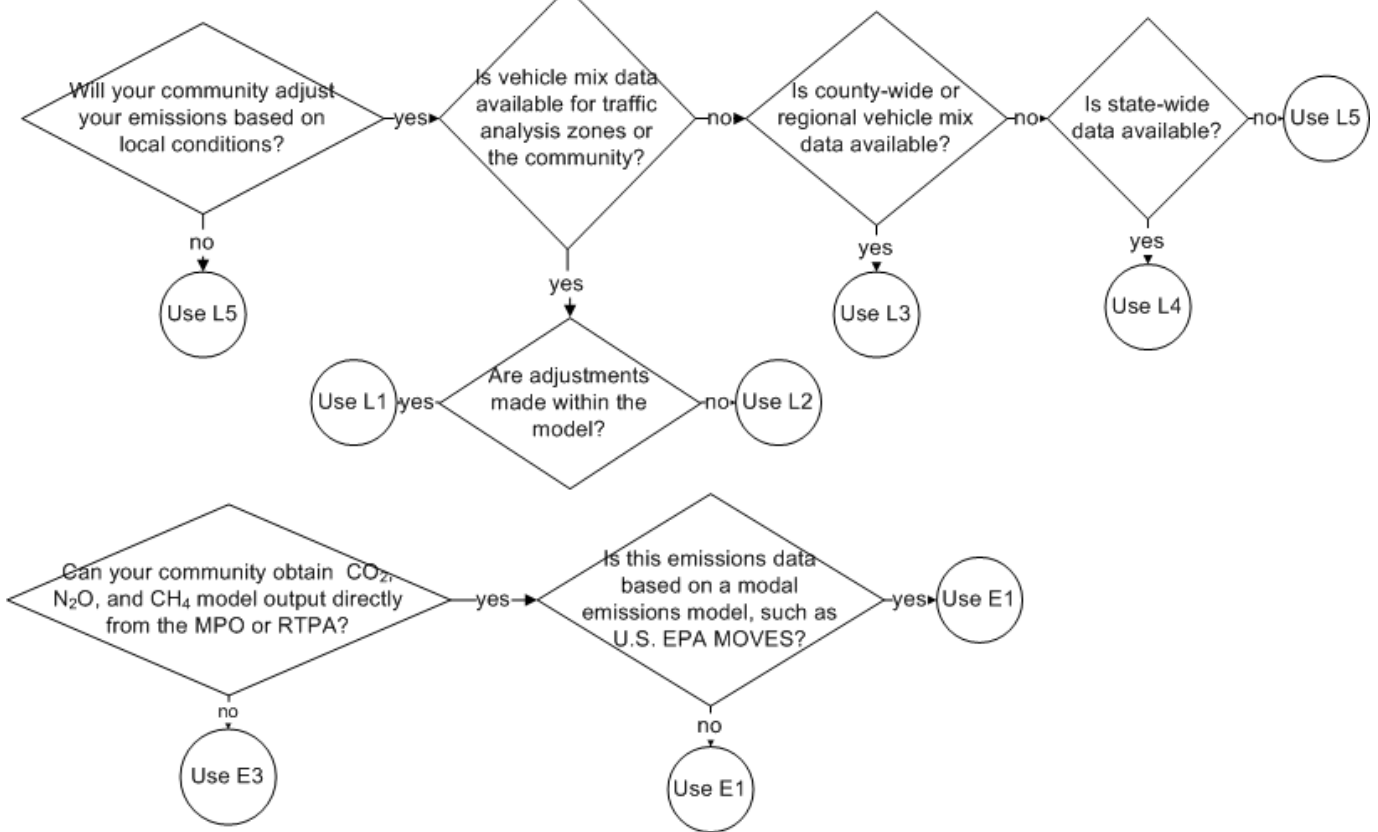
The ability of local climate managers to estimate GHG emissions from passenger vehicles will continue to improve as they have access to more precise and accurate data on travel activity and better integrated emissions models. Climate managers should be cognizant of the fact that observed changes in emissions estimates over the time can result from changes in data and methods in addition to real changes in GHG emissions.

➤ **Note for MPOs and RTPAs: Save time by producing model results for each community in your region**
ICLEI's Community Protocol presents a standardized method to estimating emissions from passenger vehicles and attributing to them cities. All cities within your region that use this Protocol to create community GHG emissions inventories will request data consistent with the Recommended Method (Method TR.1.A). Modeling staff can likely save time in the long run by producing the data once and making it available to communities rather than fielding individual requests for data.

➤ **Defining travel modeling terminology**
An **integrated trip** contains one or more trip segments and may contain one or more intermediate stops. An integrated trip often originates or terminates at home or work.
An **intermediate stop** is a stop for errands, shopping, to drop off or pick up passengers, or any other purpose that is not at the end of an integrated trip.

Emissions and Local Adjustments Data

Use this flowchart to determine which Emissions (E) and Local Adjustment (L) Input Data to use, then proceed to the Travel Data flowchart to determine which method to use.



Travel Data

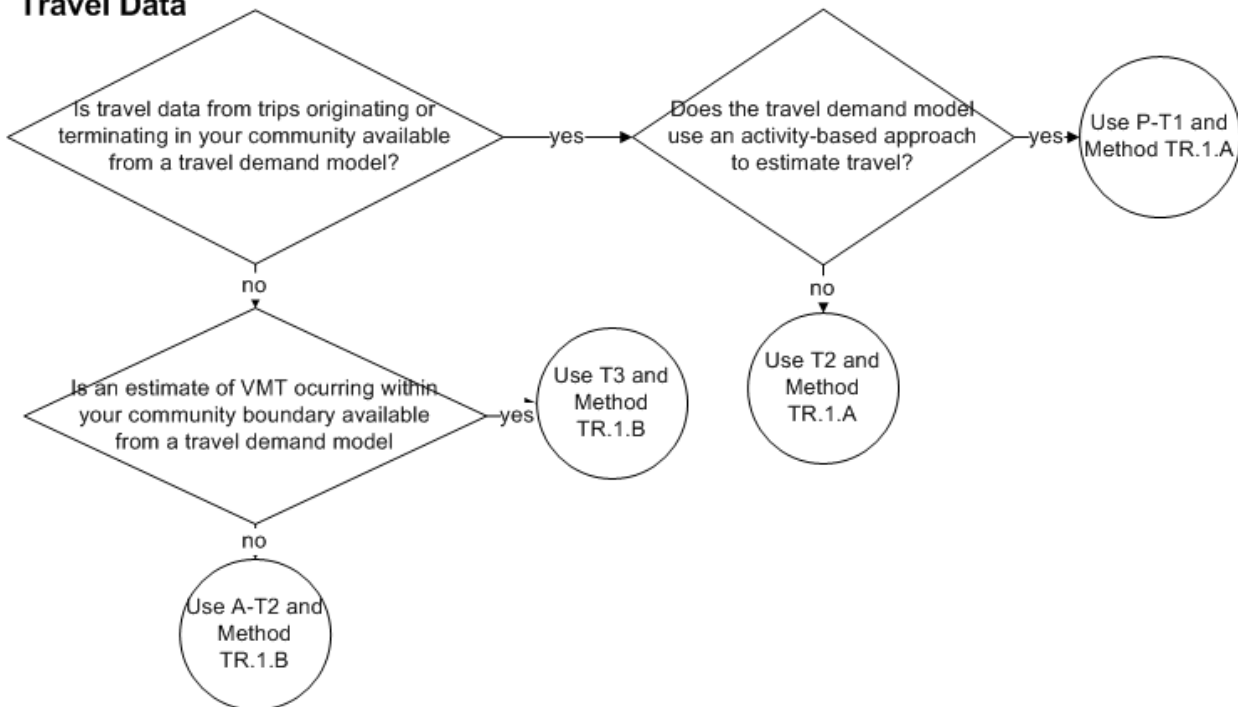


Table TR.1.1 Descriptions of Input Data Conditions

You may choose different combinations of input data conditions across columns, but not within each column. The input data conditions in each column are presented in order of preference.

| Travel Activity (T) | Emissions or Energy (E) | Local Adjustments for vehicle efficiency and fuel type (L) |
|--|--|--|
| <p>For Recommended Method: Model data of all travel originating or terminating within the jurisdictional boundaries of a community, from: (T1) an activity-based* regional travel demand model with trip origin and destination data (T2) a trip-based travel demand model with trip origin and destination data (four step models)</p> <p>For Alternate Method Only: (T3) An estimate of VMT within the community from a travel demand model (cordon method), with model calibrated to observed traffic counts within the community; (T4) an estimate of VMT within the community from a source other than a travel demand model (see equation TR.1.B.1 below)</p> | <p>For All Methods: Output of CO₂, N₂O, and CH₄ for each or the aggregate of all traffic analysis zones within the community from: (E1) a fully-integrated modal emissions model (vehicle hours operating for each vehicle specific power bins), such as U.S. EPA MOVES (see Table TR.1.2 for details); (E2) a vehicle-mile-traveled (VMT)-based emissions model using VMT and speed outputs from the travel model, such as EMFAC or MOBILE (E3) Any post-processing method which relies on aggregated methods of vehicle activity, such as emissions per mile or assumed fuel efficiency (including equations TR.1.B.1 and TR.1.B.2)</p> | <p>For All Methods: (L1) Adjustments within the model for vehicle mix based on known data on vehicle registrations per community or traffic analysis zone; (L2) Post-processing adjustments based on known-data on vehicle registrations per community or traffic analysis zone; (L3) Adjustments based on known county-wide or regional average data (includes use of EMFAC county sub-area for California users); (L4) Adjustments based on known statewide average data (L5) No adjustments, use national averages (model default)</p> |

* 'Activity-based' in this context refers to the way in which travel demand is modeled, and is unrelated to the distinction made in this protocol between activities and sources.

➤ **Does your region have an advanced travel demand model?**

If your region's travel demand model meets T1 and E1 in Table TR.1.1, then you might be able to obtain data on travel tours with intermediate stops. This data can be used to calculate "S" using Equation TR.1.A.2 (see below). If your region's travel demand model is not able to produce S at this time, you might ask your MPO or RTPA to include this capability in future model updates.

- S = kg of emissions for integrated trips with intermediate stops outside of the community. If your region has an advanced travel demand model, modeling staff can find S by integrating code to satisfy equation TR.1.A.2 within the region's travel modeling framework. This is best done as part of a planned update to the modeling framework and local governments might request this feature in future model updates. Also see S in Step 1.3 (optional) of Method TR.1.A below.

TR.1.A Recommended Method Using Origin-Destination for Passenger Vehicle Emissions

Without the output of a regional travel model it will not be possible to use this recommended method. If your community is within the boundaries of a Metropolitan Planning Organization or Regional Transportation Planning Agency, these organizations typically maintain a regional travel demand model. Table TR.1.1 outlines the preferred modeling and data approaches along with several alternatives listed in their order of preference. Any model outputs using travel activity types T1 or T2 from Table TR.1.1 (regardless of E and L used) may be considered to meet this recommended method.

The method consists of the following 4 steps:

Step 1: Ask staff at your region's Metropolitan Planning Organization or Regional Transportation Planning Agency to use their best available input data from Table TR.1.1 to generate the following modeling output data for either a) CO₂, CH₄, and N₂O, or b) VMT:

- (Step 1.1-required) T_O = kg of emissions for each GHG or VMT from all integrated trips originating within the community, with no intermediate stops outside of the community
- (Step 1.2-required) T_D = kg of emissions for each GHG or VMT from all integrated trips with the destination within the community, with no intermediate stops outside of the community
- (Step 1.3-optional) S = kg of emissions or VMT for integrated trips with intermediate stops outside of the community. If your region has an advanced travel demand model, modeling staff can find S by integrating code to satisfy equation TR.1.A.2 within the region's travel modeling framework. This is best done as part of a planned update to the modeling framework and local governments might request this feature in future model updates.

Step 2: If you received emissions in Step 1, proceed to Step 3. If you received VMT, use equations TR.1.B.2 and TR.1.B.3 to convert VMT to emissions.

Step 3: Plug T_O , T_D , and S into equation TR.1.A.1

Step 4: Report the emissions per GHG and the type of input data used from Table TR.1.1 (e.g., T1, E1, L1)

| Table TR.1.2 EPA MOVES Source Type IDs to include in inventory | |
|---|-----------------------------|
| MOVES Source Type ID | Source Type Name |
| 11 | Motorcycles |
| 21 | Light duty passenger cars |
| 31 | Light duty passenger trucks |

| Equation TR.1.A.1 Estimate of GHG Emissions from passenger vehicles attributable to the community |
|--|
| For Each <i>GHG</i> , CO ₂ , CH ₄ , and N ₂ O, |
| $Emissions = \frac{1}{2}T_O + \frac{1}{2}T_D + S$ |
| Note: S is optional, and most travel models will not use S . |
| Where: |
| <p>T_O = kg of emissions for each GHG from all integrated trips originating within the community, with no intermediate stops outside of the community</p> <p>T_D = kg of emissions for each GHG from all integrated trips terminating within the community, with no intermediate stops outside of the community</p> <p>S (Optional) = for integrated trips with intermediate stops outside of the community, the based on equation TR.1.A.2.</p> |

Equation TR.1.A.2 Estimate of GHG Emissions from trips with intermediate stops outside of the community, S (optional)

S = The intermediate-stop trip emissions attributable to the community for each GHG

Where, for each trip:

S_T = Trip emissions for each GHG

S_H = Trip emissions for each GHG for a hypothetical direct trip without intermediate stops

N = Number of segment ends for the entire integrated trip. Segment ends are stops for errands or picking up/dropping of chauffeured passengers.

N_C = Number of segment ends that are within the community

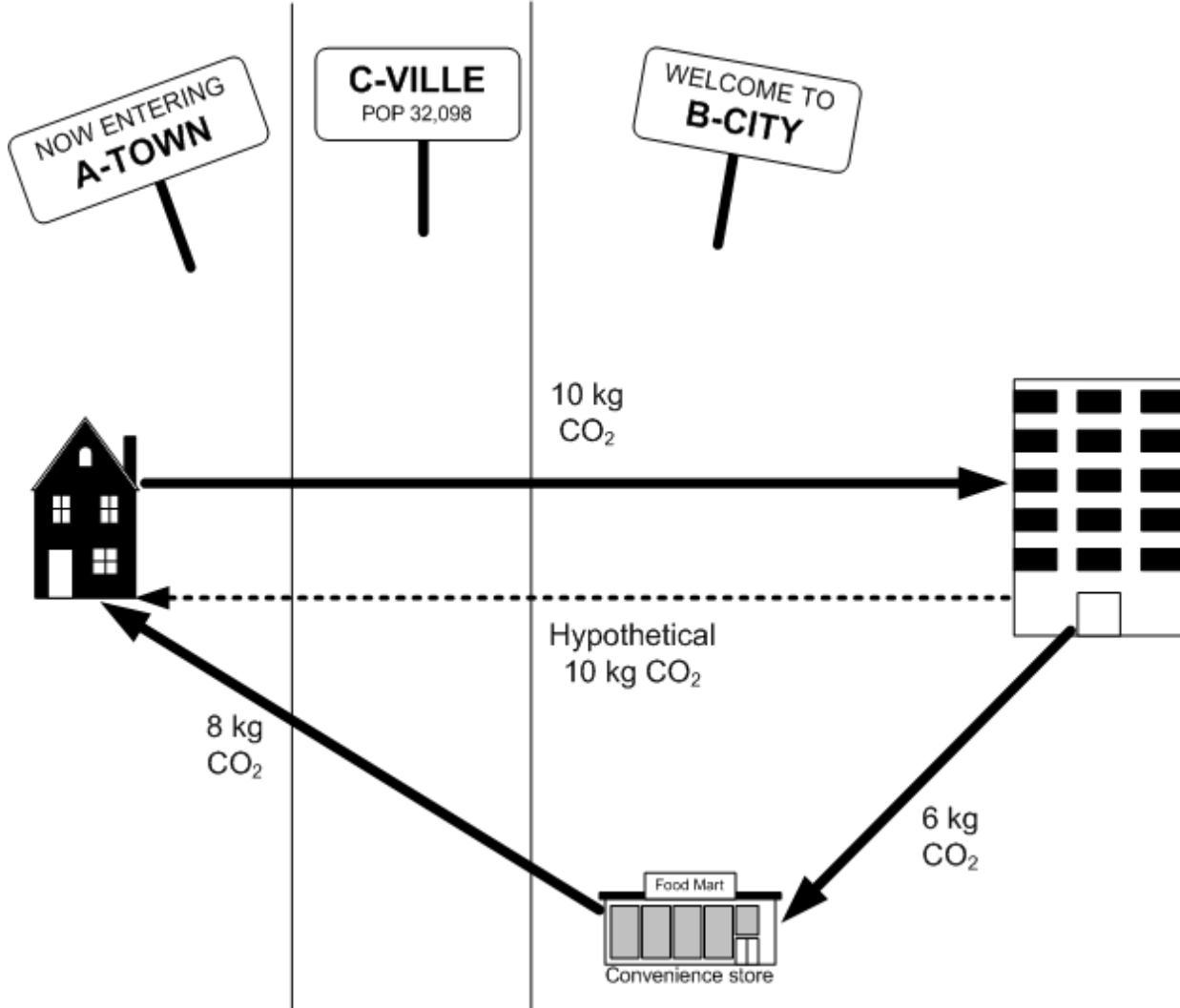
For all trips with intermediate stops outside of the community, T_S

$$S = \sum_{T_S} \left(\left(\frac{1}{2} \times S_H \right) + \frac{N_C}{N} \times (S_T - S_H) \right)$$

Note that the difference $S_T - S_H$ is the incremental impact of the intermediate stop on the trip

Box TR.1.A.1 below gives an example of how to calculate the CO₂e emissions from passenger vehicles using equations TR.1.A.1 and TR.1.A.2. Note that *S*, found using equation TR.1.A.2, is optional.

