FTA

FEDERAL TRANSIT ADMINISTRATION

Transit Greenhouse Gas Emissions Estimator v2.0: User Guide

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U.S. Department of Transportation

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The Transit Greenhouse Gas (GHG) Emissions Estimator (Estimator) is a Microsoft Excel-based spreadsheet tool that allows users to estimate the partial lifecycle GHG emissions generated from the construction, operation, and maintenance phases of a project across select transit modes. Users input general information about a project, and the Estimator calculates annual GHG emissions by project phase. Although the Estimator lacks the precision for projections that may be attainable by using more complex emission models or route-specific ridership estimates, it can generate early, informative GHG emissions estimates for a broad range of transit projects.

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1 Introduction

The Transit Greenhouse Gas (GHG) Emissions Estimator (Estimator) is a Microsoft Excel-based spreadsheet tool that allows users to estimate the partial lifecycle GHG emissions generated from the construction, operation, and maintenance phases of a project across select transit modes. Users input general information about a project, and the Estimator calculates annual GHG emissions by project phase (Table 1). Total annual GHG emissions for a transit project is the sum of amortized construction emissions, annual maintenance emissions, and annual operations emissions, minus annual displaced emissions.

The National Environmental Policy Act (NEPA) requires federal agencies to disclose and analyze the environmental effects of their proposed actions. The Federal Transit Administration (FTA) developed the original version of the Estimator in connection with its Greenhouse Gas Emissions from Transit Projects Programmatic Assessment (2016) as a tool for agencies to generate project-specific GHG emissions estimates for their NEPA analysis. Although the Estimator lacks the precision for projections that may be attainable by using more complex emission models or route-specific ridership estimates, it can generate early, informative GHG emissions estimates for a broad range of transit projects. In no case is the use of this tool mandatory, and transit agencies should work with FTA Regions to determine whether to conduct project-specific analyses of GHG emissions and the best approach for doing so.

In 2021, the FTA updated the Estimator to include more current emissions data and to make it more user-friendly.

TABLE 1: GHG EMISSION SOURCES BY PHASE AND TRANSIT MODE

Phase	Mode	GHG Emission Sources Included
Construction	Rail	New, at-grade track mile
		New, elevated track mile
		New, underground track mile
		Converted or upgraded existing track mile (light rail only)
		New, at-grade rail station
		New, elevated rail station
		New, underground rail station
		Rail catenary system
	Bus/Bus Rapid Transit (BRT)	New lane or right-of-way mile
		Converted or upgraded lane mile
		New, at-grade station
		Bus/BRT catenary system
	Parking	Surface parking
		Structured (garage) parking
Maintenance	Rail	Rail transit vehicle
		Track
	Bus/BRT	Pavement
Vehicle Operation	Rail	Electric vehicle
		Diesel vehicle (commuter rail only)
	Bus/BRT	Electric vehicle
		Diesel vehicle
		Hybrid diesel vehicle
		Compressed Natural Gas (CNG) vehicle
		Gas vehicle
	Demand Response Bus	Electric vehicle
		Diesel vehicle
		Hybrid diesel vehicle
		CNG vehicle
		Gas vehicle
	School bus	Diesel vehicle
		CNG vehicle
	Sedan/auto	Gas vehicle
		Diesel vehicle
		All electric vehicle
		Plug-in hybrid electric vehicle
		Hybrid electric vehicle
Facility Operation	Rail	Station electricity
		Station heating
		Maintenance/storage electricity
		Maintenance/storage heat
	Bus/BRT	Station electricity
		Station heating
		Maintenance/storage electricity
		Maintenance/storage heat
Carbon Storage	N/A	Change in carbon storage due to tree cover changes

Using the Estimator involves the following basic steps:

1. Select the location (state) of your project
2. Select the analysis period (years)
3. Enter construction inputs
4. Enter facility operation inputs
5. Enter vehicle operations and maintenance inputs
6. Enter displaced emissions inputs
7. Calculate and review results

Section 3 provides detailed instructions for each step. Section 4 provides information on the Estimator's data sources and assumptions. The emission factors used in the Estimator are listed in Appendix A.

2 Getting Started

When opening the tool for the first time a user will need to enable macros. If an “Enable Content” Security Warning appears, click the “Enable Content” button. If the Security Warning does not appear when the tool is first opened, it may be necessary to change the security settings for macros. To change the setting, first exit out of the tool and re-launch Microsoft Excel before opening the Estimator Tool. Next, click on the Microsoft Excel icon or File menu in the top left of the screen. Scroll to the bottom of the menu and select the “Excel Options” button to the right of the main menu. When the Excel Options box appears, select “Trust Center” in left hand menu of the box. Next, click the gray “Trust Center Settings” button. When the Trust Center options box appears, click “Macro Settings” in the left hand menu and select “Disable all macros with notification.” Once the security level has been adjusted, open the tool and enable macros as described above.

