CLIMATE LEADERS GREENHOUSE GAS INVENTORY PROTOCOL OFFSET PROJECT METHODOLOGY

for

Project Type:
Transit Bus Efficiency

Climate Protection Partnerships Division/Climate Change Division
Office of Atmospheric Programs
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***Climate Leaders** is an EPA industry-government partnership that works with companies to develop comprehensive climate change strategies. Partner companies commit to reducing their impact on the global environment by setting aggressive greenhouse gas reduction goals and annually reporting their progress to EPA.*

Introduction

An important objective of the Climate Leaders program is to focus corporate attention on achieving cost-effective greenhouse gas (GHG) reductions within the boundary of the organization (i.e., internal projects and reductions). Partners may also use reductions and/or removals which occur outside their organizational boundary (i.e., external reductions or "offsets") to help them achieve their goals. To ensure that the GHG emission reductions from offsets are credible, Partners must ensure that the reductions meet four key accounting principles:

- ***Real:*** The quantified GHG reductions must represent actual emission reductions that have already occurred.
- ***Additional:*** The GHG reductions must be surplus to regulation and beyond what would have happened in the absence of the project or in a business-as-usual scenario based on a performance standard methodology.
- ***Permanent:*** The GHG reductions must be permanent or have guarantees to ensure that any losses are replaced in the future.
- ***Verifiable:*** The GHG reductions must result from projects whose performance can be readily and accurately quantified, monitored and verified.

This paper provides a performance standard (accounting methodology) for greenhouse gas (GHG) offset projects that introduce more efficient (i.e., lower GHG emitting) transit buses. The accounting methodology presented in this paper addresses the eligibility of transit bus efficiency projects as GHG offset projects and provides measurement and monitoring guidance. Program design issues (e.g., project lifetime, project start date) are not within the scope of this guidance and are addressed in the Climate Leaders offset program overview document: Using Offsets to Help Climate Leaders Achieve Their GHG Reduction Goals.[1]

The transit bus classification covers buses transporting passengers through urban and suburban street networks. Most transit buses have two doors, one in the front and one in the center, and the engine is normally rear-mounted. U.S. transit buses also include smaller varieties with one-door, and larger articulated buses. Generally, bus models are matched to specific routes, types of operation, and demand levels, although the selection is not always optimal. The classification excludes the hundreds of thousands of school buses in North America, the approximately 44,000 commercial motor coaches

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[1] Please visit http://www.epa.gov/climateleaders/resources/optional-module.html to download the overview document.

owned by private entities that provide long-distance transport between cities, and the country's many charter and tour bus operations.[2]

GHG emissions from all buses in the United States were estimated to be 12.1 million metric tons of carbon dioxide (CO_2) equivalent, in 2006. This was slightly less than 1% of transportation-related GHG emissions. Emissions specifically from transit buses are not available.

Description of Project Type

Buses represent the dominant choice of public transportation in the United States in the total number of passengers, vehicles, and distance traveled. In 2002, 2,264 agencies operated transit buses, representing 56,241 active vehicles. The greenhouse gases released from buses are primarily in the form of carbon dioxide (CO_2), but smaller levels of methane (CH_4) and nitrous oxide (N_2O) also are emitted depending on the fuel and engine technology used. The gases are mostly emitted from the vehicle tail pipe as a product of on-board fuel combustion, but some greenhouse gases also are released during the upstream production and processing of fuels and vehicles. Buses also may produce emissions of hydrofluorocarbons (HFCs) if they operate mobile air conditioning units.

Technology/Practice Introduced. Transit bus efficiency projects involve the introduction of one or more transit buses utilizing a lower carbon content fuel or operating with a significantly improved fuel economy than the buses that would have been operated absent the project. Potential greenhouse gas offset projects could include:

- Early retirement of existing buses and replacement with more efficient buses;
- Conversion of existing buses to cleaner fuel/engine systems;
- Switching to a more efficient fuel/engine system when replacing buses at the end of their service life; and,
- Adoption of more efficient fuel/engine systems when expanding the transit fleet to meet increased service demand.