Box TR.1.A.1 Example Calculation of GHG Emissions from Passenger Vehicles



The above illustration is a simplified example of two integrated trips and the CO₂ each produces:

- Trip 1 is from A-Town to B-City, passing through C-Ville. This trip produces 10 kg of CO₂
- Trip 2 has two segments, one from an office to a market in B-City producing 6 kg CO₂, the second from the market in B-City to a home in A-Town, which passes through C-Ville, producing 8 kg of CO₂.

The resulting GHG calculation depends on which city is making the calculation.

For **A-Town**,

Trip 1 originates in A-town and has no intermediate stops outside of the community. As this is the only trip originating within the community, $T_O = 10$ kg

Trip 2 Can be calculated one of two ways. If intermediate stop data is available, calculate S as described below. If this data is not available, the model will produce a result of $T_D = 10$ or 14 kg CO₂ for trip 2, which can be attributed using Equation TR.1.A.1, as with Trip 1. Trip 2 originates on B-City and terminates in A-Town, but includes an intermediate stop in B-City. For this trip:

The integrated trip CO₂ emissions, $S_T = 8+6 = 14$ kg,

The CO₂ emissions of a hypothetical direct trip with no intermediate stop, $S_H = 10$,

The total number of segment ends, $N = 4$,

The number of segment ends within the community, $N_C = 1$

Using equation TR.1.A.2 to estimate S for A-Town, the intermediate-stop trip emissions attributable to the community:

$$\begin{aligned} S &= \sum_{T_S} \left(\left(\frac{1}{2} \times S_H \right) + \frac{N_C}{N} \times (S_T - S_H) \right) \\ &= \left(\frac{1}{2} \times 10 \right) + \frac{1}{4} \times (6 + 8 - 10) \\ &= 5 + .25 \times 4 \\ &= 6 \end{aligned}$$

Then plugging S (if available) into Equation TR.1.A.1 to find CO₂ emissions attributable to **A-Town**:

$$\begin{aligned} \text{CO}_2 \text{ Emissions (kg)} &= \frac{1}{2} T_O + \frac{1}{2} T_D + S \\ &= \frac{1}{2} \times 10 + \frac{1}{2} 0 + 6 \\ &= 5+6 \\ &= 11 \end{aligned}$$

For **B-City**,

Trip 1 originates in A-Town, terminates in B-City and has no intermediate stops outside of the community. As this is the only trip ending within the community, $T_D = 10 \text{ kg}$

Trip 2 originates in B-City, includes an intermediate stop within B-City before continuing on into A-Town. S only applies when intermediate stop data is available. If intermediate stop data is not available, the model will produce a result $T_O = 10$ or 14 kg CO_2 for trip 2, which can be carried through to TR.1.A.1. To calculate S for trip 2, you need:

The integrated trip CO_2 emissions, $S_T = 8 + 6 = 14 \text{ kg}$,

The CO_2 emissions of a hypothetical direct trip with no intermediate stop, $S_H = 10$,

The total number of segment ends, $N = 4$,

The number of segment ends within the community, $N_C = 3$

Using equation TR.1.A.2 to calculate S for B-City, the intermediate-stop trip emissions attributable to the community:

$$\begin{aligned} S &= \sum_{T_S} \left(\left(\frac{1}{2} \times S_H \right) + \frac{N_C}{N} \times (S_T - S_H) \right) \\ &= \left(\frac{1}{2} \times 10 \right) + \frac{3}{4} \times (6 + 8 - 10) \\ &= 5 + .75 \times 4 \\ &= 8 \end{aligned}$$

Then plugging S into Equation TR1.1 to find CO_2 emissions attributable to **B-City**:

$$\begin{aligned} \text{CO}_2 \text{ Emissions (kg)} &= \frac{1}{2} T_O + \frac{1}{2} T_D + S \\ &= \frac{1}{2} \times 0 + \frac{1}{2} 10 + 8 \\ &= 5 + 8 \\ &= 13 \end{aligned}$$

For **C-Ville**, there are no integrated trips or trip segments ending within the community, thus there are no attributable emissions.

➤ **Case Study: Community GHG Emissions from Passenger Vehicles in the San Francisco Bay Area**

In the San Francisco Bay Area, local communities work with a consultant that maintains a regional travel model and the Bay Area Air Quality Management District to create community inventories. The consultant produces travel model results that meet condition T1 (see *Table TR.1.1* Descriptions of Input Data Options for “conditions”). These results include VMT, divided into speed bins, for trips originating and terminating within the geographic boundaries of a community. The Bay Area Air Quality Management District uses the California Air Resources Board’s free EMFAC software, which meets conditions E2 and L3, to convert VMT at each speed into CO₂ emissions. Then, the community uses these values for its inventory of emissions from passenger vehicles.

TR.1.B Alternative Method for Estimating In-boundary Passenger Vehicle Emissions

➤ **ICLEI Members can use the CACP 2009 Software**

If your local government is a member of ICLEI, you can use the CACP 2009 software. The community transportation calculations are functionally equivalent to the alternative method presented below.

➤ **Don’t Compare Results of the Recommended and Alternative Methods**

Emissions estimates for passenger vehicles using the alternate method cannot be compared with estimates derived from the preferred method. In contrast with the recommended method, this alternative method does not account for travel that originates or terminates within the community. As such, this method is not a direct substitute for the recommended method by communities that use this method to calculate passenger vehicle emissions. Because passenger vehicles are one of the top three emitting activities for most communities, community-wide inventory totals that incorporate the alternative method for passenger vehicles should not be compared with community-wide inventory totals that utilize the preferred method.

This alternative method will over-report emissions for jurisdictions with a high proportion of pass-through traffic. Also, it will likely under-report emissions for communities with a central business district or ratio of employment to employment-age residents that is higher than the regional average.

The alternative method consists of the following three steps:

Step 1: Estimate annual vehicle miles traveled for the inventory year using equation TR.1.B.1, get data from your MPO or RTPA that meets condition T3 in Table TR.1.1, or utilize another annual VMT estimation method that your local government has developed and include documentation on this method when reporting your local government’s GHG inventory

Step 2: Convert annual vehicle miles traveled to CO₂ using an emission model or equation TR.1.B.2

Step 3: Convert annual vehicle miles traveled to CH₄ and N₂O using an emissions model (conditions E1 or E2) or equation TR.1.B.3 (condition E3)

Equation TR.1.B.1 VMT Estimate from Passenger Vehicles*Estimate of annual vehicle miles traveled:*

$$VMT = \sum_a Length_a \times Annual\ Average\ Daily\ Traffic_a \times 365$$

for each road segment *a* within your boundary (collectors/local roads, major arterial streets, limited access highways)

➤ List omitted roads and highways

The community shall report any passenger vehicle transportation facilities within the geographic boundaries that are omitted from the analysis (such as an interstate highway), regardless of whether the community has jurisdiction over the facility. Otherwise, results produced using the Alternate Method will be assumed to include emissions from all passenger vehicles within the geographic boundaries of the community.

Source: ICLEI CACP 2009. See: <http://www.icleiusa.org/tools/cacp-2009>

Equation TR.1.B.2 CO₂ Emissions from Passenger Vehicles:*Estimate of CO₂ emissions:*

$$CO_2 = \sum_{b,f} \left(\frac{VMT \times \%b}{MPG_b} \times Emission\ Factor_f \right)$$

for each vehicle type, *b* (see *Table TR.1.3*), average MPG for *b* (see *Table TR.1.5*), and emissions factor for fuel type, *f* (see *Table TR.1.6*)

| | <i>Description</i> | <i>Value</i> |
|-------------------------------------|---|---|
| <i>VMT</i> | <i>Annual vehicle miles</i> | <i>User Input</i> |
| <i>%b</i> | <i>% of vehicle miles by vehicle type b</i> | <i>From local data (Table TR.1.1 conditions L2, L3, or L4), or Table TR.1.3 (condition L5).</i> |
| <i>MPG_b</i> | <i>Average MPG of vehicle type b</i> | <i>From local data (Table TR.1.1 conditions L2, L3, or L4), or Table TR.1.5 (condition L5).</i> |
| <i>Emissions Factor_f</i> | | <i>From Table TR.1.6</i> |

Source: Adapted from The Local Government Operations Protocol, based on various EPA Inventory Appendices and Guidance Documents.

Equation TR.1.B.3 CH₄ and N₂O Emissions from Passenger Vehicles:

Estimate of CH₄ and N₂O emissions:

$$CH_4, N_2O = VMT \times \%b \times EF_b$$

for each vehicle type, *b*, see **Table TR.1.3** for U.S. default %*b* values, or use locally appropriate values. See **Table TR.1.4** for per-mile CH₄ and N₂O emission factors by vehicle type.

Source: ICLEI CACP 2009. See: <http://www.icleiusa.org/tools/cacp-2009>

Additional guidance for Passenger Vehicles

Note on scaling model results when model year and inventory year is different:

Your MPO might not create a travel demand model for all years. If you wish to estimate transportation GHGs for a year in between your MPO's model runs, you should create and utilize a scaling factor. This will extrapolate (or interpolate) emissions from a model year to emissions in a non-model year.

Methods to use include

1. **Percentage of local vehicle activity** (as measured through VMT estimates employed in 2.0 Alternate Method) in inventory year versus the model base year. For example, if your jurisdiction calculated VMT to be 100 in 2009 (the last model year) and 102 in 2011 (the inventory year), then you would multiply emissions results from the 2009 by 1.02 to obtain an estimate of 2011 emissions within your jurisdiction.
2. **Based on a rate of change determined from a sample of inventories from two model years.** For example, if model results are available from 2005 (96) and 2009 (100), you could then calculate a growth rate (1.010258%) and use an exponential growth formula to estimate emissions for 2011: $100 \times (1.010258)^2$, where 100 is the value from the most recent model-based inventory, and 2 is the number of years since that inventory.

Note on accounting for zero emission vehicles

The guidance in this section is designed to estimate tailpipe emissions from vehicles. Battery electric, hydrogen, and some other alternative fuel vehicles do not produce tailpipe emissions. For purposes of this Protocol, the emissions from the electricity or natural gas (to produce hydrogen) used for these vehicles will be captured by methods in Appendix C – Built Environment Emission Activities and Sources for the jurisdiction where the vehicle refuels/recharges. The most accurate method is to use data that is currently and regularly available to account for GHG emissions from these vehicles. Accounting for upstream emissions produced to refuel or recharge a zero emissions vehicle can be informative and is especially useful when making comparisons between vehicle technologies. Here are some guidelines to follow when considering upstream emissions from zero emissions vehicles:

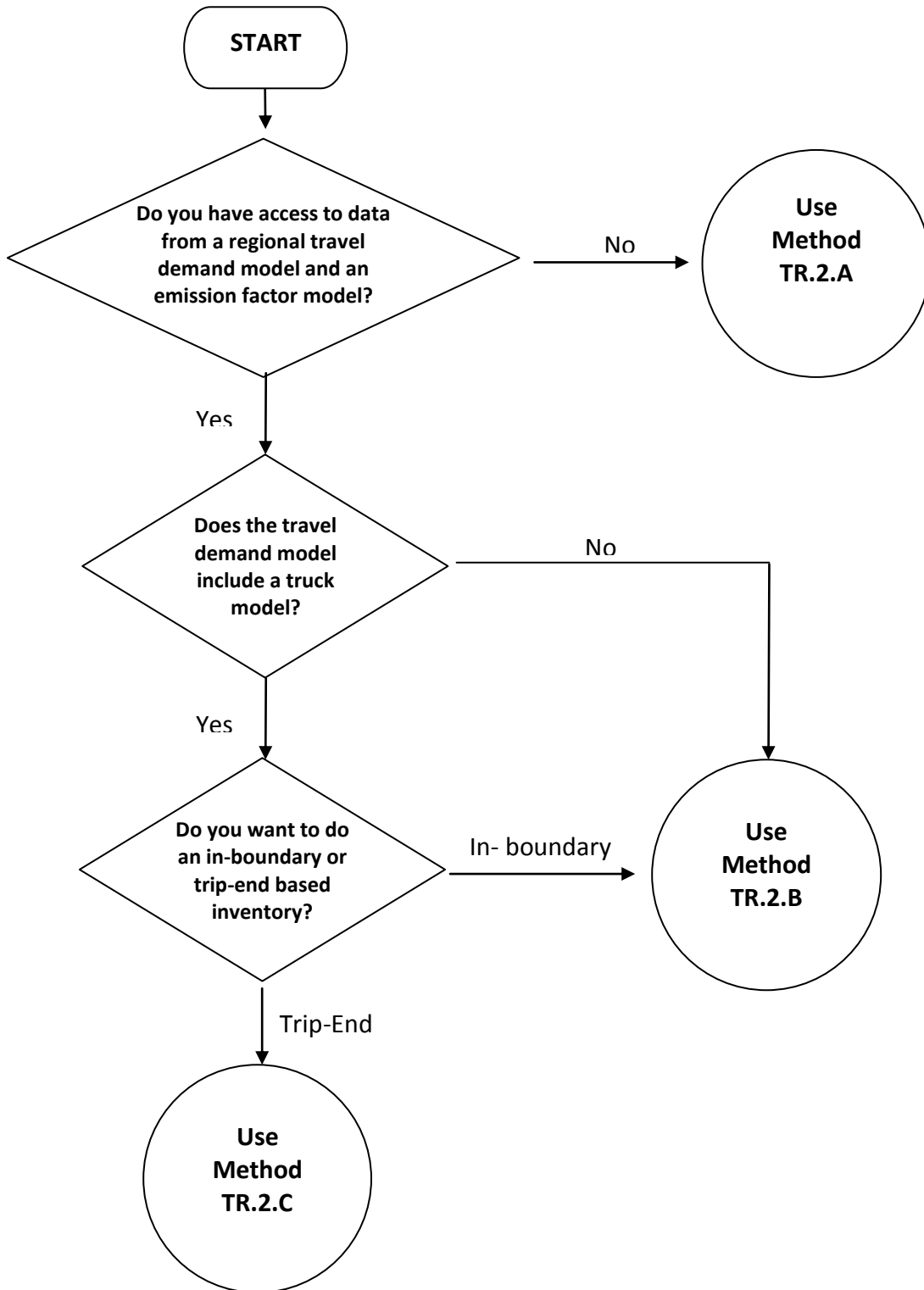
- Always compare life cycle emissions with life cycle emissions. Use emissions factors based on the Argonne or California GREET models (for more information on methodology, See Mark Delucchi – Overview of The Lifecycle Emissions Model, 2002).

- Never compare a vehicle’s direct tailpipe emissions with indirect electricity emissions. While these are the totals typically reported in community inventories, they do not allow for a valid comparison across vehicle types as the proportion of emissions at various stages of the life cycle differ with vehicle technology. As such, comparisons made based on a single stage of the life cycle will be misleading.

It is possible to “carve out” upstream emissions from zero emissions vehicles and include this total as an informational item your community’s GHG inventory. The emissions will still be reported in the built environment sector. Doing so requires the use of locally appropriate vehicle adjustments, such as input data conditions L1 or L2 from Table TR.1.1. Using conditions L3, L4, or L5 will not produce accurate results for local emissions.

TR.2 Emissions from Freight and Service Trucks

CHART TR.2.1: Decision Tree for Reporting Emissions from Freight and Service Trucks within your Community



TR.2 Overview of Emissions Associated with Surface Transportation: Freight and Service Trucks

This source includes mobile source emissions from freight and service (i.e., non-passenger) on-road transportation, including medium and heavy-duty trucks.

Freight trucks have a primary purpose of transporting goods. Service trucks include a wide variety of other heavy-duty vehicles, such as utility trucks, municipal service vehicles, contractor trucks, and tow trucks, whose purpose is not primarily to transport passengers. Data from motor carrier reporting in Connecticut suggests that over half of all heavy truck VMT may be from service vehicles rather than freight haulage.³ Light-duty trucks used by contractors are excluded from the freight and service vehicle sector, since available data do not allow these to be separated from light-duty trucks used for transporting passengers.

The contribution of this source and the ability to influence emissions will vary across communities. All communities generate some level of freight movement to transport goods to and from the local population and businesses, as well as other trucks serving local needs. Communities with high levels of manufacturing and warehousing industries will generate more goods movement. Communities with significant Interstate highways or other long-distance freight transport routes will experience significant levels of freight emissions from pass-through vehicles. A smaller number of communities will have major ports or intermodal terminals that serve regional, national, and even international markets.

Note: It is strongly recommended that communities within a state or metropolitan area that are developing GHG inventories work together to obtain and process the required data. There will be many economies of scale in processing data for multiple jurisdictions as the data within a state will be obtained from the same source. A supportive contact at the state department of transportation (DOT) or metropolitan planning organization (MPO) would be very helpful in completing the data gathering and analysis exercise.

Prescribed sources/activities:

- Medium and heavy truck travel (gross vehicle weight rating or GVWR of at least 10,000 lb.) occurring on public roads within the jurisdiction's boundaries (CO₂, N₂O, and CH₄ emissions)

Optional sources/activities:

- Medium and heavy truck travel associated with trip-ends within the community

Possibly expected sources/activities, not included:

- HFCs from refrigeration equipment used on trucks – may be included in industrial sources
- Off-road truck activity – requires specialized inventory

³ Cambridge Systematics, Inc., unpublished analysis of data from 2009 MCS-150 reporting to the Federal Motor Carrier Safety Administration.

Uncertainties

The availability and quality of data to associate freight and service truck GHG emissions with individual communities is limited. Some estimates of truck traffic can be made from national data sources, but significant uncertainties exist when using these sources at a finer geographic resolution than the county. In this Protocol, certain types of employment are used as a proxy for truck trip generation. Even if total VMT by trucks within the community is known, emissions will still depend upon the types of trucks (e.g., single-unit vs. combo, short-haul vs. long-haul), the age distribution of the vehicle fleet, and operating conditions on roads within the community (e.g., average speeds, stops and starts, grades).

TR.2.A Method for In-Boundary Estimate Based on Truck VMT

Introduction

The method to calculate truck traffic emissions is based on estimates of truck vehicle-miles of travel (VMT) within a jurisdiction. In most areas, VMT estimates (particularly truck VMT) from traffic monitoring systems will not be reliable at less than a county level. Therefore, a method is needed to disaggregate county-level VMT to the municipal level. The method proposed in this protocol is based on employment categories related to high truck trip generation.