3 How to Use the Estimator

Step 1: Select the location (state)

On the GHG Calculator tab, choose the state the project is located in from the drop-down menu. Some of the emission factors used in the tool vary based on the location of the project (see Appendix A).

Step 2: Enter analysis period (years)

On the GHG Calculator tab, enter the analysis period in years. The analysis period is the timespan over which a user wishes to assess impacts. The information will be used to amortize the construction-related GHG emissions for the project's annualized emissions, as well as to scale up operations, maintenance, and displaced emissions calculations for the project's total cumulative emissions. As an example, if a user chooses 20 years as the analysis period, construction emissions will be divided to return annual construction-related emission estimates over each of 20 years, and operations, maintenance, and emissions displaced will be multiplied over the analysis period to generate the total emissions result.

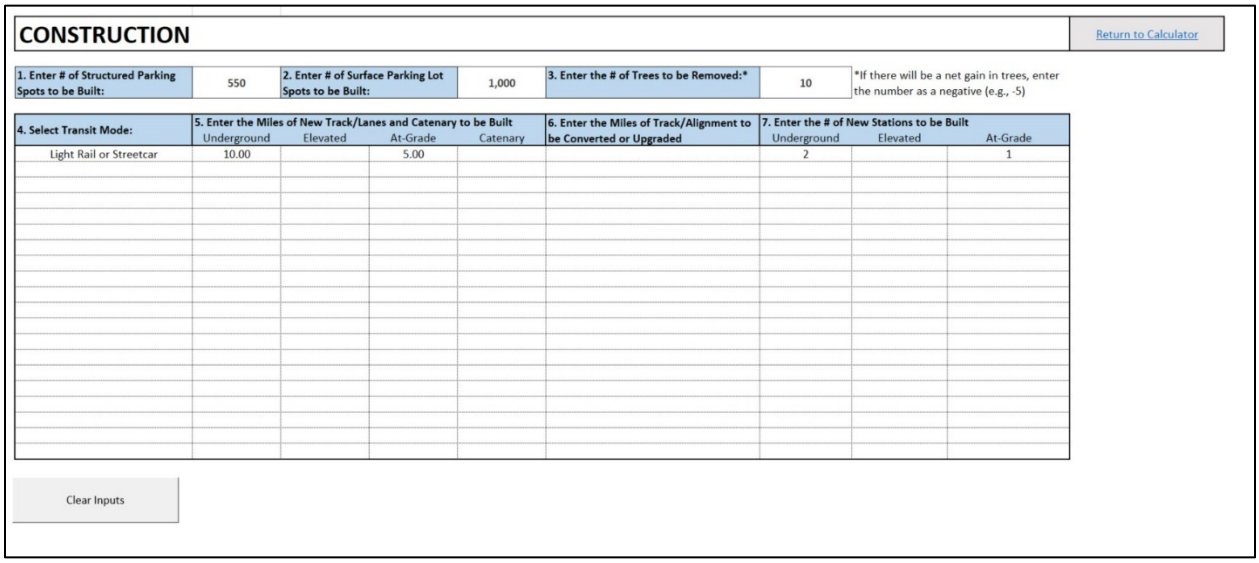
Users will then enter project information related to construction, facility operations, vehicle operations and maintenance, and displaced emissions. Users can navigate to each of the different data input screens using the buttons on the "GHG Calculator" tab, or by clicking on the individual tabs.

Step 3: Enter Construction Inputs

The annual GHG emissions from a transit project include emissions associated with new track miles, lane miles, transit stations, and/or structure (garage) and surface parking constructed as part of the project, as well as the annual, changes in carbon storage/sequestration[1] due to changes in tree cover.

The tool asks users to enter information associated with constructing a transit project (Figure 1). If this information is not applicable to the project, click the "Return to Calculator" link at the top right-hand corner of the screen or the "Facility Operations" tab to proceed to the next data input screen.

FIGURE 1: CONSTRUCTION INPUTS SCREEN



[1] Carbon sequestration describes the process by which carbon is removed from the atmosphere and stored in carbon sinks such as oceans, forests, or soils.

On the Construction tab input the following information:

1. **Structured Parking Spots:** Enter the total number of structured (garage) parking spaces that are planned to be constructed for the project.
2. **Surface Parking Lot Spots**: Enter the total number of surface parking lot spaces that are planned to be constructed for the project.
3. **Trees removed:** Enter the total number of trees that are planned to be removed due to constructing the transit project. If there will be a net gain in trees, enter the number as a negative (e.g., if a net gain of five trees is anticipated, enter -5).
4. **Select Transit Mode**: From the pull down menu, select the type of transit mode being constructed (see Appendix B for transit mode definitions).
    - Heavy Rail
    - Commuter Rail
    - Light Rail or Streetcar
    - Bus/Bus Rapid Transit (BRT)