The performance standards focus on CO_2 tailpipe emissions from transit buses. Because of the focus on CO_2 emissions, only those buses fueled by gasoline, diesel, or oil-based propane are eligible to use this standard. The performance standards elaborated below are not applicable for bus projects introducing natural gas-based fuels, such as compressed natural gas and liquefied natural gas, because the threshold does not address CH_4, a major component of natural gas. Projects introducing electricity, bio-diesel, and fuel cell buses are also

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[2] Sigurd Grava, *Urban Transportation Systems. Choices for Communities*. McGraw-Hill: New York, 2003, p.303.

ineligible to use the thresholds developed in this paper because of the potentially large contribution of upstream GHG emissions associated with generating these fuels.

Project Size/Output. All transit bus sizes (up to 35 feet, standard 40-foot buses, long 45-foot buses, and 60-foot articulated buses) are eligible for inclusion in the offset project. The GHG offset project can involve any number of buses in a fleet.

Project Boundary. This section provides guidance on which physical components, and associated greenhouse gases, must be included in the project boundary for a transit bus efficiency project.

Physical Boundary. The physical boundary includes the following components:

- transit buses designated to be part of the project

Upstream emissions from fuel production, transport, and refueling should not be included.

GHG Accounting Boundary. The GHG accounting boundary for the transit bus efficiency project includes emissions of CO_2, CH_4 and N_2O. Emissions of CH_4 and N_2O contribute a relatively minor share of total GHG emissions from gasoline, diesel, and oil-based propane buses. In most cases, the GHG accounting boundary should not include HFC emissions from the use of mobile air conditioning units. These emissions will not change under most project circumstances. In instances where the project results in an increase in HFC emissions, these emissions should be included in the baseline and project emissions.

Temporal Boundary. An annual accounting cycle should be used for transit bus efficiency projects.

Leakage. Leakage is an increase in greenhouse gas emissions or decrease in sequestration caused by the project but not accounted for within the project boundary. The underlying concept is that a particular project can produce offsetting effects outside of the physical boundary that fully or partially negate the benefits of the project. Although there are other forms of leakage, for these performance standards leakage is limited to activity shifting – the displacement of activities and their associated GHG emissions outside of the project boundary.

Potential sources of leakage from a transit bus efficiency project include an increase in GHG emissions at another transit fleet if existing vehicles are replaced early before the end of their useful life and resold for use by another transit fleet. If the old buses are purchased by another transit agency to replace buses at the end of their life instead of buying more efficient buses (defined as buses with a performance level at least equal to the performance threshold) the difference in CO_2 emissions between the replaced vehicles and the performance threshold are considered leakage and must be quantified and subtracted from the emission reductions of the project[3].

If it is determined that significant emissions that are reasonably attributable to the project occur outside the project boundary, these emissions must be quantified and included in the calculation of reductions. No specific quantification methodology is required. All associated activities determined to contribute to leakage should be monitored.

Regulatory Eligibility

The performance standard subjects greenhouse gas offset projects to a regulatory "screen" to ensure that the emission reductions achieved would not have occurred in the absence of the project due to federal, state or local regulations. In order to be eligible as a GHG offset project, GHG emissions must be reduced below the level effectively required by any existing federal, state, or local policies, guidance, or regulations. This may also apply to consent decrees, other legal agreements, or federal and state programs that compensate voluntary action.

Federal regulations. The Energy Policy Act of 1992 (EPACT 1992), Section 303, and Executive Order 13149, establish requirements for federal fleet operators to purchase alternative fuel vehicles. There are no purchasing requirements for heavy duty vehicles and buses. Moreover, even though transit agencies receive heavy government subsidies, they are normally privately owned and, therefore, not covered by such purchasing requirements. Although EPACT 1992 creates vehicle and refueling tax deductions, and encourages voluntary market development, transit bus agencies do not have any mandatory compliance requirements under EPACT or Executive Order 13149. The Energy Policy Act of 2005 does not introduce new requirements pertaining to heavy duty vehicles. [4]

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[3] This method is applicable where the buses are sold to another transit agency within the United States. In cases where the buses are sold to a transit agency outside of the United States, a different performance threshold may have to be developed to reflect conditions in that country.

[4] The Corporate Average Fuel Economy (CAFE) standard establishes fuel economy standards for original automobile manufacturers producing light duty vehicles and small trucks. Fuel economy requirements do not apply to heavy duty vehicles, such as transit buses. The U.S. EPA promotes alternative fuel use, and establishes air pollutant emission standards for heavy duty highway engines, including buses, but the regulations do not address GHG emissions or mandate alternative fuels or fuel-efficient vehicles.