The methodology requires obtaining county-level truck VMT from state-level reporting sources and disaggregating it to a municipal level based on employment data corresponding to high truck generating sectors. Average truck fuel economy is then used to estimate CO₂ emissions and Climate Registry emission factors are used to estimate N₂O and CH₄ emissions. Separate fuel economy estimates are applied for “medium-duty” and “heavy-duty” trucks; these are applied to single-unit trucks and combination trucks (i.e., tractors & trailers), respectively.

Data Needs

Below are the data inputs you will need to collect in order to estimate the GHG emitted by freight and service trucks operating within the community:

- VMT data for (a) single-unit trucks and (b) combination trucks may be obtained from the state department of transportation (DOT) for the county in which the community is located. The state DOT is responsible for the collection of traffic data for all roads within the state and for reporting this data to the Federal Highway Administration (FHWA) for use in its Highway Performance Monitoring System (HPMS), which is used for state-level statistical reporting in FHWA’s annual Highway Statistics publication. Each state has a designated HPMS Manager or HPMS Coordinator. Information on the HPMS and a link to some state HPMS web sites is provided at: <http://www.fhwa.dot.gov/policyinformation/hpms.cfm>.
- State traffic monitoring systems report traffic volumes (annual average daily traffic) by roadway segment. These must be multiplied by the segment length and summed over all segments to determine VMT. Truck volumes are also reported for a sample of sections. The critical data items reported to the HPMS are #2 (state), #4 (county code), #30 (section length), #33 (annual average daily traffic – AADT), #82 (percent single unit trucks - average daily), and #84 (percent combination trucks -average daily).⁴

⁴ For information on the HPMS see: <http://www.fhwa.dot.gov/policyinformation/hpms.cfm>

- Summaries of total VMT by county may also be available from state air agencies and/or DOTs in states with nonattainment areas, as they are required for emissions inventory development. EPA may also have county-level data for the entire U.S. for its emissions inventory. These sources may not have county breakdowns of truck percentages. If county-level data cannot be obtained from any source, state-level data can be obtained from FHWA's publication Highway Statistics, Table VM-1.
- Employment by NAICS industry sector for the community conducting the inventory and for the county in which it is located may be obtained from Employment Household Dynamics (LEHD) - OnTheMap (OTM) website the Census Bureau's Longitudinal (<http://onthemap.ces.census.gov/>). (Currently, this dataset does not include the District of Columbia, Massachusetts, or New Hampshire. Municipalities in these states will need to utilize an alternative source such as County Business Patterns.)
- Average truck fuel economy for the on-road fleet (not for new vehicles) by truck size can be obtained from the latest version of the Annual Energy Outlook (AEO) (Table 67: Freight Transportation Energy Use in the 2010 AEO). Table TR.2.1 shows estimates for 2010 from the 2010 AEO. The units in the AEO are gallons of gasoline equivalent (GGE), which accounts for the different energy content per gallon of different fuels. For diesel fuel, GGE can be converted into gallons of diesel using a conversion factor of 1.11 gallons per GGE. For this calculation, single-unit truck counts from HPMS can be assumed to correspond with medium duty truck fuel efficiency from AEO, and combination trucks with heavy-duty trucks.
- As an alternative to the use of average fuel economy, EPA's MOVES model may be used to estimate GHG emission factors. This is more resource-intensive, but has the advantage of allowing the use of local data on the vehicle fleet and fuel characteristics. The use of this model is not described here, but instead the user is referred to EPA guidance.⁵
- Gasoline/diesel fractions can be obtained from the same AEO table, as shown in Table TR.2.1.
- Carbon content of gasoline and diesel fuel are shown in Table TR.1.6. Adjustments should be made as needed for local measures that significantly affect the carbon content of fuel, such as state low carbon fuel standards or incentive programs. (Note: this calculation does not consider municipal fleets that may run on biofuels. A detailed accounting of municipal fleet emissions would be conducted as part of the local government inventory.)
- CH₄ and N₂O emission factors for heavy-duty vehicles are provided in The Climate Registry (TCR) General Reporting Protocol (GRP) v1.1 (2008) and repeated in Table TR.2.2. These factors may not reflect the latest heavy-duty vehicle emissions standards. Updated factors per vehicle-mile by fuel type may be obtained from the EPA's State Inventory Tool by entering a unit value of VMT for heavy-duty gasoline vehicles (HDGV) and heavy-duty diesel vehicles (HDDV) and dividing total emissions for the analysis year for the respective vehicle types by the VMT for that vehicle type.

⁵ U.S. EPA (2012). *Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption: Public Draft*. EPA-420-D-12-001.

Calculation Method

The method presented consists of the following steps:

1. Calculate total single-unit and combination truck VMT in the county in which the municipality is located by summing AADT * section length * % trucks by type across all roadway sections in the county from the state traffic monitoring system.
2. Determine the ratio of community to county employment in high truck-generating job sectors, using LEHD or another data source. From the North American Industry Classification System (NAICS) used in LEHD the following sectors can be used: Agriculture, Forestry, Fishing and Hunting; Mining, Quarrying, and Oil and Gas Extraction; Utilities; Construction; Manufacturing; Wholesale Trade; Retail Trade; and Transportation and Warehousing.
3. Multiply this ratio by total county-level medium (single-unit) and heavy (combination) truck VMT, to determine the medium and heavy truck VMT associated with the community.
4. Divide VMT by MPG (gallons gasoline or diesel) and multiply by percent fuel use by size category from Table TR.2.1 to obtain total gasoline and diesel fuel use for medium and heavy trucks.
5. Sum medium and heavy truck fuel use to obtain total gasoline and diesel fuel use by trucks.
6. Multiply by the carbon content of fuel (Table TR.1.6) to determine total carbon emissions by trucks.
7. Sum medium and heavy truck VMT to obtain total VMT for gasoline and diesel trucks.
8. Multiply by CH₄ and N₂O emission factors (Table TR.2.2) to determine total CH₄ and N₂O emissions.
9. Apply Global Warming Potential (GWP) factors (Appendix GWP) to each pollutant to obtain total GHG emissions in CO₂-equivalents.

Equation TR.2.A.1. CO2 Emissions from Freight and Service Trucks

$$\text{CO}_2 \text{ emissions (FT, ST)} = [(\text{VMT (Muni, ST)} * \% \text{FT}) / \text{MPG (FT, ST)}] * (\text{CO}_2/\text{gal (FT)} / 1000)$$

Where: $\text{VMT (Muni, ST)} = \text{VMT (Cnty, ST)} * \text{Jobs (Muni)} / \text{Jobs (Cnty)}$

| Description | | Value |
|------------------------------------|--|-----------------------------------|
| CO ₂ emissions (FT, ST) | Annual CO ₂ emissions (metric tons) by fuel and source type | Result |
| VMT (Cnty, ST) | Annual truck vehicle-miles of travel by source type, from state reporting for HPMS | User input |
| MPG | Average miles per gallon by source type and fuel type | From Table TR.2.1 or user input |
| CO ₂ /gal | Carbon content of fuel by fuel type (kg/gal) | Gasoline - 8.78 Diesel – 10.21 |
| %FT | % of source type vehicle miles by fuel type (gasoline or diesel) | From Table TR.2.1 or user input |
| ST | Source type (medium-duty/single-unit truck or heavy-duty/combo truck) | User input |
| Cnty | County in which municipality is located | User input |
| Muni | Municipality for which inventory is being conducted | User input |
| Jobs | Municipal or county employment in truck-generating industries, from LEHD-OTM | User input |
| 1,000 | Conversion from kg to metric tons | 1,000 |

Source:

CO₂/gal: The Climate Registry – General Reporting Protocol v1.1 (2008), Eq. 13e

Jobs: Census Bureau, Longitudinal Employment Household Dynamics (LEHD) - OnTheMap (OTM). See: <http://onthemap.ces.census.gov/>

VMT: Federal Highway Administration, Highway Performance Monitoring System (HPMS). <http://www.fhwa.dot.gov/policyinformation/hpms.cfm>

Equation TR.2.A.2. CH₄ and N₂O Emissions from Freight and Service Trucks

$$(CH_4, N_2O) \text{ emissions} = VMT (Muni, FT) * EF (FT) / 1,000,000$$

| Description | | Value |
|---|--|--|
| (CH ₄ , N ₂ O) emissions | Annual CH ₄ or N ₂ O emissions in metric tons | Result |
| VMT (Muni, FT) | Annual truck VMT occurring within municipality by fuel type, from equation X.1 | Result |
| EF | Emissions factor for CH ₄ or N ₂ O by fuel type (gas or diesel), from TCR GRP, EPA State Inventory Tool, or MOVES model (g/mi) | Given value (Table TR.2.2) or user input |
| 1,000,000 | Conversion from grams to metric tons | 1,000,000 |
| Source: The Climate Registry (TCR) General Reporting Protocol (GRP) v1.1 (2008) EPA State Inventory Tool: See http://www.epa.gov/statelocalclimate/resources/tool.html | | |

Box TR.2.A.1 below gives an example of how to calculate the CO₂ emissions from freight and service trucks using equation TR.2.A.1.

| Box TR.2.A.1 | | Example Calculation of CO₂ Emissions from Freight And Service Trucks | |
|---|--|--|--------------------------|
| 2009 inventory for City of New London, CT (in New London County). County-level VMT by truck type is available from a statewide freight study. | | | |
| Description | | Value | |
| VMT (Cnty, ST) | = 2009 truck VMT in New London County | 31,612,713 (SU) | 43,655,652 (combo) |
| Jobs | = Jobs in truck-generating industries from LEHD-OTM (Agriculture, Forestry, Fishing and Hunting; Mining, Quarrying, and Oil and Gas Extraction; Utilities; Construction; Manufacturing; Wholesale Trade; Retail Trade; and Transportation and Warehousing) | 39,648 (county) | 2,601 (city) |
| | | 6.6% (% in city) | |
| VMT (City, ST) | = 2009 truck VMT in New London City by source type $VMT (SU) = 31,612,713 * 6.6\%$ $VMT (combo) = 43,655,652 * 6.6\%$ | 2,073,867 (SU) | 2,863,911 (combo) |
| VMT (City, ST, FT) | = 2009 truck VMT in New London City by source type and fuel type = VMT (City, ST) * %FT $VMT (SU, gas) = 2,073,867 * 28.4\%$ $VMT (SU, diesel) = 2,073,867 * 71.6\%$ $VMT (combo, gas) = 2,863,911 * 2.5\%$ $VMT (combo, diesel) = 2,863,911 * 97.5\%$ | 588,978 (SU-gas) | 1,484,899 (SU-diesel) |
| | | 71,598 (combo-gas) | 2,792,313 (combo-diesel) |
| CO ₂ (SU, gas) = (588,978 mi /9.33 mpg) * (8.78 kg/gal / 1,000) = 554 metric tons | | | |
| CO ₂ (SU, diesel) = (1,484,899 mi /13.81 mpg) * (10.21 kg/gal / 1,000) = 1,099 metric tons | | | |
| CO ₂ (combo, gas) = (71,598 mi /5.36 mpg) * (8.78 kg/gal / 1,000) = 117 metric tons | | | |
| CO ₂ (combo, diesel) = (2,792,313 mi /6.06 mpg) * (10.21 kg/gal / 1,000) = 4,705 metric tons | | | |
| Total CO ₂ emissions = 554 + 1,099 + 117 + 4,705 = 6,475 metric tons | | | |

Box TR.2.A.2 below gives an example of how to calculate the CH₄ and N₂O emissions from freight and service trucks using equation TR.2.A.2.

| Box TR.2.A.2 Example Calculation of CH₄ and N₂O Emissions from Freight And Service Trucks | | |
|---|--|-------------------------------------|
| 2009 inventory for City of New London, CT (in New London County). County-level VMT by truck type is available from a statewide freight study. | | |
| Description | | Value |
| VMT (Muni, FT) | = 2009 truck VMT in New London City by fuel type, from X.1 | 677,167 (gas) 4,260,611 (diesel) |
| EF (CH ₄ , FT) | = CH ₄ emission factors by fuel type | 0.0333 (gas) 0.0051 (diesel) |
| EF (N ₂ O, FT) | = N ₂ O emission factors by fuel type | 0.0134 (gas) 0.0048 (diesel) |
| $CH_4 \text{ emissions} = (677,167 \text{ mi} * 0.0333 \text{ g/mi}) + (4,260,611 \text{ mi} * 0.0051 \text{ g/mi}) / 1,000,000 \text{ g/ton} = 0.0443 \text{ tons}$ $N_2O \text{ emissions} = (677,167 \text{ mi} * 0.0134 \text{ g/mi}) + (4,260,611 \text{ mi} * 0.0048 \text{ g/mi}) / 1,000,000 \text{ g/ton} = 0.0044 \text{ tons}$ | | |

TR.2.B Method for In-Boundary Emissions Based on Travel Demand Model and Emission Factor Model Data

Introduction

This accounting method to estimate truck traffic emissions is also based on estimates of truck vehicle-miles of travel within a jurisdiction. In this case, however, truck VMT data by speed are obtained from a statewide or regional travel demand forecasting model and used in combination with speed-based CO₂, CH₄, and N₂O emission factors from U.S. EPA's MOVES model or California's EMFAC model. This method is preferable to Method TR.2.A if:

- The travel demand model maintained by the region's metropolitan planning organization (MPO) or state department of transportation has reliable estimates of truck traffic; and
- The analyst can obtain and work with the required travel data, including truck traffic volumes and speeds by link.
- The analyst can develop speed-based emission factors for trucks using MOVES or EMFAC, or has access to such factors already developed.

A few regions maintain travel models that have an explicit freight component (i.e., truck traffic is predicted based on factors such as local employment by industry). Most, however, simply factor truck traffic as a percentage of total VMT, which is calibrated against observed traffic counts. In this case, it is still possible that the model provides a more accurate breakdown of truck VMT by jurisdiction than simply factoring county or statewide truck VMT based on employment as described in Method TR.2.A. It also allows the use of speed-based emission factors to improve the accuracy of emissions estimates and account for travel on different types of roadways and under different levels of congestion. Finally, it allows for a consistent source of traffic forecasts for future-year inventory development.

Data Needs

The data needs for this method include:

- Travel demand model outputs - Total VMT by network link (calculated from link length * traffic volume), speed, and roadway type by network link; or total VMT by roadway type and speed class (e.g., 5 mph increments).
- Heavy-duty VMT fractions by roadway type (freeway, arterial, local) unless the model includes a truck trip model. VMT fractions will need to be developed for all source types for which emission factors are produced (see Table TR.2.1). The split of heavy-duty vs. light-duty VMT is likely to be obtained from local data, but further splits (single-unit vs. combo, short-haul vs. long-haul) may need to be obtained from emissions model defaults or other sources.
- CO₂, CH₄, and N₂O (or CO₂e) emission factors for the truck source types or vehicle types shown in Table TR.2.1 (if using MOVES). Users in California will use the EMFAC model instead of MOVES.
- If travel demand model data are available but emission factors are not, the travel demand model outputs of VMT by truck type can be used in conjunction with average per-mile fuel economy as discussed under Method TR.2.A.

Table TR.2.B.1 Truck Source Types in MOVES^a

| MOVES Source Type ID | Source Type Name |
|-----------------------------|---|
| 32 | Light Commercial Truck (e.g., panel trucks, walk-in vans) |
| 52 | Single Unit Short-haul Truck (e.g., delivery “box” trucks) |
| 53 | Single Unit Long-haul Truck |
| 61 | Combination Short-haul Truck |
| 62 | Combination Long-haul Truck (e.g., tractor-trailers, tankers) |

^a“Short-haul” is defined as trips of 200 miles or less, and long-haul as trips over 200 miles.

Calculation Method

The specific calculation steps will vary depending upon the format of the travel demand model outputs available to the user and the method for applying the emission factor model. The user is referred to the below U.S. EPA reference, or the most current version of this guidance, for use of the MOVES model in this type of analysis:

- U.S. EPA (2012). *Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption: Public Draft*. EPA-420-D-12-001.

TR.2.C Method for Trip-End Based Emissions

This method to calculate truck traffic emissions uses similar data sources as Method TR.2.B, but accounts for emissions associated with truck trip-ends within the jurisdiction, rather than truck VMT. This method has the advantage that it more directly accounts for transportation activity generated within the jurisdiction. It also is consistent with a similar method to assigning passenger travel to jurisdictions. The VMT-based method is likely to capture a large amount of through traffic, especially on Interstate highways that traverse the jurisdiction. This method can only be used if the analyst has access to travel demand model data from the MPO or state DOT.

This method is suited for areas where the travel demand model includes an explicit freight component (i.e., truck traffic is predicted based on factors such as local employment by industry). Most regions do not have such a model and instead simply factor truck traffic as a percentage of total VMT, which is calibrated against observed traffic counts. In this case, truck trip-ends are not predicted and there is no way to assign trip-ends to individual jurisdictions (unless a trip generation model is developed).

Because of the very limited cases in which this method may be applicable, given the current evolution of data and models, it is not described further here. Analysts interested in developing this method may refer to the description of the trip-end method to assigning passenger emissions and develop an method consistent with that method.

TR.3 Emissions from Freight Rail

Overview

This source includes emissions associated with freight rail, including line-haul locomotives used for short and long-distance movements, as well as switching locomotives in rail yards.

Rail freight movement and associated emissions are largely beyond the direct control of a local government or a community, as this movement tends to be part of a long-distance supply chain driven by regional and national economic activity. Rail trackage is typically maintained and operated by private corporations or, in some cases, by states. Locomotive emission standards are set at the Federal level.

A community may, however, be able to influence rail use by improving infrastructure for access to intermodal terminals or through infrastructure or land use strategies to provide direct rail access to businesses. These strategies will not reduce rail emissions in the community (in fact, they may increase them) but may have the benefit of reducing total GHG emissions from freight transport, if movement of freight can be shifted from less-efficient truck to more-efficient rail modes. If a rail switching yard is located within the community, the community may also be able to work with the yard operator to reduce GHG emissions from locomotives (e.g., by introducing idle reduction technology or operational practices, or by acquiring more efficient genset or hybrid locomotives). Rail yard operations may also be of local interest for air quality reasons.