   For each transit mode enter the following:
5. **Miles of new track/lane miles by alignment type:** Enter the number of new miles of track (or lane-miles for BRT projects) that are planned to be constructed. Enter number of miles by alignment: above ground, below ground, or at-grade.
6. **Miles of converted or upgraded track/alignment (light rail, streetcar, and BRT only):** For construction that involves converting or upgrading an existing facility, enter the number of miles of converted or upgraded track (for light rail or streetcar projects) or lane-miles (for BRT projects).
7. **Miles of catenary**: Enter the number of miles of catenary overhead wire that are planned to be constructed for the project. If the project does not use a catenary system, leave the cell blank or enter zero.
8. **Number of new stations by alignment types**: Enter the number of stations that are planned to be constructed for the project. Enter number of stations by type: above ground, below ground, or at-grade.
9. Continue to add transit construction inputs as needed to account for all transit modes associated with the project.
10. Once all construction related inputs associated with the transit project have been added click the “Return to Calculator” link at the top of the page to return to the summary/results page, or select the “Facility Maintenance” tab to move to the next data input screen.

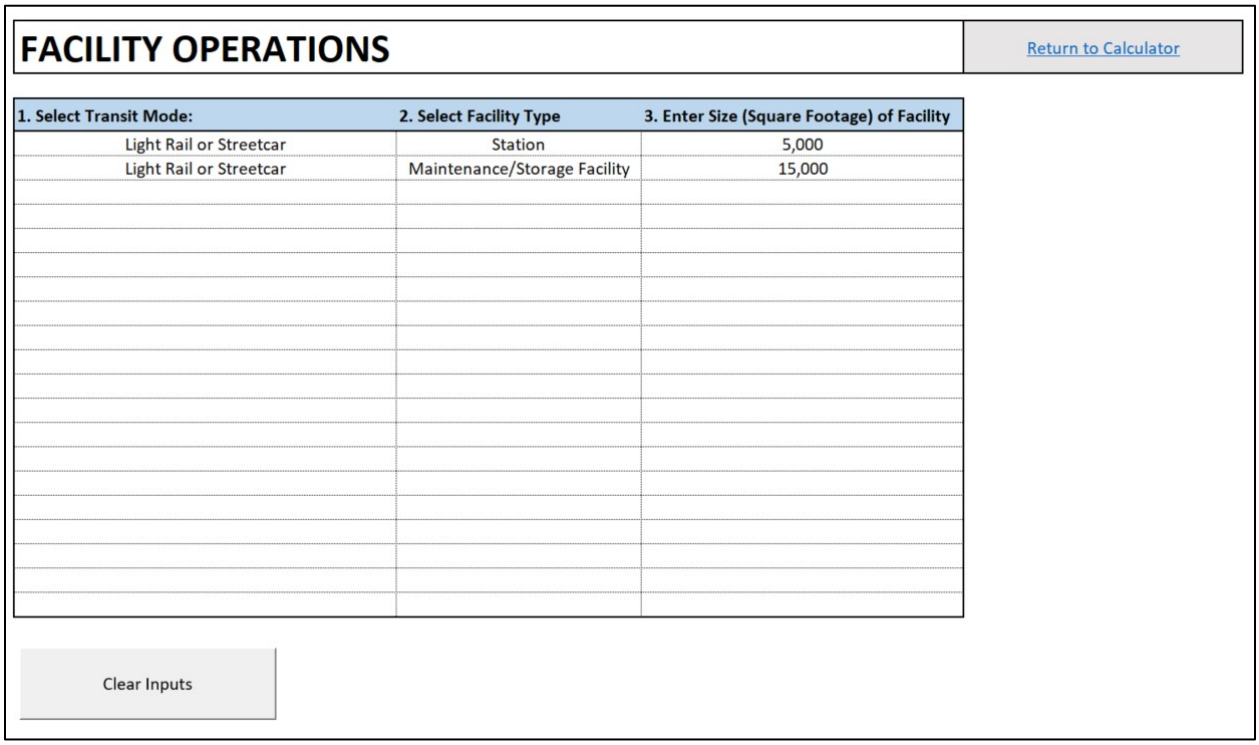
Note: The information entered on the construction page is used to generate the GHG emissions associated with maintaining the transitway.

Step 4: Enter Facility Operations Inputs

The annual GHG emissions from a transit project include emissions associated with the operations of new maintenance/storage facilities and/or transit stations constructed as part of the project. The tool asks user to enter information associated with new facilities constructed as part of the new transit

project (Figure 2). If this information is not applicable to the project, click the "Return to Calculator" link at the top right-hand corner of the screen or the "Vehicle Operations" tab to proceed to the next data input screen.