State and Local Regulations. Some states and local governments may encourage the purchase of alternative-fueled buses or fuel-efficient buses and may have in place voluntary retrofit or early retirement programs for heavy-duty vehicles. To pass the regulatory screen, the project proponent must demonstrate that the proposed project is not being undertaken to come into compliance with any mandatory requirements contained in such state and local programs.

Determining Additionality - Applying the Performance Threshold

This section describes the performance thresholds (additionality determination) that a transit bus efficiency project must meet or exceed in order to be eligible as a GHG offset project.

Additionality Determination: The additionality determination represents a level of performance that, with respect to emission reductions or removals, or technologies or practices, is significantly better than average compared with recently undertaken practices or activities in a relevant geographic area. Any project that meets or exceeds the performance threshold is considered "additional" or beyond that which would be expected under a "business-as-usual" scenario.

The type of performance thresholds used for a transit bus efficiency project is an emissions rate. The threshold represents a level of performance (emissions rate) that is beyond that expected compared to the suite of typical transit bus efficiencies.

The performance thresholds for transit buses, which are presented in this paper, are derived from data on the fuel economy and CO_2 emissions of transit fleets in the United States (see Appendix I). Because of the use of national level data, the thresholds may not be representative of all transit agencies if their fleet (bus size, fuel consumed), driving conditions, and climate differ significantly from the national average.

To allow for a comparison across bus fuel types, a fuel-neutral metric of CO_2 emissions per miles driven was used for the performance thresholds. Appendix I provides a rationale for the use of a fuel-neutral metric and summarizes the method and data used to develop the performance thresholds.

A stringency level of the top 10th percentile has been selected as the performance threshold for transit buses. Due to the different driving conditions (e.g., stop-and-go traffic) in larger metropolitan areas versus smaller metropolitan areas, separate thresholds are developed for cities with a population more than one million (referred to as "large metropolitan areas") and less than one million (referred to as "small metropolitan areas"). For projects in large metropolitan areas, the performance threshold is set at the top 10th percentile - 2.11 kg CO_2 per mile. A proposed project in a large metropolitan area must meet or exceed this rate of 2.11 kg CO_2 per mile in order to be considered additional (See Appendix I, Table I.b. for further explanation). For projects in small metropolitan areas, the performance threshold is set at the top 10th percentile - 1.46 kg CO_2 per mile. A proposed project in a small metropolitan area must meet or exceed this rate of 1.46 kg CO_2 per mile in order to be considered additional.

Quantifying Emissions Reductions

Quantification of reductions from a transit bus project encompasses four steps; two are pre-project implementation (selecting and setting the emissions baseline and estimating project emission reductions) and two are post-project implementation (monitoring and calculating actual reductions).

Selecting and Setting an Emission Baseline: The emissions baseline for a transit bus efficiency project depends on whether the project involves the conversion or early retirement of an existing vehicle or the purchase of new capacity. The emissions baselines are presented below:

> **1. Conversions and Early Retirement.** For projects involving an engine conversion or early retirement and replacement of existing vehicles with more efficient buses, the baseline should be equal to the annual emissions ($KgCO_2e$) of the *existing buses* (i.e., the buses to be replaced).
>
> **2. New Capacity.** For projects involving procurement of buses to meet new capacity or replacement of existing buses at the end of their service life, the emissions baseline should be equal to *the performance threshold*. The performance threshold is 2.11 kg CO_2 per mile for large metropolitan areas and 1.46 Kg CO_2 per mile for small metropolitan areas. This emissions rate should be multiplied by the expected annual miles traveled by the buses in the offset project to estimate annual baseline CO_2 emissions. When developing the baseline for new capacity, emissions of CH_4 and N_20 must be added to the CO_2 emissions in order to estimate total CO_2 equivalent emissions for a full calendar year. In cases where special adjustments were made to the physical boundary to address upstream or downstream emissions changes, these must also be included in the baseline.

Estimating Project Emission Reductions. To estimate the potential GHG emission reductions from the offset project, the project proponent must compare emissions of the baseline with the emissions of the proposed project.