Note: It is strongly recommended that communities within a state that are developing GHG inventories work together to obtain and process the required data. There will be many economies of scale in processing data for multiple jurisdictions as the data within a state will be obtained from the same sources – namely, the state department of transportation, (DOT), private rail operators, and/or commercial data providers.

Prescribed sources/activities:

- CO₂, CH₄, and N₂O from line-haul locomotives operating on trackage within the community.
- CO₂, CH₄, and N₂O from switching locomotives operating in rail yards within the community.

Uncertainties

There are a variety of uncertainties associated with estimating GHG emissions from rail freight movement within a community. These include:

- The tonnage and ton-miles of goods moved within the community may not be known with certainty.
- Fuel consumption and emission factors per ton-mile will depend upon the type of cargo moved (e.g., intermodal containers, tractor-on-flatcar, carload shipments of bulk commodities) which will affect aerodynamics, the type and age of locomotives used, operating conditions (e.g., speeds), topography, and other factors that affect load profiles.
- Emissions from yard locomotives will also depend upon the locomotive technology and operating profiles.

Data Needs

Below are the data inputs you will need to collect in order to estimate the GHG emitted by rail freight movement operating within the community:

- Annual ton-miles of goods moved by rail within the county must be estimated. There are multiple possible ways of deriving this information:
 - If a statewide rail study has been conducted, statewide tonnage and/or ton-miles may have been estimated for this study. They probably are not reported at a community level. However, tonnage may be reported by rail line or segment. In this case, it can be multiplied by the mileage of the rail line within the municipality to obtain ton-miles.
 - It may be possible to obtain rough estimates of annual tons moved by rail line from operators of rail service using tracks within the municipality. Again, this may be converted to ton-miles based on the mileage of the rail line within the municipality.
 - Data on rail flows can also be obtained from the Surface Transportation Board's full Carload Waybill Sample, which contains a stratified sampling of carload and rail intermodal traffic moving in the United States. Obtaining this data, however, typically requires the cooperation of the State Department of Transportation (DOT) or another public agency. It also must be assigned to a rail network (such as the national network derived from the Oak Ridge National Laboratory Center for Transportation Analysis) to obtain ton-miles by county. This procedure is only recommended to be applied by experienced analysts.
- Fuel consumption and/or CO₂ emission rates per ton-mile must be estimated. The Annual Energy Outlook provides national average fuel consumption for all rail freight moved. At 3.3 ton-miles per thousand BTU (AEO 2010 value) and 138,500 BTU per gallon or 73.15 kg CO₂ per MMBTU for diesel fuel, this equates to 457 ton-miles per gallon or 22.17 tons CO₂ per million ton-miles.
- Alternatively, fuel consumption and volume of cargo handled for Class 1 carriers (i.e., major national carriers) may be obtained from the Federal Railroad Administration (FRA) R-1 data, for Class 1 carriers operating within the state. (Class 2 and 3 carriers – smaller and local carriers – are not required to report similar data.) These can be converted to emission rates using CO₂ conversion factors for diesel fuel.
- For yard operations, a census of yard locomotives must be conducted by contacting rail yard operator(s) within the municipality. The number of switching locomotives and annual fuel consumption should be determined. If annual fuel consumption is not available, it may be estimated based on annual hours of operation (4,450 hours/year) and fuel consumption (about 13.6 gallons per hour for the pre-2008 fleet).⁶ Fuel consumption rates should take into consideration the technology of the locomotive. A 2008 rulemaking by U.S. EPA required that all newly manufactured and nearly all remanufactured locomotives be equipped with idle reduction

⁶ U.S. EPA (2008). *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotives and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder*. EPA 420-R-08-001a. Hours of operation per locomotive from Table 3-70. Gallons per hour calculated from total gallons of fuel and hours per locomotive (Table 3-70) and total locomotives (p. 3-79) for large switch operators.

technology that will automatically shut locomotives down if they are left idling unnecessarily.⁷ An idling locomotive consumes between 3 and 6 gallons of fuel per hour.⁸

Calculation Method

The method presented consists of the following steps:

1. Multiply annual of tonnage of goods moved by rail through the municipality by the average distance traveled through the municipality in miles, to obtain ton-miles of goods moved. For example, if the municipality is traversed by one rail line 10 miles in length, and all goods are moving through the municipality without stopping, the tonnage of goods would be multiplied by 10. If the municipality is traversed by more than one rail line, the length of each line should be multiplied by the tonnage moved on that line, and the results summed.
2. Multiply ton-miles by fuel consumption rates (gallons per ton-mile) for line-haul locomotives to get total gallons of fuel consumed. Fuel will typically be no. 2 diesel.
3. For yard locomotives, multiply the total number of locomotives by hours of operation per locomotive by fuel consumption rate (gallons/hour) to obtain total fuel consumption (unless fuel consumption can be obtained directly from the yard operator).
4. Multiply fuel consumption for both line-haul and yard locomotives by the carbon content of fuel (10.15 kg CO₂/gallon of diesel) to obtain annual CO₂ emissions.
5. Obtain locomotive emission factors for CH₄ and N₂O (g/gallon) from a published source such as TCR-GRP Table 13.6, or a model such as EPA's NONROAD model.
10. Multiply CH₄ and N₂O emission factors by gallons of fuel consumed (for line-haul plus yard operations).

| Equation TR.3.1. Fuel Consumed by Freight Rail: Line-Haul | | |
|---|--|----------------|
| <i>Fuel consumed = Tons moved * Length of track * (1 / Fuel efficiency)</i> | | |
| Description | Value | |
| Fuel consumed | Total fuel consumed in municipality by line-haul locomotives | Result |
| Tons moved | Annual tons of goods moved by rail on rail lines traversing the municipality | User input |
| Distance traveled | Average distance traveled by goods moving through county by rail | User input |
| Fuel efficiency | Fuel efficiency | 457 ton-mi/gal |
| Source: Calculated from Annual Energy Outlook 2011 | | |

⁷ "Final Rule: Control of Emissions of Air Pollution from Locomotives and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder." Federal Register 73:126, pp. 37096 - 37144.

⁸ Hotstart, "Fuel Consumption Calculator," <http://www.hotstart.com/home/products/locomotive-products/idle-reduction-solutions-2/fuel-consumption-calculator/>. Accessed April 10, 2012.

| Equation TR.3.2. Fuel Consumed by Freight Rail: Switchyard | | |
|---|--|---------------------------|
| <i>Fuel consumed = Number of locomotives * Hours of operation * Fuel consumption rate</i> | | |
| Description | | Value |
| Fuel consumed | Total fuel consumed in municipality by switchyard locomotives | Result |
| Number of locomotives | Total number of switchyard locomotives operating within jurisdiction | User input |
| Hours of operation | Average hours of operation per locomotive per year | User input or 4,450 |
| Fuel consumption rate | Fuel consumed per hour by the average switchyard locomotive | User input or 13.6 gal/hr |
| Source: U.S. EPA (2008). <i>Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotives and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder</i> . EPA 420-R-08-001a. | | |

| Equation TR.3.3. CO₂ Emissions from Freight Rail | | |
|--|---|--------------------------------------|
| <i>CO₂ emissions = Fuel carbon content * Total fuel consumed / 1000 kg/ton</i> | | |
| Description | | Value |
| CO ₂ | Carbon dioxide emissions from rail freight locomotives (line-haul), in tons | Result |
| Fuel carbon content | Carbon content of diesel or other railroad fuel | 10.15 kg CO ₂ /gal diesel |
| Total fuel consumed | Fuel consumed by freight rail: line-haul (from Eq. X.1) + fuel consumed by freight rail: switchyard (Eq. X.2) | User input |
| Source: The Climate Registry (TCR) General Reporting Protocol (GRP) v1.1 (2008), Table 13.1 | | |

Equation TR.3.4. CH₄ and N₂O Emissions from Freight Rail

$$(CH_4, N_2O) \text{ emissions} = \text{Total fuel consumed} * (CH_4, N_2O) \text{ emission factor} / 1,000,000 \text{ g/ton}$$

| Description | Value | |
|--|---|--|
| (CH ₄ , N ₂ O) emissions | Total CH ₄ or N ₂ O emissions from freight rail locomotives operating in jurisdiction | Result |
| Total fuel consumed | Fuel consumed by freight rail: line-haul (from Eq. X.1) + fuel consumed by freight rail: switchyard (Eq. X.2) | User input |
| (CH ₄ , N ₂ O) emission factor | Locomotive emission factors for CH ₄ and N ₂ O | User input or N ₂ O - 0.26 g/gal CH ₄ - 0.80 g/gal |
| Source: The Climate Registry (TCR) General Reporting Protocol (GRP) v1.1 (2008), Table 13.6 | | |

Boxes TR.3.1 through TR.3.4 below give examples of how to calculate emissions from freight rail using Equations TR.3.1 through TR.3.4

Box TR.3.1. Fuel Consumed by Freight Rail: Line-Haul

Sample calculations for New Haven County, CT, based on data from Connecticut Freight Air Quality Study (2012)

| Description | Value | |
|---|--|----------------|
| Tons moved | Annual tons of goods moved by rail on rail lines traversing the municipality | 1,510,000 tons |
| Distance traveled | Average distance traveled by goods moving through county by rail | 22 mi |
| Fuel efficiency | Fuel efficiency | 457 ton-mi/gal |
| <i>Fuel consumed = 1,510,000 tons * 22 mi * (1 / 457 ton-mi/gal) = 72,700 gal</i> | | |

Box TR.3.2. Fuel Consumed by Freight Rail: Switchyard

*Fuel consumed = Number of locomotives * Hours of operation * Fuel consumption rate*

| Description | | Value |
|-----------------------|--|-------------|
| Number of locomotives | Total number of switchyard locomotives operating within jurisdiction | 3 |
| Hours of operation | Average hours of operation per locomotive per year | 4,450 |
| Fuel consumption rate | Fuel consumed per hour by the average switchyard locomotive | 13.6 gal/hr |

*Fuel consumed = 3 * 4,450 hrs * 3.6 gal/hr = 181,600 gal*

Box TR.3.3. CO₂ Emissions from Freight Rail

*CO₂ emissions = Fuel carbon content * Total fuel consumed / 1000 kg/ton*

| Description | | Value |
|---------------------|---|--------------------------------------|
| Fuel carbon content | Carbon content of diesel or other railroad fuel | 10.15 kg CO ₂ /gal diesel |
| Total fuel consumed | Fuel consumed by freight rail: line-haul (from Eq. X.1) + fuel consumed by freight rail: switchyard (Eq. X.2) | User input |

Total fuel consumed = 72,700 gal + 181,600 gal = 254,300 gal

*CO₂ emissions = 10.15 kg/gal * 254,300 gal / 1000 kg/ton = 2,580 tons*

Box TR.3.4. CH₄ and N₂O Emissions from Freight Rail

*(CH₄, N₂O) emissions = Total fuel consumed * (CH₄, N₂O) emission factor / 1,000,000 g/ton*

| Description | | Value |
|--|---|--|
| Total fuel consumed | Fuel consumed by freight rail: line-haul (from Eq. X.1) + fuel consumed by freight rail: switchyard (Eq. X.2) | User input |
| (CH ₄ , N ₂ O) emission factor | Locomotive emission factors for CH ₄ and N ₂ O | User input or N ₂ O - 0.26 g/gal CH ₄ - 0.80 g/gal |

*CH₄ emissions = 254,300 gal * 0.26 g/gal / 1,000,000 g/ton = 0.066 tons*

*N₂O emissions = 254,300 gal * 0.80 g/gal / 1,000,000 g/ton = 0.203 tons*

TR.4 Emissions from Transit

Emissions from the revenue service operation of transit (aka “public transportation” or “mass transit”) vehicles, including motor buses, heavy, light and commuter rail trains, ferries, vanpools and, demand response vehicles, constitute a small portion of U.S. GHG emissions from transportation. All bus and rail-related emissions (some of which are not transit-based) totaled less than 4% of U.S. transportation emissions in 2010.⁹

Transit vehicle GHG emissions consist of direct emissions from the combustion of petroleum-based fuel by internal combustion engine transit vehicles and indirect emissions from transit vehicles using electric traction power. This includes emissions from combustion of liquid fuels, like gasoline, diesel, and liquefied gasses, compressed fuels such as natural gas, and the anthropogenic share of emissions from biofuel blends. The guidance in this section can be used to estimate the total CO₂, N₂O, and CH₄ emissions from transportation fuels and electric traction power that can be attributed to a local government. The guidance does not include methods to estimate direct fugitive fluorocarbon emissions from vehicle air conditioners. For guidance with this emission source, consult Section 7.4 of the Local Government Operations Protocol.

Local governments possess a range of authority over GHG emissions from transit vehicles, depending on whether the local government operates the transit service. Local governments with operational control of transit service have the highest and most direct level of authority over transit emissions due to their ability to set service levels and operational practice. In essence, the local government is the “transit agency” for the purposes of this guidance in this case.

For local governments that do not have operational control over transit service, their authority over GHG emissions is lower and indirect, but exists to the extent that a local government is able to influence transit service levels in its jurisdiction through more or less transit-supportive land use policies and infrastructure investments.

Many communities are served by regional transit agencies. The attribution method in this guidance recognizes that most local governments do not possess operational control over transit service in their jurisdiction. In contrast with private passenger vehicles, local governments without operational control of transit service do not possess the authority to influence GHG emissions from transit vehicle trips both inside and outside of a community’s geographic boundaries. As such, this method recommends attribution based solely on transit service within geographic boundaries. In doing so, it draws upon the American Public Transportation Association’s (APTA) *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit*¹⁰ that provides guidance to transit agencies for calculating their emissions from operations and in turn draws upon The Climate Registry’s *General Reporting Protocol*.

Note: It is strongly recommended that communities within a transit service district that are developing GHG inventories work together to obtain and process the required data. There will be many economies of scale in processing data for multiple jurisdictions as the data within a transit service district will be

⁹ U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. 2-22.

¹⁰ http://www.aptastandards.com/portals/0/suds/sudspublished/apta_climate_change_final_new.pdf

obtained from the same source. A supportive contact at the transit agency serving the district would be very helpful in completing the data gathering and analysis exercise.

Uncertainties

Local government accounting for greenhouse gas emissions from transit vehicles based on the level of transit service provided in that jurisdiction is a simple, reproducible, and relatively accurate means of accounting for the relatively small proportion of transportation emissions coming from transit vehicles, over which most local jurisdictions do not have operational control. However, this attribution method does introduce uncertainty with regard to the proportion of transit service attributed to a jurisdiction due to system design and operation, such as the location of trunk lines that combine multiple feeder lines, the location of transit centers, Park & Ride lots and other access or transfer points that might be serving trips originating outside of the jurisdiction.

TR.4.A Carbon Dioxide Emissions from Mobile Combustion

This category includes propulsion emissions from transit vehicles fueled by diesel, natural gas and biofuels, but not electric traction where the electricity is generated off-site.¹¹ Carbon dioxide is emitted from the tailpipes of motor buses, diesel trains, ferries, vanpools, and demand response vehicles. The U.S. National Inventory includes these sources.

This method applies to all transit service using mobile combustion as a power source, including vehicles directly operated by a transit agency and vehicles operated by contractors. If a transit agency serving your community also serves other communities, you will need to apply methods TR.4.D, TR.4.E, and/or TR.4.F after completing this method.

Data Needs

Below are the data inputs you will need to collect in order to estimate the **Carbon Dioxide** Emissions from **Mobile Combustion in Transit**:

| | |
|-----------------|--|
| Preferred Data: | Actual fuel use data by fuel type is the preferred, and simplest, data input. For most transit agencies, this data is available from National Transit Database Form R-30. ¹² |
| Alternate Data: | If actual fuel use data are not available, fuel use can be estimated using vehicle miles traveled and vehicle fuel economy. For most transit agencies, annual mileage by mode is available from National Transit Database Form S-10. |

¹¹ 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. For guidance on how to measure lifecycle emissions from fuel extraction, refining and transportation, see Method TR.9.

¹² Form R-30 is required for NTD reporters serving urbanized areas and directly operating their services. Agencies serving non-urbanized areas will need to refer to fuel purchase records or estimate fuel consumption through mileage and fuel economy. 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, 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.

The method presented consists of the following 2-3 steps:

Step 0: If actual fuel use data are not available for a given mode, estimate fuel use using equation TR.4.A.1. Vehicle miles traveled can be obtained from the National Transit Database, transit agencies, or their contractors. Fuel economy estimates can be obtained from transit agencies or their contractors. Then skip to Step 2.

Step 1: Obtain actual fuel use data for each transit mode and fuel type from the National Transit Database, transit agencies, or their contractors. If actual fuel use data are not available, see Step 0.