FIGURE 2: FACILITY OPERATIONS INPUTS SCREEN



On the Facility Operations tab input the following information:

1. **Select a Mode**: From the pull down menu, select the transit mode that the facility is associated with:
    - Heavy Rail
    - Commuter Rail
    - Light Rail or Streetcar
    - Bus/Bus Rapid Transit
2. **Select Building Type:** From the pull down menu, select the type of facility that will be constructed as part of the transit project:
    - Station
    - Maintenance/Storage Facility
3. **Enter Size of Facility**: Enter the size (in square footage) of the new facility to be constructed as part of the new transit project. Note: Enter the square footage for the building itself, and not the overall property.
4. Continue to add facility operations inputs as needed to account for all new facilities constructed as part of the transit project.

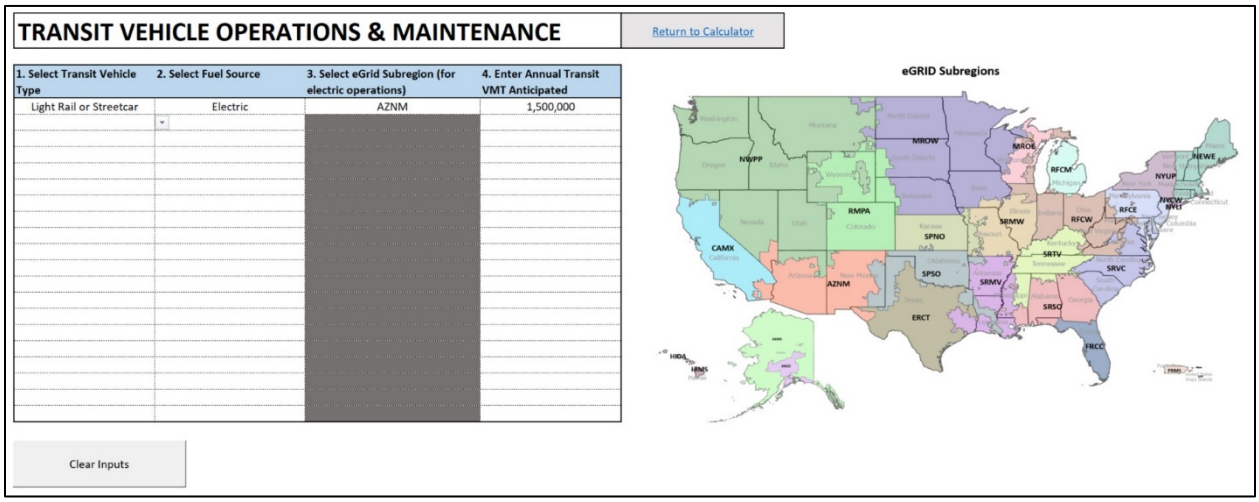
5. Once all facility operations related inputs associated with the transit project have been added click the “Return to Calculator” link at the top of the page to return to the summary/results page, or select the “Vehicle Operations & Maintenance” tab to move to the next data input screen.

Step 5: Enter Transit Vehicle Operations and Maintenance Inputs

The annual GHG emissions from a transit project include emissions associated with the operations and maintenance of rail- and road-based transit vehicles.

The tool asks user to enter information associated with vehicle operations of the new transit project (Figure 3). If this information is not applicable to the project, click the “Return to Calculator” link at the top right-hand corner of the screen or the “Displaced Emissions” tab to proceed to the next data input screen.

FIGURE 3: TRANSIT VEHICLE OPERATIONS & MAINTENANCE INPUTS SCREEN



On the Vehicle Operations tab input the following information:

1. **Select a Transit Mode:** From the pull down menu, select the type of transit mode that will operate as part of the transit project
    - Heavy Rail
    - Light Rail or Streetcar
    - Commuter Rail
    - Bus/Bus Rapid Transit
    - Vanpool
    - School bus
    - Demand Response (DR) Bus
    - Sedan/Auto
2. **Select Fuel Source:** From the drop-down menu, select the type of fuel that the transit vehicle will use to operate. Notes regarding fuel source:
    - Heavy rail, light rail, and streetcar have electric as the only fuel source option.

- The tool does not include all possible vehicle fuels for buses, demand response vehicles, and vanpools. For example, buses fueled by liquefied propane gas, ethanol, kerosene, and hydrogen are not included in the tool because either the data for the emissions associated with these fuel types were not readily available or the size of the existing fleet of these vehicles is significantly smaller than that of those buses included in the Estimator.