> **Estimating Baseline Emissions.** Separate equations are presented for estimating baseline emissions from conversions (i.e., retrofits) and early retirement (Equations A, B, and C) and new capacity (Equations D, E).

Conversions and Early Retirement

Equation A.

$$\textbf{Baseline } CO_2 \textbf{ emissions}_{\text{conversions/early retirement } ij} = \Sigma\, F_i * GHC_{ij} * CC_{ij} * OX_j * 44/12 \div 42$$

Where:

Baseline CO_2 emissions $_{\text{conversions/retrofits}}$ = total CO_2 emissions from all buses in the fleet, $kgCO_2$
F_i = annual fuel consumption by vehicle i, Gallons/yr
GHC_{ij} = gross heat of combustion for fuel type j in vehicle i, MMBtu/barrel (Appendix II, Table II.a)
CC_{ij} = carbon content of fuel type j used by vehicle i, TgC/QBtu (Appendix II, Table II.a)
OX_j = oxidation rate for fuel type j, (assume 100%)
42 = conversion from gallons to barrels
44/12 = conversion from C to CO_2
i = index of vehicle
j = index of fuel type

Equation B.

$$\textbf{Baseline } CH_4 \textbf{ and } N_20 \textbf{ emissions}_{\text{conversions/early retirement}} = \Sigma[(VMT * EF_{CH4} * 21 \div 1000) + (VMT * EF_{N20} * 310 \div 1000)]$$

Where:

Baseline CH_4 and N_20 emissions $_{\text{conversions/retrofits}}$ = total CH_4 and N_20 emissions from all buses in the fleet, $kgCO_2e$
VMT = vehicle miles traveled by bus, miles
EF_{CH4}, $EF_{N20,}$ = CH_4 and N_2O emission factors, respectively, g/mi (Appendix II, Table IIb)
21, 310 = the global warming potential for CH_4 and N_20, respectively
1000 = conversion from grams to kilograms

Equation C.

$$\textbf{Baseline GHG emissions}_{\text{conversions/early retirement}} = \textbf{Equation A + Equation B}$$

New Capacity

Total CO_2 equivalent emissions also must be calculated when estimating baseline emissions from new capacity. Baseline CO_2 emissions for new capacity are based on the performance threshold for transit bus efficiency projects (Equation D). Because the performance threshold reflects only CO_2 emissions, CH_4 and N_2O emissions must be added to the calculation of CO_2 emissions. The calculation for non-CO_2 emissions follows Equation B above, but uses estimates for project-level vehicle miles traveled.

Equation D.

Baseline CO_2 emissions $_{\text{new capacity}}$ = PT * VMT

Where:

Baseline CO_2 emissions $_{\text{new capacity}}$ = total CO_2 emissions in baseline for new capacity, $kgCO_2$
PT = performance threshold, $kgCO_2$/mile
VMT = vehicle miles traveled, miles

Equation E.

Total Baseline GHG Emissions $_{\text{New Capacity}}$ = Equation B + Equation D.

Estimating project emissions*:* Project-related emissions are estimated using the baseline estimate equations above but using estimated project-level data.

Estimating project-related emission reductions: Emission reductions are estimated using Equation F.

Equation F.

Reductions $_{\text{project}}$ = Emissions $_{\text{baseline}}$ – Emissions $_{\text{project}}$

Monitoring

There are two broad categories of monitoring options that can be used to monitor CO_2 emissions from transit fleets. The first option is based on the use of purchase or refueling records (individual or bulk). The second option is based on mileage. Although not described further here, direct measurement of emissions using an onboard CO_2 monitoring system is also an acceptable approach.[5]

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[5] These methods are not directly applicable to calculating CH_4 and N_20 emissions. Where project-specific emissions or emission factors are known, these can be used to calculate CH_4 and N_20. Where project level data are not available, default values can be used (Appendix II, Table IIb).

All transit bus efficiency greenhouse gas offset projects must also monitor any regulatory requirements (or changes in regulatory requirements) or substantive changes in the project that might affect the continued eligibility of the project as a greenhouse gas offset project.