Step 2: Plug into Equation TR.4.A.2.

| Equation TR.4.A.1. Fuel Use in Transit | | |
|--|--|------------|
| <i>Annual Fuel Use = vehicle miles traveled by vehicle type₁ / average fuel economy by vehicle type₁ + vehicle miles traveled by vehicle type₂ / average fuel economy by vehicle type₂ + ...</i> | | |
| Description | | Value |
| Vehicle miles traveled by vehicle type | Total miles traveled annually by vehicle type (broken out by fuel type and vehicle size, as necessary) | User input |
| Average fuel economy by vehicle type | Average fuel economy by vehicle type (broken out by fuel type and vehicle size, as necessary) | User input |

Box TR.4.A.1 below gives an example of how to calculate the fuel used for mobile combustion in transit vehicles

| Box TR.4.A.1 Example Calculation of Fuel Use in Transit | | |
|--|--------------------------------|------------|
| A transit agency operates two vehicle types: a 45 foot CNG bus and a 30 ft. diesel bus. The CNG buses annually travel a total of 2,000,000 miles and have an average fuel economy of 0.026 miles per cubic foot of CNG. The diesel buses travel a total 1,000,000 miles annually and have an average fuel economy of 5 miles per gallon. | | |
| Description | | Value |
| Vehicle miles traveled by CNG buses | 2,000,000 miles | User input |
| Average fuel economy of CNG buses | 0.026 miles per cubic foot CNG | User input |
| Vehicle miles traveled by diesel buses | 1,000,000 miles | User input |
| Average fuel economy of diesel buses | 5 miles per diesel gallon | User input |
| Sample Calculation: $\text{Annual Fuel Use} = 2,000,000 \text{ miles} / 0.026 \text{ miles per cubic foot CNG} + 1,000,000 / 5 \text{ miles per diesel gallon}$ $= 76,923,077 \text{ cubic feet CNG} + 200,000 \text{ diesel gallons}$ | | |

| Equation TR.4.A.2. Carbon Dioxide Emissions from Mobile Combustion | | |
|---|--|---|
| $\text{Annual Carbon Dioxide emissions} = \text{Volume Used of Fuel}_1 \times \text{Carbon Content of Fuel}_1 + \text{Volume Used of Fuel}_2 + \text{Carbon Content of Fuel}_2 + \dots$ | | |
| Description | | Value |
| Volume Used of Fuel | =Annual gallons (or other unit) of fuel combusted in vehicles | User input |
| Carbon Content of Fuel | =kg CO ₂ per gallon (or other unit) of fuel combusted | Given value (see Chapter 13 of The Climate Registry's General Reporting Protocol) |
| Source: (APTA) <i>Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit</i> See: http://www.aptastandards.com/portals/0/suds/sudspublished/apta_climate_change_final_new.pdf | | |

TR.4.B Methane and Nitrous Oxide Emissions from Mobile Combustion

This category includes propulsion emissions from vehicles fueled by diesel, natural gas and biofuels, but not electric traction where the electricity is generated off-site.¹³ Methane and Nitrous Oxide are emitted from the tailpipes of motor buses, diesel trains, ferries, vanpools, and demand response vehicles. The U.S. National Inventory includes these sources.

This method applies to all transit service using mobile combustion as a power source, including vehicles directly operated by a transit agency and vehicles operated by contractors. If a transit agency serving your community also serves other communities, you will need to apply methods TR.4.D, TR.4.E, and/or TR.4.F after completing this method. Note that N₂O and CH₄ emission factors must be included for all mobile sources. For diesel vehicles, these will be negligible, but for compressed natural gas vehicles, CH₄ emissions may be significant, due to incomplete combustion.

Data Needs

Below are the data inputs you will need to collect in order to estimate the stationary **Methane and Nitrous Oxide** Emissions from **Mobile Combustion in Transit**:

| | |
|-----------------|---|
| Preferred Data: | Miles traveled by vehicle type is the preferred data input for all modes, except locomotives (for which fuel use is the preferred data input). For most transit agencies, annual mileage by mode is available from National Transit Database Form S-10. |
| Alternate Data: | Actual fuel use data by vehicle type can also be used. For locomotives, this is the preferred data input. For most transit agencies, this data is available from National Transit Database Form R-30. ¹⁴ |

The method presented consists of the following 2 steps:

- Step 1:** Obtain vehicle miles traveled data by vehicle type for each mode from the National Transit Database, transit agencies, or their contractors. Calculate methane emissions and nitrous oxide emissions using Equation TR.4.B.1.
- Step 2:** For locomotives and for any transit modes for which VMT data are not available, obtain actual fuel use data for each transit mode and fuel type from the National Transit Database, transit agencies, or their contractors. Calculate methane and nitrous oxide emissions using Equation TR.4.B.2.

¹³ 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. For guidance on how to measure lifecycle emissions from fuel extraction, refining and transportation, see Method TR.9.

¹⁴ Form R-30 is required for NTD reporters serving urbanized areas and directly operating their services. Agencies serving non-urbanized areas will need to refer to fuel purchase records or estimate fuel consumption through mileage and fuel economy. 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, 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.

Equation TR.4.B.1. Methane and Nitrous Oxide Emissions from Mobile Combustion Calculated from VMT data

$$\text{Annual CH}_4 \text{ or N}_2\text{O emissions} = \text{VMT by Vehicle Type}_1 \times \text{Emission Factor for Vehicle Type}_1 + \text{VMT by Vehicle Type}_2 \times \text{Emission Factor for Vehicle Type}_2 + \dots$$

| Description | | Value |
|---------------------------------|---|---|
| VMT by Vehicle Type | =Vehicle miles traveled by Vehicle Type | User input |
| Emission Factor by Vehicle Type | =grams CH ₄ or N ₂ O per mile | Given value (see Chapter 13 of The Climate Registry's General Reporting Protocol) |

Source: (APTA) *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit* See: http://www.aptastandards.com/portals/0/suds/sudspublished/apta_climate_change_final_new.pdf

Equation TR.4.B.2 Methane or Nitrous Oxide Emissions from Mobile Combustion Calculated from fuel data

$$\text{Annual CH}_4 \text{ or N}_2\text{O emissions} = \text{Volume Used of Fuel}_1 \times \text{Emission Factor for Fuel}_1 + \text{Volume Used of Fuel}_2 \times \text{Emission Factor for Fuel}_2 + \dots$$

| Description | | Value |
|-------------------------|---|---|
| Volume Used of Fuel | =Annual gallons (or other unit) of fuel combusted in vehicles | User input |
| Emission Factor of Fuel | =grams CH ₄ or N ₂ O per gallon (or other unit) of fuel combusted | Given value (see Chapter 13 of The Climate Registry's General Reporting Protocol) |

Source: (APTA) *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit* See: http://www.aptastandards.com/portals/0/suds/sudspublished/apta_climate_change_final_new.pdf

TR.4.C Carbon Dioxide, Methane, and Nitrous Oxide Emissions from Traction Power

This category includes emissions from revenue vehicles propelled by electric traction, such as rail and trolleybus, where the electricity is generated off-site. This method applies to all transit revenue service using electric traction as a power source, including vehicles directly operated by a transit agency and vehicles operated by contractors. The method accounts for the end use by transit agencies and does not account for any transmission and distribution (T&D) losses, which are better accounted for in the electric generation sector. If a transit agency serving your community also serves other communities, you will need to apply methods TR.4.D, TR.4.E, and/or TR.4.F after completing this method.

Data Needs

Below are the data inputs you will need to collect in order to estimate the **Carbon Dioxide, Methane, and Nitrous Oxide Emissions from Traction Power in Transit:**

| | |
|-----------------|--|
| Preferred Data: | Actual electricity used for traction power is the preferred, and simplest, data input. For most transit agencies, this data is available from National Transit Database Form R-30. |
|-----------------|--|

Calculation method

Electricity use must be quantified for each National Transit Database mode (e.g., Heavy Rail, Light Rail, Trolleybus). Electricity use for traction is reported by mode on National Transit Database Form R-30.

Emission factors for each of the three pollutants are then applied to electricity used for traction power for all modes. If the source of power is the same for all modes, *a single emission factor may be used*. If the source of power varies across modes, then source specific emission factors should be used.

If the power used for electric traction is purchased directly from a specific source, generator-specific emission factors may be used. If this is not the case, the eGRID region-specific emission factors should be used.

Note that “green power” purchases are not assessed differently, unless the power is purchased from a specific generator. For example:

- An agency installs photovoltaic panels on its property and consumes this energy itself. An emission factor of zero is used, even if contractual arrangements mean the power is actually resold to the agency from a third-party supplier.
- An agency enters into a contract with a supplier to obtain energy from a specific hydroelectric, natural gas, or wind plant. The generator-specific emission factor is used.
- An agency purchases renewable energy through a utility’s “green power” program, or purchases renewable energy credits. No credit is given for the purchases, as this renewable energy is already reflected in the regional emission factor.

Equation TR.4.C.1 Carbon Dioxide, Methane and Nitrous Oxide Emissions from Traction
Annual Carbon Dioxide, Methane and Nitrous Oxide emissions = Volume of Electricity Used for Mode₁ x Emission Factor for Electricity Used for Mode₁ for Carbon Dioxide, Methane and Nitrous Oxide + Volume Used of Electricity Used for Mode₂ x Emission Factor for Electricity Use for Mode₂ for Carbon Dioxide, Methane and Nitrous Oxide + ...

| <u>Description</u> | | <u>Value</u> |
|--------------------------------------|--|---|
| Volume of Electricity Used | = Annual kWh (or other unit) of electricity used for traction | User input |
| Emission Factor for Electricity Used | = grams CO ₂ , CH ₄ , and N ₂ O per kWh (or other unit) of electricity used | From eGRID, utility, or specific generator. |

Source: (APTA) *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit* See: http://www.aptastandards.com/portals/0/suds/sudspublished/apta_climate_change_final_new.pdf

Attribution of Transit Emissions¹⁵

In many metropolitan areas, emissions for the regional transit system will be calculated by the regional transit agency using the established APTA methodology. In these cases, the main task for local jurisdictions to include transit emissions in their inventories will be to identify for which portion of the regional system emissions that their jurisdiction is responsible. This section details a methodology to accomplish this task. The section is divided into three parts: attribution of fixed route transit emissions (excluding ferries) attribution of ferry emissions, and attribution of variable route transit emissions.

For any of these three methods, you should first obtain the total transit system emissions from an existing inventory conducted by the transit agency, or calculate those emissions using methods TR.4.A through TR.4.C.

TR.4.D Attribution of Fixed Route Transit (excluding ferries)

The lion's share of emissions from public transit in most jurisdictions will fall under this category. The methodology outlined here allocates regional transit emissions according to each jurisdiction's share of vehicle revenue miles traveled within the jurisdiction. This method is presented as the most widely applicable. However, you may also be able to attribute emissions based on share of boardings and alightings, or based on a travel demand model. Some communities may find one of these alternate methods more policy relevant.

For the vehicle revenue mile method, the data needed is a geographic data source of the transit agency's routes for each mode as well as the transit vehicle schedule (headways). Emissions from each transit mode (e.g., bus, light rail, and heavy rail) should be allocated separately and then aggregated.

Vehicle revenue miles for each mode and transit agency within a jurisdiction are calculated as follows. First, GIS shapefiles for each transit route are subdivided by jurisdiction and the lengths for each route segment within each jurisdiction are calculated. Then, schedule information is used to weight each route segment by the number of transit vehicles traveling the route daily.¹⁶ Equation TR.4.4.1 is used to calculate vehicle revenue miles:

Equation TR.4.D.1

where: VRM_{ijm} = vehicle revenue miles within jurisdiction i for transit agency j and mode m
 L_{kjm} = length of route segment k for transit agency j and mode m
 V_{kjm} = transit vehicles per day traveling on route segment k for transit agency j and mode m

¹⁵ More details on transit attribution methods can be found in the following paper:

Gallivan, F., E. Sall, E. Hesse, D. Salon, and C. Ganson. 2012. Including regional transit emissions in local GHG inventories: A comparison of methods with examples from Portland, OR and the San Francisco Bay Area, CA. *Forthcoming in Transportation Research Record*.

¹⁶ Many transit agencies are beginning to adopt standard geographic schedule formats such as Google Transit Feed Service (GFTS). These can easily be translated into revenue miles; however, smaller agencies are not likely to have this data.

Once vehicle revenue miles for each mode and transit agency have been calculated, Equation TR.4.D.2 is then used to allocate regional transit emissions from each mode and agency across jurisdictions.

Equation TR.4.D.2

$$E_{im} = \sum_j RE_{jm} * \frac{VRM_{ijm}}{\sum_i VRM_{ijm}}$$

where: E_{im} = transit emissions allocated to jurisdiction i from transit agency j and mode m
 RE_{jm} = regional emissions from transit agency j and mode m
 VRM_{ijm} = vehicle revenue miles within jurisdiction i for transit agency j and mode m

Box TR.4.D.1 provides an example calculation of fixed route transit emissions to a jurisdiction with one transit agency operating within its boundaries and two modes. The magnitudes here do not correspond to an actual scenario, but rather are chosen to be round numbers to illustrate the calculation method.

Emissions from non-revenue (deadhead) miles traveled by transit vehicles within each mode and transit agency should be allocated to jurisdictions in proportion to their share of regional revenue miles.

The final jurisdiction-level public transit emissions inventory for fixed route service, then, is the sum of the emissions from the revenue miles that pass through that jurisdiction and that jurisdiction's share of the emissions from non-revenue miles.

| Box TR.4.D.1 | Example Calculation of Emissions Attribution to a Jurisdiction (City A) | |
|---|---|------------|
| <p>The regional transit agency reports that its <i>bus emissions are 10,000 metric tons and its light rail emissions are 5,000 metric tons of CO₂-equivalent GHG emissions annually.</i> The total <i>regional vehicle revenue miles per day are 1000 for buses and 400 for light rail.</i> Of these, <i>100 bus revenue miles and 25 light rail revenue miles traverse City A each day.</i></p> | | |
| Description | | Value |
| Regional Bus Emissions | <i>10,000 metric tons CO₂-eq.</i> | User input |
| Regional Light Rail Emissions | <i>5,000 metric tons CO₂-eq.</i> | User input |
| Regional Bus Revenue Miles | <i>1000 miles</i> | User input |
| Regional Light Rail Revenue Miles | <i>400 miles</i> | User input |
| City A Bus Revenue Miles | <i>100 miles</i> | User input |
| City A Light Rail Revenue Miles | <i>25 miles</i> | User input |
| <p>Sample Calculation:</p> <p><i>Annual Fixed-Route Bus GHG emissions in City A</i> = $10,000 \text{ mtCO}_2\text{e} * 100/1000$ = $1,000 \text{ mtCO}_2\text{e}$</p> <p><i>Annual Fixed-Route Light Rail GHG emissions in City A</i> = $5,000 \text{ mtCO}_2\text{e} * 25/400$ = $312.5 \text{ mtCO}_2\text{e}$</p> <p><i>Annual Fixed-Route Transit GHG emissions in City A</i> = $1,000+312.5 \text{ mtCO}_2\text{e}$ = $1,312.5 \text{ mtCO}_2\text{e}$</p> | | |

TR.4.E Attribution of Emissions from Ferries

Ferries operate on waterways that are often between rather than within jurisdictions. Since there are usually no intermediate ferry stops, it makes sense to allocate emissions from ferries according to stops and frequency rather than miles of travel “within” each jurisdiction and frequency. This method is simpler than that for over-ground fixed route service because miles need not be divided by jurisdiction. Instead, regional ferry emissions are allocated according to the share of ferry stops that occur in each jurisdiction.

As with over-ground fixed route service, emissions from non-revenue (deadhead) miles traveled by ferries should be allocated to jurisdictions in proportion to their share of stop-based emissions.

TR.4.F Attribution of Emissions from Variable Route Transit (vanpools + demand response)

Data on the location of vehicle revenue miles are often not available for demand response service. In this case, emissions from demand response service should be allocated in proportion to each jurisdiction’s share of emissions from bus service.

If data are available, however, a more accurate method is to allocate demand response service emissions according to vehicle revenue miles traveled within each jurisdiction.

TR.5 Emissions Associated with Inter-City Passenger Rail

This method includes emissions associated with intercity passenger rail, including Amtrak services. Emissions associated with urban rail passenger rail modes, including commuter rail as well as light and heavy rail, are covered under TR.4: Emissions from Transit.

Passenger rail GHG emissions consist of direct emissions from the combustion of diesel fuel by locomotives and/or indirect emissions from locomotives using electric traction power. The guidance in this section can be used to estimate the total CO₂, N₂O, and CH₄ emissions from transportation fuels and electric traction power that can be attributed to a community.

Passenger rail movement and associated emissions are largely beyond the direct control of a community, as intercity passenger rail trips tend to be longer-distance travel and most will be passing through the community, unless it is a major rail passenger hub. The community through which a passenger rail line passes may or may not generate passenger rail trips, depending upon whether there is a station located in or near the community. Communities with stations may, however, be able to influence passenger rail use by improving infrastructure for access to rail stations (e.g., park-and-ride lots, pedestrian and bicycle access, feeder bus service) and by improving comfort and convenience at these stations (e.g., heated waiting areas, services). Community-led land use strategies to create “transit-oriented development” can create a larger market for rail by focusing jobs and housing in walkable or transit-accessible neighborhoods around intercity rail stations.

This method recommends attribution of GHG emissions based solely on passenger rail service within geographic boundaries. An alternative method would be to assign passenger rail emissions to communities in proportion to trip-ends originating within each community. While this method may be preferable from a conceptual standpoint, it is not described here simply because the data will not usually be available to support the method. Also, intercity passenger rail emissions will in nearly every instance be very small compared to other sources of transportation emissions, especially highway vehicles and air travel.

Prescribed sources/activities:

- CO₂, CH₄, and N₂O from passenger rail locomotives operating on trackage within the community.

Uncertainties

The energy intensity of passenger rail services (per train-mile) will vary depending upon the type of train (e.g., conventional vs. high-speed rail), power source (diesel vs. electric), age and technology of locomotives, the number of cars per train, terrain, number of stops, operating speeds, and other factors. Accounting for these factors, however, requires a detailed operating assessment that is likely to be beyond the scope of the available data. In addition, emissions associated with electricity use will vary depending upon the local or regional generating mix.

Data Needs

Below are the data inputs you will need to collect in order to estimate the GHG emitted by passenger rail movement operating within the community:

- the number of intercity passenger trains per day passing through the community. This may be determined by reviewing Amtrak schedules for routes passing through the community;
- the length of track upon which intercity passenger services operate within the community; this may be estimated using tools such as geographic information systems (GIS), Google maps, etc.;
- whether the services operate on diesel or electric power;
- the energy intensity of the service.; this may be expressed in British thermal units (Btu) per train-mile, or per passenger-mile; the Transportation Energy Databook published by Oak Ridge National Laboratory (<http://cta.ornl.gov/data/index.shtml>) provides national statistics for Amtrak from which these factors may be calculated; for example, a total of 36,484,000 train-miles were reported in 2007, and a total of 1.45×10^{13} Btu, for an average of 399,000 Btu per train-mile (TEDB Edition 28, Chapter 9); and
- if a rate per passenger mile is used, the average number of passengers per train also needs to be estimated; this may be appropriate if trains serving the community are particularly high or low capacity compared to national averages.