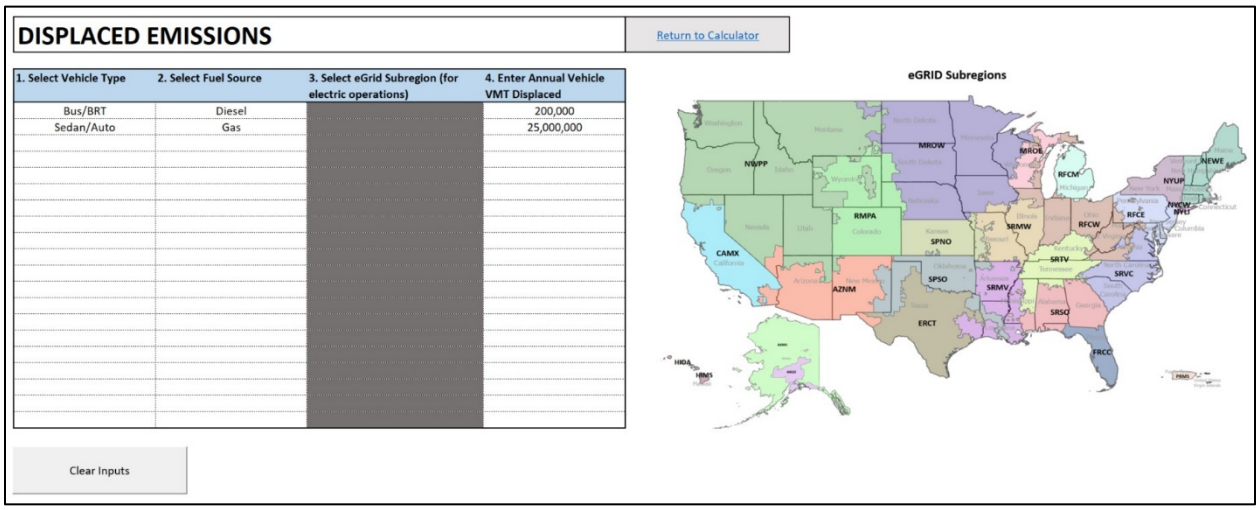
3. **Select eGrid Subregion:** For electric fuel sources, users will need to select an eGRID subregion from the corresponding drop down menu. The tool allows the user to choose the "US Mix", which represents the average electricity generation mix for the country, or an eGRID subregion, which reflects more region-specific electricity generation. Refer to the map of eGRID subregions to identify the applicable subregion or refer to the eGRID Power Profiler tool to look up the subregion by zip code.
4. **Enter Annual Transit Vehicle Miles Traveled (VMT):** Enter in the annual VMT for the selected transit mode.
5. Continue to add transit operation inputs as needed to account for all transit operations associated with the transit project.
6. Once all transit operations related inputs associated with the transit project have been added, click the "Return to Calculator" link at the top of the page to return to the summary/results page, or select the "Displaced Emissions" tab to move to the next data input screen.

Step 6: Enter Displaced Emissions Inputs

The annual GHG emissions from a transit project includes vehicle emissions displaced by the new transit project.

The tool asks users to enter information associated with transit and personal vehicle VMT that a user expects the new transit project to displace (Figure 4). If this information is not applicable to the project, click the "Return to Calculator" link at the top right-hand corner of the screen.

FIGURE 4: DISPLACED EMISSIONS INPUT SCREEN



On the Displaced Emissions, tab input the following information:

1. **Select a Mode**: From the pull down menu, select the type of mode that will have VMT displaced due to the transit project:
    - Heavy Rail
    - Light Rail or Streetcar
    - Commuter Rail
    - Bus/Bus Rapid Transit
    - Vanpool
    - School bus
    - Demand Response (DR) Bus
    - Sedan/Auto
2. **Select Fuel Source:** From the drop down menu, select the type of fuel that the vehicle is expected to use to operate. Notes regarding fuel source:
    - Heavy rail, light rail, and streetcar have electric as the only fuel source option.
    - The tool does not include all vehicle fuels for buses, demand response vehicles, and vanpools. For example, buses fueled by liquefied propane gas, ethanol, kerosene, and hydrogen are not included in the tool because either the data for the emissions associated with these fuel types were not readily available or the size of the existing fleet of these vehicles is significantly smaller than that of those buses included in the Estimator.
3. **Select eGrid Subregion:** For electric fuel source, users will also need to select an eGRID subregion from the corresponding drop down menu. The tool allows the user to choose the "US Mix", which represents the average electricity generation mix for the country, or an eGRID subregion, which reflects more region-specific electricity generation. Refer to the map of eGRID subregions to identify the applicable subregion or refer to the eGRID Power Profiler tool to look up the subregion by zip code.
4. **Enter Annual Displaced Vehicle VMT:** Enter in the annual displaced VMT for the selected vehicle type.
5. Continue to add displaced VMT inputs as needed to account for all VMT displaced due to the transit project.
6. Once all displaced VMT inputs have been added click the "Return to Calculator" link at the top of the screen to return to the GHG Calculator tab.

Step 7: View Results

Once all of the projects inputs have been entered, return to the "GHG Calculator" tab. Users can review the inputs entered for each input screen. To generate results, click the "Calculate Results" button in the Results section of the screen.

The tool displays summary and detailed results for the total annual GHG emissions and the total GHG emissions over the analysis period generated by the transit project in metric tons of CO_2 equivalent ($MTCO_2eq$). The tool presents the emissions by project phase and by upstream and downstream emissions (Figure 5).