Fuel Purchase or Refueling Records. Fuel consumption-based approaches rely on collection of activity data on the quantity of fuel consumed and fuel-based emission factors to calculate CO_2 emissions. Vehicle fuel consumption may be calculated from individual fuel purchase records or bulk fuel purchase records. Because the two approaches differ slightly, they are described separately.

Individual Fuel Purchase or Refueling Records. Fleets that track fuel purchase or refueling records for each individual vehicle may use this method, which requires vehicle-specific fuel consumption data. The data collection system can be as simple as requiring drivers to maintain a written log of fuel purchases or refueling quantities with the vehicle, periodically entering the logs into an electronic format (i.e. spreadsheet), and conducting the required calculations. Miles driven also must be tracked to estimate CH_4 and N_20 emissions.

An alternate approach is to use a "dedicated card" electronic system that is swiped at the fuel pump, similar to a credit card, for tracking vehicle fuel consumption. The key is to ensure that each card is used only for the individual vehicle to which it is assigned and only captures the fuel quantity; the purchase cost is not relevant). For both tracking methods, the measurement of vehicle fuel consumption during a designated period is calculated as follows (Equation G):

Equation G.

Fuel consumption = Fuel in Vehicle at Beginning of the Period + (Fuel Added to Vehicle during the Period – Fuel in Vehicle at End of Period).

Fuel consumption, after being summed for the year, is then multiplied by the appropriate emission factors (Appendix II, Table II.a) for the specific fuel type, and then multiplied by the CO_2 to carbon ratio, to determine the annual CO_2 emissions. To calculate the project total, CO_2 emissions from each project vehicle should be summed (Equation A).

Bulk Fuel Purchase Records to Estimate Fuel Use per Vehicle. This approach is similar to the individual fuel purchase record approach, except that it allows for situations where an individual vehicle fuel tracking and cost allocation system does not exist and all fueling takes place at a central fuel tank. This approach is only applicable in instances where the central fuel tank is servicing just those buses that are included within the project boundary, and the buses are not using any alternative locations for fueling. This is likely to be a rare circumstance. The measurement of total fleet fuel consumed during a designated period is calculated as follows for the bulk fuel storage tanks:

Equation H.

Fuel consumption = Fuel in Storage at Beginning of the Period + (Fuel Deliveries during the Period – Fuel in Storage at End of Period)

Mileage-Based Approach for Estimating CO_2 Emissions: This approach is applicable to projects designed to retrofit existing buses, to replace buses before the end of their lifetime, or the introduction of new buses. The method uses data on the actual miles driven by each vehicle, the known fuel economy of the buses, and a fuel carbon content-based emission factor to calculate CO_2 emissions. It relies on manually collected odometer mileage data and requires the fleet operator to incorporate a miles-driven tracking system that applies to all the vehicles included in the GHG offset project boundary. The tracking system must provide sufficient detail to allow for analysis of individual vehicle driving distances during specified time-periods. It can be as simple as requiring drivers to log odometer readings at regular intervals (e.g., at least once a month). Data analysis would consist of manually entering the data into an electronic format (i.e., spreadsheet) and executing the required calculations. An alternate approach would be to use data records kept during the maintenance of each vehicle. Data must be captured in time intervals that are consistent with the emission reporting requirements.

The emissions calculation should be repeated for each project vehicle. To calculate the project emissions total, CO_2 emissions from each project vehicle should be summed. The equation for calculating CO_2 emissions from a project vehicle is as follows (Equation I).

Equation I.

$$CO_{2\,i} = (VMT_i / FE_{ij}) * GHC_{ij} * CC_{ij} * (44/12) * OX_j + 42 + 1000$$

Where:
CO_{2i} = total annual carbon dioxide emissions from vehicle i (ton/yr)
VMT_i = total annual miles driven by vehicle i, mi/yr

FE_{ij} = actual vehicle fuel economy for vehicle i, to convert VMT to fuel use of type j, mi/gal
GHC_{ij} = gross heat of combustion for fuel type j in vehicle i, MMBtu/barrel
CC_{ij} = carbon content of fuel type j used by vehicle i, TgC/QBtu
44/12 = ratio of the weight of CO_2 to carbon
OX_j = oxidation rate for fuel type j (100%)
42 = conversion from gallons to barrels
1000 = conversion to tons
i = index of vehicle
j = index of fuel type

Calculating Actual Project Reductions. Quantifying project GHG emission reductions occurs after the project has been implemented and monitored. To quantify project reductions, apply the equations presented in the above section using actual monitored project data and adjust for any leakage (Equation J). Again, the above equations address only CO_2 emissions. CH_4 and N_20 emissions, in units of CO_2 equivalents, should be added to the CO_2 calculations to estimate total project emissions.