Calculation Method

The method presented consists of the following steps:

1. Multiply the number of trains per day (in both directions) by track length in the community to obtain train-miles traversing the community each day. If service varies significantly on weekends vs. weekdays, identify the number of trains on weekdays, Saturdays, and Sundays. Convert daily to annual train-miles using appropriate factors. Perform this calculation separately for diesel and electric rail services.
2. Multiply annual train-miles by Btu per train-mile to obtain total annual energy consumption by fuel type (diesel, electric).
3. Divide by appropriate energy conversion factors (Btu per gallon diesel fuel or Btu per kWh electricity) to obtain energy consumption in gallons of diesel fuel or kWh of electricity.
4. Multiply by fuel-specific CO₂, CH₄, and N₂O emission factors for diesel fuel and locomotives, or by regional emission factors for electricity. For electricity, the most current factors can be obtained directly from EPA's eGRID database.

Equation TR.5.1 Energy Consumed by Passenger Rail

$Energy\ consumed\ (gal\ diesel) = Energy\ consumed\ (diesel\ Btu) / 138,500\ Btu/gal$

$Energy\ consumed\ (kWh\ electricity) = Energy\ consumed\ (electricity\ Btu) / 3,412\ Btu/kWh$

$Annual\ energy\ consumed(Btu) = Trains\ per\ year * Length\ of\ track * Btu/train-mile$

$Trains\ per\ year = trains\ per\ weekday * 261 + trains\ per\ Saturday * 52 * trains\ per\ Sunday * 52$

| Description | Value | |
|--|---|---|
| Energy consumed (Btu) | Total energy consumed in municipality by passenger rail locomotives | Result |
| Trains per year | Number of trains traversing community annually | Result |
| Trains per weekday, Saturday, and Sunday | Number of trains traversing community (both directions) by day of week | User input from train schedules |
| Length of track | Length of track traversed by passenger trains with community's boundaries (one-way) | User input |
| Btu/train-mile | Average energy use per train | 399,000 Btu/train-mile or most recent value from ORNL |
| Source: Oak Ridge National Laboratory (ORNL): Transportation Energy Databook | | |

Equation TR.5.2 CO₂, CH₄, and N₂O Emissions from Passenger Rail: Diesel

$(CO_2, CH_4, N_2O)\ emissions = gallons\ diesel * emission\ factor\ (CO_2, CH_4, N_2O)$

| Description | Value | |
|---|--|--|
| (CO ₂ , CH ₄ , N ₂ O) emissions | Annual emissions of CO ₂ (in kg) or CH ₄ or N ₂ O (in g) | Result |
| Gallons diesel | Gallons of diesel fuel consumed annually by passenger rail locomotives within the municipality | Calculated from Eq. TR.5.1 |
| Emission factor (CO ₂) | CO ₂ emissions per gallon diesel fuel | 10.21 kg/gal |
| Emission factor (CH ₄ , N ₂ O) | CH ₄ and N ₂ O emission factors for locomotives | User input or N ₂ O - 0.26 g/gal CH ₄ - 0.80 g/gal |
| Source: The Climate Registry (TCR) General Reporting Protocol (GRP) v1.1 (2008), Tables 13.1 and 13.6 | | |

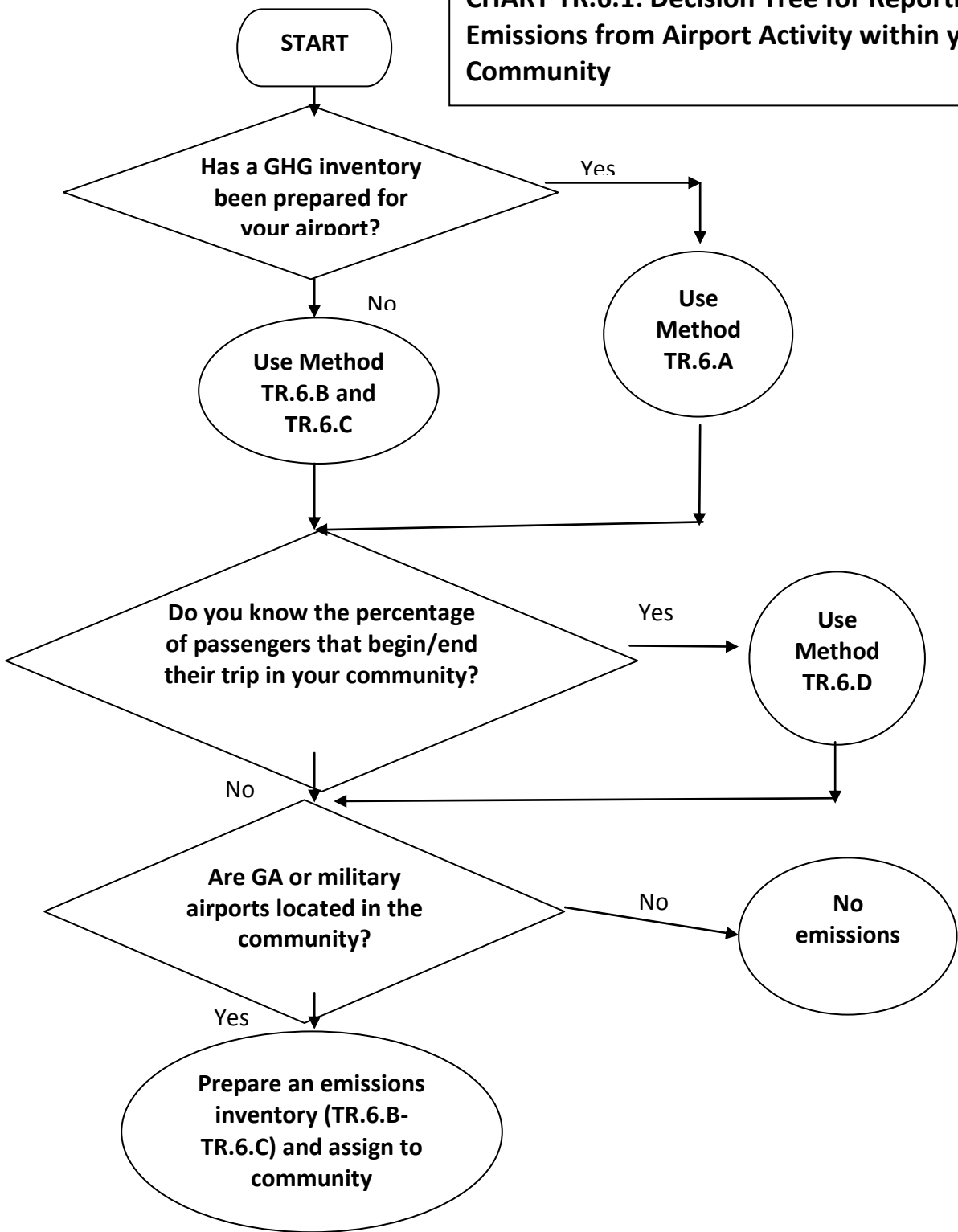
Equation TR.5.3 CO₂, CH₄, and N₂O Emissions from Passenger Rail: Electric

$$(CO_2, CH_4, N_2O) \text{ emissions} = kWh \text{ electricity} * \text{emission factor } (CO_2, CH_4, N_2O) \text{ (lb/MWh)} * 454 \text{ g/lb} / 1,000 \text{ kWh/MWh}$$

| Description | | Value |
|--|--|--|
| (CO ₂ , CH ₄ , N ₂ O) emissions | Annual emissions of CO ₂ (in kg) or CH ₄ or N ₂ O (in g) | Result |
| kWh electricity | kWh of electricity consumed annually (end-use) by passenger rail locomotives within the municipality | Calculated from Eq. TR.5.1 |
| Emission factor (CO ₂) | CO ₂ emissions per kWh for regional power mix | EPA's eGRID database or Chapter 14 of The Climate Registry's General Reporting Protocol (lb/MWh) |
| Emission factor (CH ₄ , N ₂ O) | CH ₄ and N ₂ O emission factors per kWh for regional power mix | EPA's eGRID database or Chapter 14 of The Climate Registry's General Reporting Protocol (lb/MWh) |
| Source: U.S. EPA, eGRID. http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html The Climate Registry (TCR) General Reporting Protocol (GRP) v1.1 (2008) | | |

TR.6 Emissions from Air Travel

CHART TR.6.1: Decision Tree for Reporting Emissions from Airport Activity within your Community



Overview of Emissions Associated with Air Travel

Community-based emissions inventories can account for air travel in several forms:

1. Emissions from Airports located in the Community;
2. The emissions associated with residents of the community using nearby airports, regardless of whether they are located in the community.

This method addresses the GHG emissions associated with air travel activities from the airport as well as the air traveler perspectives. Many communities have multiple airports located within their jurisdictional boundaries. In other locations, residents of the community use airports located in other communities. Airports are facilities that may provide commercial passenger air travel services, as well as smaller reliever and general aviation airports that support business and recreational travel or military bases providing local and national security. These airports may serve broad regions, including multiple cities, counties, and states. This Protocol provides guidance for reflecting the appropriate boundaries for capturing the airport emissions associated with the air traveler. Because it relies in several cases on the creation of an airport inventory, information is provided to prepare that inventory if one is not already available.

The Transportation Research Board's Airport Cooperative Research Program (ACRP)¹⁷ has issued guidance that will assist airport operators with preparing airport specific inventories. The methods in this section are a simplified and streamlined version of that same guidance. A number of the source emissions reflected in the ACRP method are not included here, as they are redundant of other elements of the community inventory.

Uncertainties

Airport operator inventories of total airport-related emissions have shown that direct and indirect emissions are rarely more than 5% of total airport-related emissions. Airport tenant emissions, most notably aircraft emissions, often represent more than 90% of airport-related emissions. Since aircraft typically provide service to residents of a broad region, consideration is often given to allocating these emissions to the community generating demand for use of the airport.

Information is not readily available concerning the origin of cargo within the community that travels on aircraft at an individual airport. Some airports conduct surveys of where passengers begin and end their air travel in the community. These surveys can be used as a surrogate for all airport-related usage.

Information is not available to precisely ascribe an airport's emissions to a specific community. Therefore this section identifies the best way to apportion the air traveler emissions to a specific community based on the amount of travel associated with its residents. Users should recognize that if an airport is located in their community, as much as 5% of the airport's emissions are already captured by methods in the Built Environment sector (see Appendix C – Built Environment Emission Activities and Sources). Because that apportionment relies on the airport emission inventory, guidance is provided on how to develop such an airport GHG inventory.

¹⁷ ACRP Report 11 is available at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf (4-5-2012)

TR.6.A Using Emissions from an Existing Airport Inventory

In 2009 the Transportation Research Board released its Airport Cooperative Research Program (ACRP) Report 11 *Guidebook for Preparing Airport Greenhouse Gas Inventories*.¹⁸ Many airports have prepared their inventories in accordance with ACRP Report 11, which stratifies emissions as Scope 1 (direct), Scope 2 (indirect), and Scope 3 (other indirect). Communities wishing to prepare a GHG inventory for their airport facility are referred to ACRP Report 11 that provides details about the preparation of those inventories. A brief airport GHG inventory methodology is provided in methods TR.6.B through TR.6.C. The methodologies are consistent with the general method reflected in ACRP Report 11 for these airport sources. However, recognizing that communities may not have access to comprehensive airport data, some liberty was taken relative to the ACRP Report 11 methods. If an existing airport inventory is available, the emissions calculated in it should be used in your community inventory. In this case, proceed to TR.6.D to appropriately allocate the emissions to your community.

Airport GHG inventories prepared using ACRP Report 11 capture emissions from:

- airport owned and operated facilities and mobile vehicles (direct emissions),
- purchased electricity (indirect emissions),
- tenant operations/aircraft operations and service vehicles (other indirect emissions), and
- public vehicular access to the airports (other indirect emissions).

The ACRP Report 11 provides guidance in the preparation of these inventories, and also includes a regime that notes the degree of influence that the airport owner may have over sources not owned or controlled by the airport operator. Reflecting that influence, ACRP Report 11 notes a) airport owned or controlled; b) tenant owned and controlled; and c) public owned and controlled. This first category (airport owned or controlled) often captures direct, indirect, and some other indirect emissions. While categories b) and c) capture the remaining other indirect emissions.

Airport inventories prepared using ACRP Report 11 include the following sources:

- Aircraft and Auxiliary Power Units (APU) – most airport operators do not own or control aircraft. As a result, they are identified as other indirect emissions and placed in a category of emissions noted as "tenant";
- Airport Fleet Vehicles: vehicles used by the airport operator to service the airport (direct emissions);
- Aircraft Ground Support Equipment – vehicles that service aircraft (other indirect emissions);
- Stationary source and purchased electrical consumption: Direct and indirect emissions for the airport operator or other indirect emissions for fuel consumption purchased by airport tenants; and

¹⁸ ACRP Report 11 is available at: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf (4-5-2012)

- Ground Access Vehicle (GAV): This travel is associated with employees of the airport and tenants, as well as all other vehicles (passengers, meeters/greeters, cargo, and tenants) that travel to and from the airport.

To provide a perspective about the distribution of emissions among the various source categories, a review of inventories prepared following the ACRP Guidebook was conducted. The results of this review are summarized in Table TR.6.1

Table TR.6.1 Typical Percent of Airport Emissions by Source

| Source | Percent of total airport emissions (range) | | |
|------------------------|--|-----------------------------|-----------------------------|
| | Large Commercial Airport | Small Commercial Airport | General Aviation Airport |
| Aircraft/APU | 73%-93% | 80%-98% | 82%-98% |
| Airport Fleet Vehicles | <0.5%-1% | <0.5% | <0.5% |
| GSE | <1%-2% | <1% | <0.5% |
| Stationary Sources | 1%-13% | <2% | <2% |
| Ground Access Vehicles | 4%-15% | <0.5%-17% | <0.5%-9% |

Based on a sample of 15 airport inventories

As the table above shows, aircraft operations (when including cruise emissions) represent a range of 73% to 98% of an airport's total airport-related emissions. Depending on the source of electrical power, stationary sources can represent the next largest source at 1% to 13% of total airport-related CO₂e emissions. Ground Access Vehicles can represent as high as 17% of an airport's total related CO₂e emissions depending on how far passengers travel and how they travel to/from the airport. Fleet vehicles and GSE typically represent less than 2% of CO₂e emissions.

Because stationary source emissions and ground access vehicles are captured elsewhere in the community inventory, they should not be included in community air travel emissions. Emissions from aircraft/APU, ground support equipment, and airport fleet vehicles should be carried forward to method TR.6.E to attribute these emissions correctly to your community.

TR.6.B Emissions from Aircraft, Including Auxiliary Power Units (APUs)

Data Needs

| | |
|-----------------|--|
| Preferred Data: | ACRP Report 11 Method 3 (Preferred) uses data from the FAA's SAGE model. |
| | At this time, the SAGE model data has not been made available by FAA for individual airport, and thus, ACRP Report 11, Aircraft Methods 1 or 2 can be used by communities until Method 3 is available. |
| Alternate Data: | No alternative method is available |

Note that ACRP Report 11 Aircraft Methods 1 and 2 produce the same total GHG results for aircraft GHG emissions. The difference between the two methods is that Method 2 enables segregation of the

emissions by operating mode of the aircraft [separating cruise emissions from emissions when the aircraft is: 1) on the ground, and 2) between the ground and 3,000 feet above ground.] Such segregation may not be important to the community inventory, but is important to the airport operator. Therefore, this guidance relies on ACRP Report 11 Aircraft Method 1 for ease in preparing community inventories. Note that this method captures GHG emissions from aircraft operation including that of the auxiliary power units (APUs) as it captures all fuel dispensed to the aircraft.

For aircraft emissions, the only non-CO₂ pollutants that are possibly emitted are CH₄ and N₂O. Rather than undertake a complex evaluation of these two pollutants, this methodology assumes that CH₄ and N₂O (after applying a global warming potential factor to the emissions) would represent approximately 0.7% of total CO₂ emissions. Therefore, this methodology multiplies the CO₂ results by 1.007. For a more precise consideration of non-CO₂ pollutants, see ACRP Report 11.

Calculation method

The method consists of the following 3 steps:

Step 1: Obtain the amount of jet fuel in gallons dispensed at the airport.

Step 2: Obtain the amount of aviation gasoline (AvGas) in gallons dispensed at the airport.

Step 3: Plug the data collected in Step 1 and 2 into Equation TR.6.B.1

| Equation TR.6.B.1 CO₂e Emissions from Aircraft | | |
|---|--|----------------------------|
| Annual CO ₂ e emissions = $[[JET \times 9.57] + [AVGAS \times 8.31] \times 0.001 \times 1.007]$ or simplified as $[[JET \times 9.57] + [AVGAS \times 8.31]] \times 0.001007$ | | |
| Where: | | |
| Description | | Value |
| JET | = The amount of Jet fuel sold (dispensed) at the airports. If the fuel is reported in pounds, convert to gallons by dividing the fuel number by 6.84 lbs/gallon. | Value in gallons |
| AVGAS | = The amount of AvGas fuel sold (dispensed) at the airports. If the fuel is reported in pounds, convert to gallons by dividing the AvGas fuel number by 6.00 lbs/gallon. | Value in gallons |
| 9.57 | = The amount of CO ₂ in a gallon of Jet fuel | kg CO ₂ /gallon |
| 8.31 | = The amount of CO ₂ in a gallon of AvGas | kg CO ₂ /gallon |
| 0.001 | = Conversion factor to convert kg to metric tons | MT/kg |
| 1.007 | = factor to account for N ₂ O and CH ₄ | 1.007 |

Box TR.6.B.1 below gives an example of how to calculate aircraft emissions using equation TR.6.B.1.

| Box TR.6.B.1 Example Calculation of CO₂e Emissions from Aircraft | | |
|--|--|----------------------------|
| Airport ABC reported the amount of fuel dispensed/sold to be 170,000,000 gallons of Jet fuel and 16,000 gallons of AvGas during the study year. | | |
| Description | | Value |
| JET | = The amount of Jet fuel dispensed/sold at airport ABC | 170,000,000 |
| AVGAS | = The amount of AvGas dispensed/sold at airport ABC | 16,000 |
| 9.57 | = The amount of CO ₂ in a gallon of Jet fuel | kg CO ₂ /gallon |
| 8.31 | = The amount of CO ₂ in a gallon of AvGas | kg CO ₂ /gallon |
| 0.001 | = Conversion factor to convert kg to metric tons | MT/kg |
| 1.007 | = factor to account for N ₂ O and CH ₄ | 1.007 |
| Sample Calculation: | | |
| $\text{Annual CO}_2\text{e emissions} = [170,000,000 \times 9.57 + 16,000 \times 8.31] \times 0.001 \times 1.007$ $= 1,638,198.5 \text{ mtCO}_2\text{e}$ | | |

TR.6.C Emissions from Airport Fleet Vehicles and Ground Support Equipment

Airport fleet vehicles reflect the ground vehicles owned and operated by the airport for maintenance and operation of the airport. This may include service vehicles, police vehicles, fire fighting vehicles and administrative vehicle use.