FIGURE 5: RESULTS SCREEN

RESULTS

Calculate Results

Summary Results

	Upstream Materials	Upstream Transport	Downstream	Total
Annual	61,548	1,653	-6,808	56,393
Total Analysis Period	1,846,433	49,589	-204,228	1,691,793

Detailed Results

Annual GHG Emissions

	Upstream Materials	Upstream Transport	Downstream	Total
Construction	58,318	1,653	1,767	61,738
Transitway Maintenance	0	0	66	66
Facility Operations	0	0	148	148
Vehicle Operations	5,257	0	0	5,257
Vehicle Maintenance	0	0	18	18
Displaced Emissions	2,027	0	8,806	10,834
Cumulative Emissions	61,548	1,653	-6,808	56,393

Total GHG Emissions Over Analysis Period

	Upstream Materials	Upstream Transport	Downstream	Total
Construction	1,749,547	49,589	53,003	1,852,138
Transitway Maintenance	0	0	1,989	1,989
Facility Operations	0	0	4,429	4,429
Vehicle Operations	157,708	0	0	157,708
Vehicle Maintenance	0	0	540	540
Displaced Emissions	60,822	0	264,188	325,010
Cumulative Emissions	1,846,433	49,589	-204,228	1,691,793

4 Data Sources and Data Limitations

The Estimator uses the emissions factors listed in Appendix A to calculate GHG emissions by transit mode for the construction, maintenance, and operations phases of transit project development. This section provides details on the data sources upon which those emissions factors (and thus the Estimator) rely.

Construction Related Emission Factors

The primary data sources for construction-related GHG emissions factors in the Estimator are the Federal Highway Administration's (FHWA) Infrastructure Carbon Estimator (ICE) v2.1[2] and research by Hanson *et al* (2015)[3]:

- Emission factors for the construction of bus rapid transit facilities, and underground, at-grade, and elevated heavy rail and light rail lines and stations, and structure (garage) parking and surface parking on a per-space basis use data from FHWA's ICE v2.1. FHWA's ICE v2.1 is a planning and pre-engineering analysis tool that provides the lifecycle estimates of energy and GHG emissions based on national emission and energy use factors for materials and construction activities. ICE's lifecycle emissions include those resulting from the embodied energy and emissions associated with the extraction, transport, and production of the materials (e.g., asphalt, concrete, base stone, and steel) used in the construction of the transportation facilities, the fuel used to transport materials to site, and the energy and fuel used in construction equipment. The Estimator's commuter rail track and commuter rail station construction emissions factors are based on ICE's heavy rail construction estimates. FHWA's ICE tool provides data for heavy and light rail only and does not currently include data specific to commuter rail.

  Note, due to wide variability in the size, design, and amenities offered among transit stations, within a transit mode and among different transit modes, it is difficult to create generic assumptions regarding station construction. ICE includes emissions factors for rail stations that are based on the materials required for station structures and platforms, but the tool does not provide details on the transit station design upon which its station construction emissions are based.

- Emission factors for catenary system construction are based on data for commuter rail electrified track are from Hanson *et al* (2015). The material components for catenary systems in the Matrix's emissions factors for commuter rail and light rail include the emissions associated with the steel and aluminum in the scaffolding and copper in the copper wire. The trolleybus catenary system emissions factors includes the emissions associated with the copper component only as the copper requirements for trolleybus overhead wires are expected to be similar to that for commuter rail.

[2] FHWA. Infrastructure Carbon Estimator version 2.1. Available at http://www.dot.state.mn.us/sustainability/ghg-analysis.html.

[3] Christopher S. Hanson, Robert B. Noland & Christopher D. Porter (2016) Greenhouse gas emissions associated with materials used in commuter rail lines, International Journal of Sustainable Transportation, 10:5, 475-484, DOI: 10.1080/15568318.2014.985859

Maintenance Related Emission Factors

The Estimator's GHG emission factors for track/lane-mile maintenance use data from FHWA's ICE v2.1. ICE v2.1 accounts for direct emissions associated with routine maintenance activities such as snow removal, vegetation management, routine maintenance, among other activities.

The Estimator's GHG emission factors for vehicle maintenance use research by Chester (2008)[4], which calculated GHG emissions for vehicle maintenance for buses and rail. GHG emission rates for bus vehicle maintenance are based on a 40-foot bus. GHG emission rates for rail vehicle maintenance, which includes routine maintenance (standard upkeep and inspection), cleaning, and flooring replacement, are based on four types of vehicles: Bay Area Rapid Transit heavy rail trains, Caltrain commuter rail trains, Muni light rail trains, and the Massachusetts Bay Transit Authority's (MBTA's) Green Line light rail trains. The Estimator's emissions factors for light rail vehicle maintenance are based on an average of Chester's Muni and MBTA light rail vehicle estimates.