Equation J.

$$\textbf{Reductions}_{\textbf{project}} = \textbf{Emissions}_{\textbf{baseline}} - \textbf{Emissions}_{\textbf{project}} \textbf{ (+/- leakage adjustments)}$$

Appendix I. Development of the Performance Threshold – Data Set

The data source used for this performance threshold is the National Transit Database (NTD) published by the Federal Transit Administration.[6] The NTD covers about 75 percent of active transit buses in service in the United States (see Table I.a).

The most common fuel type used for transit buses is diesel. As indicated in Table I.a, diesel buses represent 86 percent of transit vehicles on the road and 84 percent of the fuel consumed. Other fuel types include compressed natural gas (10.6 percent), liquefied natural gas (1.7 percent), gasoline (0.4 percent), electric vehicles (0.3 percent), and propane (0.2 percent). Although non-diesel buses still represent a smaller fraction of transit buses in the United States, their share of total vehicles has grown consistently during the past decade.

Table Ia. Number, Fuel Source, and Efficiency of Transit Buses by Mode, 2002

Power Source	Transit Buses		Fuel Consumption		Efficiency – Diesel Gallon Equivalent (Miles per Gallon)
	Number	Percent (%)	Thousands of Gallons	Percent (%)	
Compressed Natural Gas (CNG)	5,977	10.6	77,787	11.7	2.77
Diesel	48,545	86.3	558,990	84	7.05
Gasoline	231	0.4	1,264	0.2	4.72
Liquefied Natural Gas (LNG)	974	1.7	16,762	2.5	2.19
Methanol	0	0.0	0	0	0.96
Propane	101	0.2	1,830	0.3	1.41
Other (a)	174	0.3	8,982	1.3	N/A
Total Non-Electric	**56,002**	**99.6**	**665,615**	**100**	**N/A**
Electric and other	239	0.4	75,901 (b)	N/A	0.59 (c)
Total	**56,241**	**100**	**665,615**	**N/A**	**N/A**

Source: American Public Transportation Agency (APTA), "Transit Statistics," www.apta.com. Table 81: Power Source Efficiency, Miles per Gallon; Table 77: Bus and Trolleybus Power Sources, 2004. APTA uses data reported to the Federal Transit Administration's National Transit Database,

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[6] http://www.ntdprogram.com/NTD/ntdhome.nsf/?Open The following NTD data fields on 2002 data were used: transit agency name and relevant statistics, including population covered by the service; annual transit vehicle miles traveled, aggregated by transit mode (e.g., bus, light rail, trolley bus) for each transit agency; and annual fuel consumption, by fuel type (e.g., diesel, CNG, LNG), aggregated by transit mode for each agency.

(a) Includes bio or soy diesel, biodiesel, jet fuel, and propane blends; (b) KWh; (c) Miles per kilowatt hour.

In developing the performance standard a fuel-neutral metric of CO_2 emissions per miles driven was selected after evaluating alternative metrics such as CO_2 emissions per gallon of fuel consumed and miles driven per gallon consumed. The fuel-neutral metric was selected after considering three characteristics of fuels typically consumed in bus fleets:

1) Diesel has a much higher energy density (energy per gallon) than alternative fuels (LNG, CNG, and Propane) and, therefore, is much more efficient when combusted than its alternatives.

2) Diesel engines also operate at a higher thermal efficiency than dedicated alternative fuel engines, which may translate into a fuel economy improvement of up to 25 percent per Btu of diesel fuel used.

3) Meanwhile diesel fuel contains more carbon per unit fuel (i.e., produces more CO_2 when combusted) than alternative fuels.

Because of these properties, a comparison of fleet efficiency based on "miles per gallon" would not be representative of emissions performance as it would tend to show diesel vehicles as more fuel efficient while ignoring their CO_2 penalty. The metric of "CO_2 emissions per gallon of fuel consumed" would not be effective either, because it does not allow for an assessment of the service/output provided by the transit buses, which is miles driven. Using CO_2 emissions per gallon of fuel consumed, a range of performance cannot be derived for buses, as the carbon content of fuels remains constant regardless of vehicle efficiency.