Ground support equipment (GSE) refers to the vehicles that service and support aircraft operations and are typically owned and operated by airport tenants (airlines or their contractors). Relative to the airport inventory, GSE are listed as other indirect emissions. Emissions from fleet vehicles and GSE are separated in airport inventories because of the different degree of control airport operators have over each, but for this Protocol are calculated by the same method.

ACRP Report 11 recommends that the evaluation of GSE emissions be based on tenant surveys of fuel use by their GSE and or surveys of the use of GSE. Such information is time consuming and can be costly to collect, but would have the highest accuracy. An alternative method suggested by ACRP Report 11 is the use of the FAA's Emissions Dispersion Modeling System (EDMS)/Aviation Emissions Design Tool (AEDT) to identify default GSE use associated with the aircraft operating at the airport. With this information, emissions factors from EPA's NONROAD model can be used to identify the CO₂ emissions associated with GSE. Because this is also a complex method requiring an understanding of the GSE vehicles and their use, as well as likely fuel deployed on each vehicle, the method below is recommended.

| | |
|-----------------|---|
| Preferred Data: | The amount of fuel consumed by Airport ground vehicles of each fuel type used. Note that electrical vehicle power use is already accounted for in the built environment sector. |
| Alternate Data: | Estimate fleet vehicle emissions as equal to 0.3% of total aircraft emissions. Estimate GSE emissions as equal to 1% of total aircraft emissions. Assume no GSE if airport is a General Aviation airport. |

TR.6.C.1 Recommended Calculation Method

The method consists of the following 3 steps:

Step 1: Obtain the amount of gasoline, diesel, and any other fuels used by airport fleet vehicles.

Step 2 Obtain the amount of gasoline, diesel, and any other fuels used by airport ground support equipment.

Step 3: Plug the data collected in Steps 1 and 2 into Equations TR.6.C.1 and TR.6.C.1.1

| Equation TR.6.C.1 CO₂ Emissions from Airport Fleet and Ground Support Vehicles | | |
|--|---|----------------------------|
| $Annual\ CO_2\ emissions = [GAS \times 8.78] + [DIESEL \times 10.21] + [LPG \times 5.79] + [CNG \times 4.46] \times 0.001 \times 0.007$ | | |
| Where: | | |
| Description | | Value |
| GAS | = The amount of motor gasoline fuel used by fleet vehicles. | User input |
| DIESEL | The amount of diesel fuel used by fleet vehicles. | User input |
| LPG | The amount of liquid propane gas used by fleet vehicles. | User input |
| CNG | The amount of liquid CNG fuel used by fleet vehicles | User input |
| 8.78 | The amount of CO ₂ in a gallon of gasoline | kg CO ₂ /gallon |
| 10.21 | The amount of CO ₂ in a gallon of diesel | kg CO ₂ /gallon |
| 5.79 | The amount of CO ₂ in a gallon of LPG | kg CO ₂ /gallon |
| 4.46 | The amount of CO ₂ in a gallon of LNG | kg CO ₂ /gallon |
| 0.001 | Conversion factor to convert kg to metric tons | mt/kg |
| Source: ACRP Report 11 Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories. See: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf | | |

Box TR.6.C.1 below gives an example of how to calculate the CO₂ emission from airport fleet vehicles using equation TR.6.C.1.

| Box TR.6.C.1 Example Calculation of CO₂ Emissions from airport fleet vehicles | | |
|--|--|----------------------------|
| Airport ABC reported that amount of fuel used by its fleet vehicles as 62,000 gallons of gasoline fuel, 6,000 gallons of Diesel, and 40,000 equivalent gallons of CNG during the study year. | | |
| Description | | Value |
| 62,000 | = The amount of motor gasoline fuel used | Value in gallons |
| 6,000 | The amount of diesel used | Value in gallons |
| 0 | The amount of liquid propane gas used by fleet vehicles. | Value in gallons |
| 40,000 | The amount of liquid CNG fuel used by fleet vehicles | Value in gallons |
| 8.78 | The amount of CO ₂ in a gallon of gasoline | kg CO ₂ /gallon |
| 10.21 | The amount of CO ₂ in a gallon of diesel | kg CO ₂ /gallon |
| 5.79 | The amount of CO ₂ in a gallon of LPG | kg CO ₂ /gallon |
| 4.46 | The amount of CO ₂ in a gallon of LNG | kg CO ₂ /gallon |
| 0.001 | Conversion factor to convert kg to metric tons | mt/kg |
| Sample Calculation: | | |
| $\text{Annual CO}_2 \text{ emissions} = \frac{[[[62,000 \times 8.78] + [6,000 \times 10.21] + [40,000 \times 4.46]] \times 0.001]}{1,000,000} = 784 \text{ mtCO}_2\text{e}$ | | |

| Equation TR.6.C.1.1 CH₄ and N₂O Emissions from Airport Fleet and Ground Support Vehicles | | |
|--|--|--|
| $(\text{CH}_4, \text{N}_2\text{O}) \text{ emissions} = \frac{[[\text{GAS} * \text{EF}(\text{gasoline})] + [\text{DIESEL} * \text{EF}(\text{diesel})] + [\text{LNG} * \text{EF}(\text{LNG})] + [\text{LPG} * \text{EF}(\text{LPG})]]}{1,000,000}$ | | |
| Description | | Value |
| (CH ₄ , N ₂ O) emissions | Annual CH ₄ or N ₂ O emissions in tons | Result |
| GAS | = The amount of motor gasoline fuel used by fleet vehicles. | User input |
| DIESEL | The amount of diesel fuel used by fleet vehicles. | User input |
| LPG | The amount of liquid propane gas used by fleet vehicles. | User input |
| CNG | The amount of liquid CNG fuel used by fleet vehicles | User input |
| EF (fuel) | Emissions factor for CH ₄ or N ₂ O by fuel type (gasoline, diesel, CNG, LNG) | Given value (See Table TR.6.C.1 in Appendix) |
| 1,000,000 | Conversion from grams to tons | 1,000,000 |

TR.6.C.2 Alternative Method for Airport Fleet Vehicles

The method consists of the following 2 steps:

Step 1: Obtain total aircraft-related CO₂e emissions (including cruise emissions).

Step 2: Plug the data collected in Step 1 into Equation TR.6.C.2

| Equation TR.6.C.2 CO₂e Emissions from airport fleet vehicles | | |
|--|--|------------|
| <i>Annual CO₂e emissions = [ACE x 0.003]</i> | | |
| Where: | | |
| Description | | Value |
| ACE | = Emissions from aircraft operations (including cruise) in metric tons CO ₂ e | User input |
| 0.003 | = Estimate of the average emissions from airport fleet vehicles as a fraction of aircraft emissions. | 0.003 |
| Source: Survey of 15 airport inventories | | |

TR.6.C.3 Alternate Method for Airport Tenant Ground Support Vehicles

It is important to note that GSE fuel use can vary substantially from on airport to another. This alternative method assumes that GSE are powered primarily by diesel vehicles, whereas at many airports, airport tenants may have already converted many of these vehicles, where possible, to electric. Thus, this method may produce conservatively high emissions estimates.

The method consists of the following 2 steps:

Step 1: Obtain total aircraft-related CO₂e emissions (including cruise emissions).

Step 2: Plug the data collected in Step 1 into Equation TR.6.C.3

| Equation TR.6.C.3 CO₂e Emissions from GSE | | |
|---|---|------------------------|
| <i>Annual GHG₁ emissions = [ACCO2 x 0.01]</i> | | |
| Where: | | |
| Description | | Value |
| ACCO2 | = CO ₂ e emissions from aircraft operations (including cruise) | Tons CO ₂ e |
| 0.01 | = Estimate of the average emissions from GSE as a percentage of aircraft emissions. | factor |
| Source: Review of 15 airport inventories. | | |

TR.6.D Attribution of Air Travel Emissions to your Community

This section discusses the assignment of the airport emissions to a specific community. This assignment is based on some known or estimated portion of passengers that begin or end their air travel in the community.

Note that communities may use or include A) commercial service airports and B) other airports, such as general aviation airports and military bases. The inventories for non-commercial airports could be obtained from the airports, or calculated for each airport using methods TR.6.B-TR.6.C. If the community boundary includes non-commercial service airports, the emissions associated those airports should be included in the community inventory in their entirety (not allocated), in addition to any allocated emissions associated with commercial service airports.

A number of alternative means¹⁹ of allocating airport emissions to the communities they serve were considered. These include:

- All emissions from the airport are allocated to the community in which it is located. However, because economic activity associated with the airport accrue to more than just the host community, this alternative is not recommended;
- Allocate the emissions from the airport in accordance with the economic benefits of the airport. However, while many airport operators have sponsored the preparation of economic impact studies, not all studies identify the economic contribution to each community.
- Allocate the emissions from the airport in accordance with the users of the airport. Users of the airport represent primarily passengers and cargo. Passenger information was selected as that information is often more readily available.

Data Needs

| | |
|-----------------|--|
| Preferred Data: | Airport passenger surveys that identify the number of passengers that are traveling to/from the community. |
| Alternate Data: | Estimates of the % of passengers that are traveling to/from the community. |

If a passenger survey identifying the number or percentage of passengers who are traveling to or from your community is not available, you can try to estimate the percentage of passengers traveling through the airport who are from your community. Information from taxi and shared ride companies may be

¹⁹ Ramaswami, A., Hillman, T., Janson, B., et al. (2008). A Demand- Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories. *Environ. Sci. Technol.*, 42 (17), 6455-6461.

Hillman, T., & Ramaswami, A. (2010). Greenhouse Gas Emission Footprints and Energy Use Benchmarks for Eight U.S. Cities. *Environ. Sci. Technol.*, 44(6), 1902-1910.

helpful in making this estimation. Examples of surveys can be found in Chavez et al. (2011), and Bay Area Airline Passenger Survey.²⁰

Note that airports may report passengers in several ways. “Total passengers” often refers to the passengers that enplane (board aircraft), deplane (disembark), and origin & destination (begin or end their trip at the airport). It is important that when preparing the inventory that the passengers (either total, enplanements, or O&D) be in the same format. For instance, if information about passengers that begin/end their trip in the community are noted as O&D, then that information should be paired with total O&D passengers. If community passengers are noted as enplanements, then they should be paired with the airport's total enplanements (which are usually about half of total passengers).

Calculation Method

The method consists of the following 4 steps:

Step 1: Collect the total number of passengers that use each airport. Identify the basis of the data (total passengers, enplanements, or O&D).

Step 2: Collect from the airport passenger survey, the number of passengers that are traveling to/from the community. Identify the basis of the data (total passengers, enplanements, or O&D).

Step 3: Collect airport emissions from method TR.6.A or TR.6.B and TR.6.C.

Step 4: Plug the data collected in Steps 1 through 3 into Equation TR.6.D.1.

| Equation TR.6.D.1 Attribution of Emissions from Air Travel | | |
|---|--|----------------------------|
| <i>Annual CO₂e emissions = [CMPAX / TPAX] x AGHG</i> | | |
| Where: | | |
| Description | | Value |
| TPAX | = Total number of passenger origins and destinations at airport | Total passengers |
| CMPAX | = The number of passengers traveling to/from the community that use the airport. Note that if enplanements are used here, then TPAX should be total enplanements | Community based passengers |
| AGHG | The CO ₂ e inventory reflecting only aircraft/APU, GSE, and airport fleet vehicles | Tons CO ₂ e |

²⁰ 1. Chavez, A., Ramaswami, A., Dwarakanath, N., Ranjan, R., & Kumar, E. (2012). Implementing Expanded Geographic-Based Greenhouse Gas Accounting for Delhi, India. Data Availability and Methods. *Journal of Industrial Ecology*. In Press.

2. MTC. (2007). 2006 Airline Passenger Survey: Oakland and San Francisco International Airports. Metropolitan Transportation Commission. JD Franz Research, Inc.

Box TR.6.D.1 below gives an example of how to calculate the CO₂e emission from air travel associated with your community using Equation TR.6.D.1

| Box TR.6.D.1 Example Calculation Attributed CO₂e Emissions from Air Travel | | |
|--|---|---------------------------------------|
| Airport ABC conducted passenger surveys five years ago, showing that 45% of their origin and destination passengers reported that their air travel trip started or ended in XYZtown. The airport currently accommodated 1.25 million total passengers. The GHG inventory for the airport indicated a total airport-related GHG levels of 2,345,000 mt. | | |
| Description | | Value |
| TPAX | = Total number of passengers using the airport | 1,250,000 total passengers |
| CMPAX | = The number of airport passengers traveling to/from XYZtown | 562,500 passengers (45% of the total) |
| A-GHG | = The CO ₂ e inventory reflecting ONLY aircraft/APU, GSE, and airport fleet vehicles | 2,345,000 mtCO ₂ e |
| Sample Calculation: | | |
| $\text{Annual CO}_2\text{e emissions} = [562,500 / 1,250,000] \times 2,345,000$ $= 1,055,250 \text{ mtCO}_2\text{e}$ | | |

TR.7 Emissions from Marine Vessels

Overview

This source includes emissions associated with marine freight and passenger vessels. Freight carrying vessels may include ships, barges, tugboats, towboats, fishing vessels, patrol boats, and industrial boats (such as drilling boats and dredges). Passenger carrying vessels may include ferries, cruise ships, and recreational boats. This source is only likely to be significant if an operating port exists within the community. Ferry boats for transit systems reporting to the National Transit Database may be more appropriately covered under method TR.4, Emissions from Transit, and if so should not be included in this section.

Marine vessel activity is largely beyond the direct control of a community, especially international cargo, which is part of a long-distance supply chain driven by national and international economic activity. A community may, however, be able to influence marine vessel emissions by working with the port to implement strategies such as ship hoteling (providing electric power while in port so that the ship's engines do not need to run) or implementing reduced-speed zones in waters adjacent to the community. These types of strategies are typically implemented to reduce air pollution, but they can have GHG benefits as well. Some marine vessels (such as ferries) may be owned or regulated by a local agency and improvements such as purchase of newer, cleaner vessels may be implemented directly.

Standardized methods for conducting a GHG emissions inventory for marine vessels do not exist. A 2009 EPA document²¹, however, does provide a review of methodologies for mobile-source inventories at ports, describing both a “detailed inventory” and a “streamlined inventory.” An inventory must typically be conducted using a “bottom-up” approach by taking inventory of the number of vessels, their power requirements, hours of operation, and emissions characteristics. It is also possible that an inventory of marine vessel activity may already have been conducted as part of an emissions inventory or air quality study. This section provides a sketch of the method for estimating marine vessel emissions. Readers who are interested in conducting an inventory of marine vessel emissions for their community are referred to the 2009 EPA document for more detail than is provided here.

It is useful to be familiar with some terminology. Marine vessels can largely be divided into two categories – (1) ocean-going vessels and (2) harbor craft. Harbor craft are commercial and recreational vessels that spend the majority of their time within or near a port or harbor. Marine engines are grouped into three classes for regulatory purposes. Category 1 is up to 7 liters per cylinder displacement; Category 2 is 7 to 30 liters per cylinder displacement; Category 3 is over 30 liters per cylinder displacement. Almost all harbor craft use Category 1 or Category 2 engines while Category 3 engines are typically used for propulsion on ocean-going vessels. Category 1 and 2 marine engines are currently regulated by U.S. EPA for air pollutant emissions as established in a 2008 rulemaking, but not for fuel efficiency. Category 1 and 2 engines typically run on diesel fuel while Category 3 engines may run on lower-grade residual fuels. Category 3 engines are not regulated by national entities, but are subject to international standards developed by the International Marine Organization (IMO) as ratified by participating countries.

²¹ U.S. EPA (2009). *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*. Prepared by ICF International.

Relevant sources/activities:

- CO₂, CH₄, and N₂O from harbor craft operating on waters within the community.
- CO₂, CH₄, and N₂O from ocean-going vessels operating on waters within the community.

Uncertainties

There are a variety of uncertainties associated with estimating GHG emissions from marine vessels within a community. In particular, the number of vessels operating, their hours of operation, and power consumption and emissions characteristics may not be known with certainty.

Power output of ship engines is measured in kilowatts (kw). Thus kw and kw-hr in the following section refer to power and energy output of ship engines, while kWh during hoteling may also include electrical energy provided to the ship from port.

TR.7.A Method for Marine Vessels

Data Needs

Below are the data inputs you will need to collect in order to estimate the GHG emitted by marine vessels operating within the community:

- Total number of vessels operating within community's waters by type.
- Activity hours of vessel within community's waters (may be based on number of annual trips that each vessel makes to and from the port & distance traversed by vessel within the municipality's waters).
- Maximum power (kilowatt) rating of each vessel and average load factor (percent of power used).
- Power used by ships during hoteling (i.e., while docked).
- CO₂ emission factors (g/kw-hr) by vessel and fuel type or by engine category (1, 2, or 3).
- CH₄ and N₂O emission factors (g/kw-hr or g/kg fuel). EPA (2009) provides emission factors in g/kw-hr for harbor craft by emissions category. The EPA State Inventory Tool 2010 (default factors from 1996 revised IPCC guidelines) cites factors of 0.23 g CH₄/kg and 0.08 g NO₂/kg.