Vehicle Operations Related Emission Factors

The Estimator uses upstream and downstream GHG emissions factors for the operation of road- and rail-based transit vehicles across a range of fuel sources. During the operations phase, upstream emissions are associated with the extraction, production, and transportation of the vehicle fuel; downstream emissions are the tailpipe emissions resulting from the operation of a transit vehicle.

Emissions factors for road-based vehicles, including buses, are from Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, 2020 release. The vehicles included in the Estimator map to GREET vehicle types as summarized here:

ESTIMATOR VEHICLE TYPE	GREET2020 VEHICLE
Diesel bus	CIDI Transit Bus: Conventional and LS Diesel
CNG bus	SI Transit Bus: CNG, NA NG
Hybrid diesel bus	Grid-Independent CIDI Hybrid Transit Bus: Conventional and LS Diesel
Gas bus	SI: Medium Heavy-Duty Vocational Vehicle: Low-Level EtOH Blend with Gasoline
Electric bus	Transit Bus, Electricity
Vanpool and DR bus diesel	CIDI: Light Heavy-Duty Vocational, Conventional and LS Diesel
Vanpool gas	SI: Medium Heavy-Duty Vocational Vehicle: Low-Level EtOH Blend with Gasoline
School bus diesel	CIDI School Bus: Conventional and LS Diesel
School bus CNG	SI School Bus: CNG, NA NG
DR bus CNG	SI: Light Heavy-Duty Vocational: CNG, NA NG
Sedan/Auto gas	SI - Gasoline Vehicle: Gasoline
Sedan/Auto diesel	CIDI Vehicle: Conventional and LS Diesel
Sedan/Auto HEV-gas	Grid-Independent SI HEV: Gasoline
Sedan/Auto all electric	BEV Electric Vehicle
Sedan/Auto PHEV-gas	Grid-Connected SI PHEV: Gasoline and Electricity

[4] Chester, Mikhail. 2008. "Life-cycle Environmental Inventory of Passenger Transportation in the United States." University of California, Berkeley Institute of Transportation Studies.

GHG emissions factors for transit vehicles are based solely on VMT by vehicle and fuel type and do not account for additional location specific factors such as different fleet mixes, vehicle age distributions, load factors, and speed profiles.

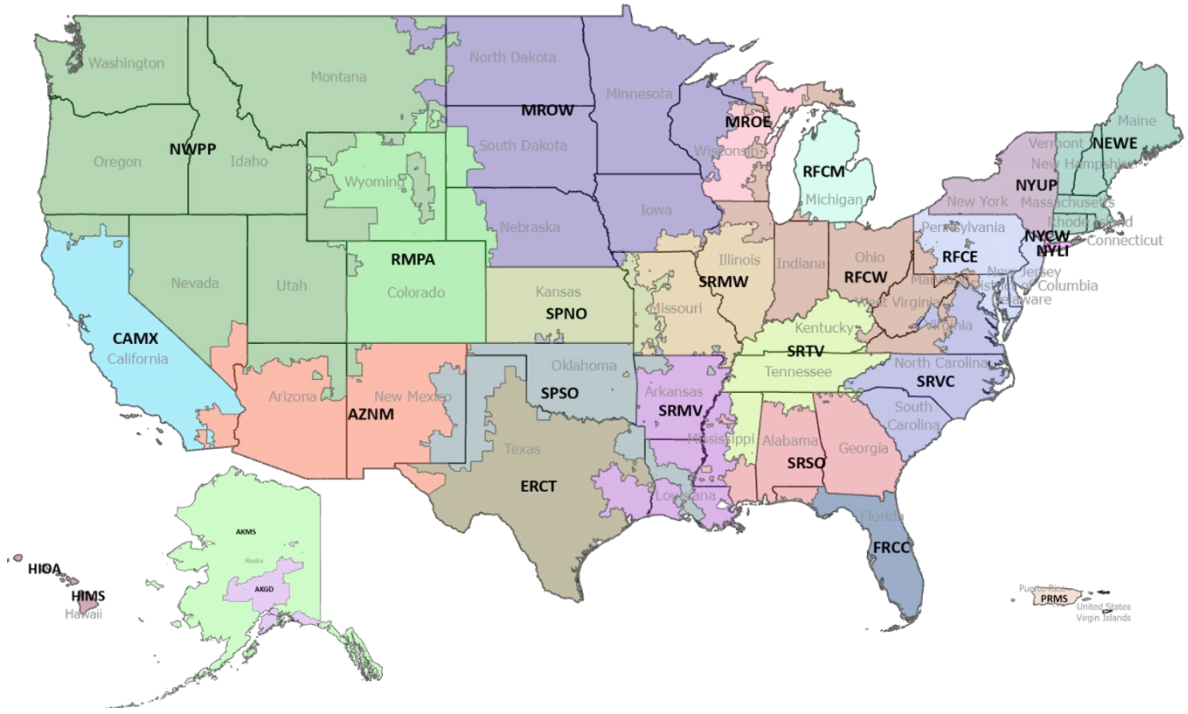
The Estimator uses emissions factors for each rail mode's electric vehicle operations based on energy consumption rates derived from energy use and transit VMT data reported in the National Transit Database (NTD) and electricity emission rates from the Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID) 2019 (see Figure 6), as follows for heavy rail and light rail:

(1) *Total 2010–2019 rail mode electricity use / Total 2010–2019 rail mode VMT = kilowatt-hours (kWh)/VMT rail mode*

(2) *kWh/VMT rail mode * eGRID2019 annual CO2eq total output emission rates*[5]

The Estimator's emissions factors for commuter rail use the same calculation but using NTD data from 2019.