The fuel neutral metric of CO_2 emissions per miles driven is the only metric that captures all the factors that determine emissions performance of transit buses in terms of miles driven (i.e., service provided), including fuel efficiency, engine efficiency, and carbon content of fuel. It also enables the development of a range of emissions performances representing miles driven of transit buses from which a threshold can be selected.

The steps for estimating average CO_2 emissions per mile per transit agency for the performance threshold included:

- Manually link data for entity (i.e., transit agency), annual vehicle miles traveled for all directly operated[7] bus fleets, and annual fuel consumption by all directly operated entity buses;
- Multiply fuel consumption by a fuel type-specific CO_2 emissions factor;

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[7] Excluding purchased transportation.

- Sum CO_2 emissions across fuel types used by bus mode for each transit entity; and,
- Divide total annual CO_2 emissions from buses for each entity by total annual bus miles traveled to produce average kilogram of CO_2 per mile for each entity.

Spatial Area. Two distinct spatial areas - large metropolitan areas and small metropolitan areas - have been considered in the development of the performance thresholds. The thresholds were developed based on population figures in the U.S. Census 2000. The different spatial areas are necessary because transit agencies in large urbanized areas typically experience similar patterns of stop-and-go, short acceleration and deceleration cycles associated with heavy vehicular traffic. These driving patterns are different than in cities with smaller populations.

Owing to differences in climate, driving cycles, and fleet composition and sizes across the United States, however, the performance thresholds developed in this paper may not be applicable for all transit bus projects. The following paragraphs detail under what circumstances a narrower spatial area may apply:

> *Driving Cycle* – Individual driving cycles have significant impact on the emissions performance of individual vehicles. For example, the driving patterns in New York City (NYC) have a much higher occurrence of stop-and-go traffic than any other metropolitan region, contributing to much lower vehicle fuel economy in this city. It is likely that even a vehicle project that significantly improves the fuel economy of a NYC bus (e.g., a hybrid bus project) would not pass a performance standard based on the U.S. average fuel economy. The NYC Transit Agency, or other interested party may, therefore, choose to develop a performance standard based on the fuel economy of its own bus fleet. This would be feasible given the large number of vehicles operated by NYC Transit.
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> *Ambient Temperature/Regional Climate* – The ambient temperature and climate conditions in which a bus operates affects its fuel efficiency and performance. Therefore, if a transit agency operates in an extreme climate (e.g., very hot or cold air temperature), the agency may wish to develop a specific performance threshold which is representative of the temperature conditions in which its bus fleet operates.
>
> *Vehicle Size* – Although bus length affects bus passenger capacity and mass (weight), which again affects fuel economy, this performance threshold is not disaggregated by fuel consumption and bus size. If a transit agency operates a fleet that has a large share of small or articulated buses, the project developer may wish to develop a specific performance threshold that contains a similar mix

of bus sizes, or has an average bus length, close to that of the subject transit agency fleet.

Fuel Type –All fuel types used in the United States are included in the performance thresholds. Some regions in the United States may have a higher representation of alternative fuel vehicles in their fleet mix and may opt to develop a performance threshold that better reflects this mix of engine types in their transit fleet.

Temporal Range. The temporal range for the national level performance thresholds includes buses of all ages in operation in 2002. Available national level data on transit buses does not allow for a further disaggregation by bus vintage and fuel consumption.

Performance Thresholds. The level of stringency is a measure that demonstrates that the project performs better than would be expected under business-as-usual. Using a performance standard for transit buses, the level of stringency is rate-based and denotes a threshold performance that a project must satisfy. Using data from the 2002 National Transit Database (NTD) performance thresholds have been developed for fleets operating in large and small metropolitan areas. The summary data for large and small metropolitan areas can be found in Table I.b. and Table I.c., respectively.