Calculation Method²²

The method presented consists of the following steps:

1. Compile data on vessel movements for vessels that operate at or visit ports within the municipality, by type of vessel. These may be obtained from a local port authority, marine exchange, board of trade, or other local organization. The U.S. Army Corps of Engineers maintains data of individual ship movements that may be matched to a source such as Lloyd's Registry of Ships data to determine parameters such as ship type, tonnage, power (kilowatts), maximum vessel speed, draft, and other relevant factors.
2. Identify distance traversed within the community by different types of vessels per trip into/out of the port.
3. Estimate total activity time within the community by type of vessel. This may be computed as distance traversed / speed. For a detailed inventory, activity time should be broken out by time-in-mode for different operating modes (e.g., cruise, maneuvering, hoteling; see EPA 2009).²³
4. Estimate total kw-hr by type of vessel = power rating (kw) * total operating time.
5. Multiply total kw-hr * CO₂ emission factor (g/kw-hr) to get total CO₂ emissions by vessel type (g). See EPA (2009) for some emissions factors for different types of vessels and fuels.
6. Sum across all vessel types to get total CO₂ emissions from vessel movements.
7. For vessels that run engines while hoteling, estimate total time spent hoteling (hrs per year) and power consumption while hoteling (kw), and multiply to get kWh.
8. Multiply kWh from hoteling by CO₂ per kWh to get total CO₂ from hoteling.
9. Compute CH₄ and N₂O emissions by multiplying emission factors by power consumption (kWh) or fuel consumed (gal).

²² Method based on the following three sources:

U.S. Army Corps of Engineers 2009 U.S. Waterway Data, Vessel Entrances and Clearances, <http://www.ndc.iwr.usace.army.mil/data/dataclen.htm>,

²³ U.S. EPA (2009). *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*. Prepared by ICF International,

and

U.S. EPA (2008). *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotives and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder*. EPA 420-R-08-001a.

TR.8 Emissions from Other Off-road Equipment

This methodology applies to emissions from fuel combustion in agricultural, construction, commercial and industrial, lawn and garden, and recreational equipment engines.

TR.8 Method for Estimating Emissions from Other Off-road Equipment Using US EPA NONROAD Model.

There are two steps to the emissions estimation method for these sources:

1. Obtain county level emissions data from the EPA NONROAD model.
2. If inventory is being conducted for a sub-county local government, allocate county level emissions based on indicators.

Data Needs

No data is needed for producing county-level emissions from the NONROAD model. The model produces CO₂ emissions for each county using a set of pre-loaded default inputs. While local inputs can be used for more accurate results, that data is not generally available.

The following data is needed to allocate county-level emissions to sub-county local governments:

- Number of households in the jurisdiction and in the county.
- Number of building permits issued in the jurisdiction and in the county in the inventory year.

OR

- Population of jurisdiction and county

Step 1: Download and run NONROAD model

The NONROAD model and instructions for running it can be downloaded from

<http://www.epa.gov/otaq/nonrdmdl.htm> Refer to the instructions associated with the model for more information.

Step 2: Attribute Emissions

Emissions outputs from the NONROAD model are at the county level. If an inventory is being conducted for a sub-county jurisdiction, the portion of countywide emissions attributed to that jurisdiction must be determined.

- Construction equipment: counties generally retain information on numbers of building permits issued, which can be used to determine what percentage of those total permits came from different jurisdictions within the county. That percentage can be used to apportion construction emissions to each jurisdiction.
- Lawn and garden equipment: lawn and garden equipment is closely related to number of households. Use the percentage of county households located in a given jurisdiction to apportion a percentage of the county's emissions of lawn and garden equipment to that jurisdiction.
- For either of the two above methods, population can be used as a surrogate, but would not be as accurate as these methods.

TR.9 Emissions Associated with the Lifecycle of Transportation Fuels

Introduction

The transportation source emissions described in sections TR.1 – TR.8 include only direct emissions from combustion of fuels by vehicles (for vehicles with internal combustion engines), as well as emissions associated with the combustion of fuel to generate electricity for electrically-powered modes. Communities may also choose to include upstream emissions associated with the production and delivery of transportation fuels in their inventories.

Accounting for emissions from the full lifecycle of fuels, or “full fuel-cycle” emissions, allows for a more accurate comparison of GHG emissions associated with the use of alternative versus conventional fuels. However, this method is proposed as an optional rather than recommended method for communities due to the considerable uncertainty that still exists with respect to full fuel-cycle emissions, especially for biofuels. In addition, alternative fuels still have very limited penetration in the transportation sector. As reliance on alternative fuels increases in the future, it will be important to develop better methods and data for incorporating life-cycle factors into inventory development. It will also be important to be consistent with other sectors (e.g., home heating fuels) and to include life-cycle factors in order to place transportation in better perspective with other sectors.

The full lifecycle of a transportation fuel consists of five steps:

1. Feedstock Recovery
2. Feedstock Transportation
3. Fuel Production
4. Fuel Transportation
5. In-Vehicle Combustion

To estimate GHG emissions from the full fuel cycle (steps 1-5), emissions from step 5 (operating or “tailpipe” emissions) should first be estimated for each fuel type. Scaling factors representing average ratios between tailpipe emissions (step 5) and full fuel cycle emissions (steps 1-5) for each fuel type are then applied.

Uncertainties

The ratio of full fuel-cycle to direct emissions varies not only by fuel type, but also characteristics of the fuel source and the production pathway of the fuel, reflecting required energy inputs as well as other GHG emissions associated with the various steps of the process (e.g., flaring of natural gas at oil wells). For example, petroleum derived from tar sands will have different life-cycle GHG emissions than petroleum from conventional wells. There are numerous feedstocks and refining methods for biofuels, again having different energy requirements and GHG emissions. The distance from the fuel source to point of final delivery will affect GHG emissions associated with steps 2 and 4 of the fuel life cycle. Not all aspects of the fuel lifecycle may be captured – for example, emissions associated with making the steel used in the refinery or tanker trucks – but these omitted emissions are typically a small fraction of the total life cycle emissions.

For biofuels, an area of particular uncertainty is indirect emissions, and especially indirect emissions associated with land use change. Indirect land use emissions are associated with changes that occur at locations *other than the site of feedstock production* – for example, land conversion that takes place because of the competition for land between biofuel production and agricultural resources. Indirect land use emissions are potentially significant, but estimates are not widely agreed-upon due to the number of uncertain factors that underlie these estimates. Estimates of life cycle emissions for biofuels also vary depending upon the time horizon over which the analysis is conducted, and the discount rate used.

Data Sources

The method described in this section accounts for fuel cycle emissions by applying a scaling factor to direct GHG emissions, to represent the ratio of fuel cycle to direct emissions. These scaling factors differ by the type of fuel. The analyst therefore needs to provide inputs of GHG emissions, in CO₂-equivalents, by fuel type.

The Argonne National Laboratory's GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model contains data and procedures for estimating the life cycle emissions associated with a large number of alternative production pathways. GREET is widely used in the U.S. for life cycle analysis. The most recent version of the GREET model at the time of this writing, GREET1_2011, does not account for indirect land use change given the significant uncertainties that exist regarding these effects.

The GREET model can be used to develop scaling factors for the various fuels in use or considered for use in transportation. While the GREET model is intended for application to light-duty vehicles, the fuel-cycle factors should be similar for the same fuels used in other transportation subsectors (e.g., biodiesel in trucks). Scaling factors derived from GREET1_2011 using default inputs for all variables, for the year 2013, are shown in Table TR.9.1. This table shows the scaling factors both for CO₂ only, and for CO_{2e}, reflecting life cycle CH₄ and N₂O emissions. Most analysts will want to use the CO_{2e} scaling factors unless a separate life-cycle assessment of CH₄ and N₂O emissions is being conducted. For gasoline, use of a low-level ethanol blend is generally appropriate since most gasoline in the U.S. is now blended with ethanol.

For electricity, the values shown represent the ratio of fuel-cycle to fuel CO₂ emissions, where the fuel-cycle includes feedstock recovery and transportation (steps 1 and 2) and fuel emissions are from the point at which the fuel enters the power plant (including generating, transmission and distribution losses). These scaling factors should be applied to emissions that are derived using factors for CO_{2e} emissions per unit of electricity generated (e.g., as obtained from EPA eGRID data as shown in Table 14.1 of The Climate Registry General Reporting Protocol v1.1), adjusted for transmission and distribution losses (average 6.5 percent nationwide in 2009).

Table TR.9.1 Scaling Factors for Full Fuel-Cycle Emissions

| Fuel Type | Fuel cycle to operating CO ₂ | Fuel cycle to operating CO ₂ e |
|--|---|---|
| Gasoline – conventional and reformulated | 1.21 | 1.26 |
| Gasoline - Low-level (~10%) corn ethanol blend | 1.19 | 1.25 |
| Ethanol - Flex-Fuel Vehicle on E85 from corn | 0.87 | 1.06 |
| Diesel – conventional and low-sulfur | 1.21 | 1.25 |
| Biodiesel – soy-based B20 (20% blend) | 1.02 | 1.07 |
| CNG - Dedicated | 1.19 | 1.44 |
| | Fuel cycle to fuel CO ₂ | Fuel cycle to fuel CO ₂ e |
| Electricity | 1.03 | 1.10 |

Source: Analysis by Cambridge Systematics, Inc. using Argonne National Laboratory GREET model v. GREET1_2011

Jurisdictions using transportation fuels with life cycle emissions substantially different from the national average are encouraged to use locally specific scaling factors. For example, the California Air Resources Board (CARB) has developed the CA-GREET model that can be used by jurisdictions in California. CARB has also developed fuel-cycle emission rates (g CO₂e/MJ) using a variety of fuels with production pathways specific to California, for use in applying the statewide low-carbon fuels standard. CARB provides indirect as well as direct emission rates. In general, caution should be applied in the use of life cycle factors from any source, especially for biofuels, given the significant amount of uncertainty associated with these factors.

Calculation Method

1. Identify total direct transportation GHG emissions in your community’s inventory by type of fuel. This requires that in creating the community’s inventory, emissions for each transportation subsector be tracked by fuel type.
2. Apply scaling factors from the GREET model or another suitable source to emissions from each fuel type.
3. Sum across fuel types to determine full fuel-cycle transportation GHG emissions.

Equation TR.9.1 Full Fuel-Cycle Emissions from Transportation

*Full fuel-cycle emissions = sum of [(direct emissions by fuel type) * (scaling factor by fuel type)]*

| Description | Value |
|-------------------------------|--|
| Direct emissions by fuel type | Direct emissions (CO ₂ e) from internal-combustion vehicles Emissions associated with power plants for electricity production for electrically-powered modes (CO ₂ e) User input |
| Scaling factor | Fuel-specific scaling factor of life-cycle to direct emissions Table TR.9.1 or user input |

Box TR.9.1 shows a sample calculation.

Box TR.9.1 Sample Calculation of Full Fuel-Cycle Emissions from Transportation

| Description | Value |
|--|---|
| Direct emissions by fuel type | Direct emissions (CO ₂ e) from internal-combustion vehicles Gasoline (ethanol blend): 61,460 Diesel (conventional): 17,560 CNG: 642 |
| Direct emissions by fuel type | Emissions associated with power plants for electricity production for electrically-powered modes (CO ₂ e) 313 |
| Scaling factor | Fuel-specific scaling factor of life cycle to direct emissions Gasoline (ethanol blend): 1.25 Diesel (conventional): 1.25 CNG: 1.44 Electricity: 1.10 |
| <i>Total fuel-cycle emissions = 61,460 * 1.25 + 17,560 * 1.25 + 642 * 1.44 + 313 * 1.10 = 100,045 tons CO₂e</i> | |

References

California Air Resources Board (2009). "Lifecycle Analysis (CA-GREET) as of December 2009"; and "LCFS Lookup Tables as of December 2009." <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>

Appendix TR: Transportation & Other Mobile Emission Activities and Sources

| Fuel | Vehicle Type | Default Value for %b |
|----------|----------------|----------------------|
| Gasoline | Light trucks | 32.4% |
| Gasoline | Passenger cars | 60.6% |
| Diesel | Heavy trucks* | 5.4%* |
| Diesel | Light trucks | 1.3% |
| Diesel | Passenger cars | 0.3% |

Note: The community can substitute locally appropriate %b if it has this data. Include this substitution in the notes for your report.

* Heavy trucks should be excluded from your emissions estimates. To calculate emissions from heavy trucks, use section TR.2.

Source: CACP 2009 Software.

| Year | Gasoline Passenger Cars | | Gasoline Light Trucks | |
|------|-------------------------|-----------------|-----------------------|-----------------|
| | N ₂ O | CH ₄ | N ₂ O | CH ₄ |
| 2010 | 0.017 | 0.020 | 0.025 | 0.023 |
| 2009 | 0.020 | 0.021 | 0.029 | 0.025 |
| 2008 | 0.023 | 0.023 | 0.034 | 0.027 |
| 2007 | 0.026 | 0.025 | 0.040 | 0.030 |
| 2006 | 0.030 | 0.027 | 0.046 | 0.034 |
| 2005 | 0.033 | 0.030 | 0.053 | 0.037 |
| 2004 | 0.037 | 0.033 | 0.060 | 0.042 |
| 2003 | 0.041 | 0.037 | 0.067 | 0.047 |
| 2002 | 0.044 | 0.041 | 0.074 | 0.052 |
| 2001 | 0.048 | 0.045 | 0.080 | 0.058 |
| 2000 | 0.051 | 0.050 | 0.087 | 0.064 |
| | Diesel Passenger Cars | | Diesel Light Trucks | |
| All | 0.001 | 0.0005 | 0.0015 | 0.001 |

Source: GHG Inventory 2012, ANNEX 3 Methodological Descriptions for Additional Source or Sink Categories.

<http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Annex-3-Additional-Source-or-Sink-Categories.pdf>, Calculated from tables A-97, A-99, A-100 and A-103.

Table TR.1.5 Default fuel efficiency by vehicle type for inventory year

| Inventory Year | Average Fuel Efficiency for year | |
|-----------------------|---|---------------------|
| | Passenger Car | Light Trucks |
| 1980 | 16.0 | 12.2 |
| 1985 | 17.5 | 14.3 |
| 1990 | 20.3 | 16.1 |
| 1991 | 21.2 | 17.0 |
| 1992 | 21.0 | 17.3 |
| 1993 | 20.6 | 17.4 |
| 1994 | 20.8 | 17.3 |
| 1995 | 21.1 | 17.3 |
| 1996 | 21.2 | 17.2 |
| 1997 | 21.5 | 17.2 |
| 1998 | 21.6 | 17.2 |
| 1999 | 21.4 | 17.0 |
| 2000 | 21.9 | 17.4 |
| 2001 | 22.1 | 17.6 |
| 2002 | 22.0 | 17.5 |
| 2003 | 22.2 | 16.2 |
| 2004 | 22.5 | 16.2 |
| 2005 | 22.1 | 17.7 |
| 2006 | 22.5 | 17.8 |
| 2007 | 22.9 | 17.1 |
| 2008 | 23.7 | 17.3 |
| 2009 | 23.8 | 17.4 |

Source: http://www.bts.gov/publications/national_transportation_statistics/html/table_04_23.html

Table TR.1.6 CO₂ Emission Factors by Transportation fuel

| Fuel Type | CO ₂ Emission Factor (kg CO ₂ / unit) |
|--------------------------------|---|
| Gasoline | 8.78 / gallon |
| Diesel Fuel (Distillate No. 2) | 10.21 / gallon |
| Biodiesel (B100)* | 9.45 / gallon |
| Ethanol (E100)* | 5.75 / gallon |
| Liquefied Natural Gas (LNG)* | 4.46 / gallon |
| Liquefied Petroleum Gas (LPG)* | 5.79 / gallon |
| Propane | 5.59 / gallon |
| Ethane | 6.01 / gallon |
| Isobutane | 6.3 / gallon |
| n-Butane | 6.58 / gallon |
| Jet Fuel | 9.75 / gallon |
| Compressed Natural Gas (CNG) | 0.054 / standard cubic foot |

Source : Local Government Operations Protocol Table G.1.

Table TR.2.1 Truck Fuel Efficiency

| Size Category: | Medium Duty/ Single Unit | | Heavy Duty/ Combination | |
|--|--------------------------|--------|-------------------------|--------|
| Fuel Type: | Gasoline | Diesel | Gasoline | Diesel |
| Miles Per Gallon | 9.33 | 13.81 | 5.36 | 6.06 |
| Percent of size category vehicle miles | 28.4% | 71.6% | 2.5% | 97.5% |

Source: U.S. Department of Energy, Energy Information Administration. 2013 Annual Energy Outlook, Freight Transportation Energy Use. Values are for 2011 existing vehicles. Values may be updated using latest AEO publication; see <http://www.eia.gov/oiaf/aeo/tablebrowser/>

Table TR.2.2 Heavy Duty Vehicle Emission Factors

| Fuel type | Units | CH ₄ | N ₂ O |
|-----------------------------|-------|-----------------|------------------|
| Gasoline-heavy duty vehicle | g/mi | 0.0333 | 0.0134 |
| Diesel-heavy duty vehicle | g/mi | 0.0051 | 0.0048 |

Values for 2010. Source: TCR-GRP v1.1, Table 13.4

Table TR.6.C.1: CH₄ and N₂O Emissions Factors for Airport Ground Support Vehicles

| Vehicle/Fuel Type | Units | CH₄ | N₂O |
|--------------------------|--------------|-----------------------|-----------------------|
| Other Diesel Sources | g/gal | 0.58 | 0.26 |
| Other Gasoline Sources | g/gal | 0.50 | 0.22 |
| LPG Non-highway | g/gal | 0.50 | 0.22 |

Source: EPA 2011. Emissions Factors for Greenhouse Gas Inventories, Table 5.
<http://www.epa.gov/climateleadership/documents/emission-factors.pdf>