The NTD contains detailed records for approximately 58,000 fleet vehicles, covering about 75 percent of the more than 76,000 active transit buses in service. Fleet average CO_2 emissions performance data were calculated from the NTD dataset and sorted. A review of the resulting data shows that, with the exception of a few outliers in both the large and small metropolitan data sets, all data are grouped relatively closely. The first two columns in Tables I.b. and Table I.c present the data summarized by ten evenly divided groupings that exclude the high and low outliers. The last column shows the cumulative percentage of buses that fall within each data range. For example, in Table I.b., the top 10th percentile of buses falls between 1.967 and 2.224 kg CO_2 per mile. Given the full data set, the top 10th percentile is equal to 2.11 kg CO_2 per mile. In Table I.c, the top 10th percentile of buses falls between 1.174 and 1.548 kg CO_2 per mile. Given the full data set for small metropolitan areas, the top 10th percentile is equal to 1.46 g CO_2 per mile.

Table Ib. CO_2 Performance Profile of U.S. Transit Bus Fleets in Cities with a Population Greater Than One Million (large metropolitan areas)

2002 Urban Transit Bus CO_2 Emissions Performance (kg CO_2 per Mile)		**Emissions Profile of Urban Transit Buses**	
Lower bound	Upper bound	Number of Transit Bus Fleets	Cumulative Percentage of Transit Bus Fleets (%)
Urbanized area with population greater than 1 million			
1.453	1.710	1	2.2%
1.710	1.967	1	4.3%
1.967	2.224	5	15.2%
2.224	2.481	12	41.3%
2.481	2.738	5	52.2%
2.738	2.995	10	73.9%
2.995	3.252	5	84.8%
3.252	3.509	3	91.3%
3.509	3.766	1	93.5%
3.766	**4.023**	3	100%
Total		**46**	**100%**

Note: The table excludes the highest and lowest values of 0.08 and 40.9 kg CO_2 per mile, because these two values are assumed to be outliers. The lowest and highest bounds of the values in the table (1.453 and 4.023 kg CO_2 per mile) are marked in bold, and reflect the lowest and highest values in the data set after the outliers have been removed.

Table Ic. CO_2 Performance Profile of U.S. Transit Bus Fleets in Cities with a Population Less Than One Million (small metropolitan areas)

2002 Urban Transit Bus CO_2 Emissions Performance (kg CO_2 per Mile)		**Emissions Profile of Urban Transit Buses**	
Lower bound	Upper bound	Number of Transit Bus Fleets	Percentage of Transit Bus Fleets (%)
Urbanized area with population less than 1 million			
0.428	0.801	2	0.7%
0.801	1.174	6	2.8%
1.174	1.548	25	11.4%
1.548	1.921	34	23.1%
1.921	2.294	66	45.9%
2.294	2.995	87	75.9%
2.668	3.252	44	91.0%
3.041	3.414	19	97.6%
3.414	3.788	3	98.6%
3.788	**4.161**	4	100.0%
Total		**290**	**100**

Note: The table excludes the highest (12.97, 12.20 kg CO_2 per mile) and lowest values (six bus fleets were below 0.428 kg CO_2 per mile) because these values are assumed to be outliers. The lowest and highest bounds of the values in the table (0.428 and 4.161 kg CO_2 per mile) are marked in bold, and reflect the lowest and highest values in the data set after the outliers have been removed.

Appendix II. Default Emission Factors

Table IIa. Default Parameters for Estimating CO_2 Emissions

Fuel	2006 Carbon Content (Tg/QBtu)	Gross Heat of Combustion (MMBtu/Barrel)
Motor Gasoline	19.33	5.218
LPG (total)	16.99	a
LPG (energy use)	17.20	a
Distillate Fuel (b)	19.95	5.825
Residual Fuel	21.49	6.287

(a) LPG is a blend of multiple paraffinic hydrocarbons: ethane, propane, isobutene, and normal butane, each with their own heat content and carbon content.

(b) Distillate fuel is a general classification for diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery.

Table IIb. Default Parameters for Estimating CH_4 and N_20 Emissions

Heavy Duty Vehicle Fuel Type (control technology)	GHG	Default Emission Factor [1]	Units
Diesel	CH_4	0.005	grams/mi
	N_20	0.005	grams/mi
Gasoline	CH_4	0.106	grams/mi
	N_20	0.079	grams/mi

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2006. U.S. Environmental Protection Agency, April 2008. Emission factors for gasoline represent weighted averages based on control technologies used in the U.S.

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