FIGURE 6: eGRID SUBREGIONS



Facility Operations Related Emission Factors

Due to the wide variability in transit station and facilities in term of size, design, amenities offered, and operating efficiencies, it is difficult to create generic assumptions regarding their associated electricity and heat usage. The emissions factors for maintenance and storage facilities used in the Estimator are based on annual electricity and heating usage data from seven transit agencies; the estimates for GHG emissions from station electricity are based on data from two subway stations. The project team aggregated the information and estimated the average annual electricity and heating fuel usage per

[5] eGRID annual total output emission rates are available at https://www.epa.gov/egrid/download-data. 2019 data last accessed 3/22/21 at https://www.epa.gov/sites/production/files/2021-02/egrid2019_data.xlsx.

square foot by facility type.[6] The aggregate average annual electricity data (kWh) and heat data, provided in gallons of heating oil, therms of natural gas, and cubic feet of natural gas, were converted to GHG emissions using the following conversion factors:

1 kWh electricity = 0.00044 $MTCO_2$ (per EPA)[7]

0.01010 MCF natural gas = 1 kWh electricity[8]

1 therm = 29.3001 kWh electricity

1 gallon residual fuel oil (#6 oil) = 43.9 kWh electricity[9]

Carbon Storage Emission Factors

The Estimator uses emissions factor for the annual, per-tree carbon sequestration[10] change due to tree cover changes. The project team referred to data from the U.S. Department of Agriculture (USDA) (Novak and Crane (2002) and Zhao and Sander (2015)). That research includes estimates of the per-tree carbon storage of an urban tree in the U.S., and the volume of carbon sequestered for every one metric ton of carbon stored annually Understanding that sequestration rates depend on tree species and diameter, among other factors, the emission factor for tree storage change used in the Estimator was derived as follows:

(1) 0.22801 MT C stored per urban tree based on data from 11 American cities (Novak and Crane; Zhao and Sander)

(2) For every 1 MT C stored annually, approximately 3.67 $MTCO_2$ are sequestered per year (USDA)

*(3) 0.22801 MT C stored * 3.67 $MTCO_2$ sequestered per year = 0.8368 $MTCO_2$ sequestered/tree/year*

[6] Though cubic footage is the preferred unit of measurement for building size, the project team was limited to the available square footage information.
[7] CO_2 only. www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references 1,558.8 lbs CO2/MWh × (4.536 × 10-4 metric tons/lb) × 0.001 MWh/kWh = 4.4 × 10-4 metric tons CO2/kWh
[8] Energy Information Administration: www.eia.gov/tools/faqs/faq.cfm?id=667&t=8
[9] www.think-energy.net/energy_units.htm
[10] Carbon sequestration describes the process by which carbon is removed from the atmosphere and stored in carbon sinks such as oceans, forests, or soils.

APPENDIX A: Emissions Factors Used in the Estimator

TABLE 2: HEAVY RAIL EMISSON FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
CONSTRUCTION	TRACK MILE	UNDERGROUND	163,642	4,592	See state-specific table below	/mi
		ELEVATED	5,343	167	912	/mi
		AT-GRADE	695	110	460	/mi
	CATENARY		3,161	-	-	/mi
	STATION	UNDERGROUND	209,486	5,964	1,640	/facility
		ELEVATED	194,969	5,573	1,135	/facility
		AT-GRADE	119,188	3,433	457	/facility
MAINTENANCE	TRACK MILE	UNDERGROUND	-	-	4.42	/mi/yr
		ELEVATED	-	-	4.42	/mi/yr
		AT-GRADE	-	-	4.42	/mi/yr
	VEHICLE		-	-	0.00029	/veh-mile/yr
OPERATIONS	VEHICLE	ELECTRIC	See region-specific table below	-	-	
	STATION	ELECTRICITY	-	-	0.00739	/sqft/yr
	MAINTENANCE/ STORAGE FACILITY	ELECTRICITY	-	-	0.00559	/sqft/yr
		HEAT	-	-	0.00179	/sqft/yr

TABLE 3: COMMUTER RAIL EMISSON FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
CONSTRUCTION	TRACK MILE	UNDERGROUND	163,642	4,592	See state-specific table below	/mi
		ELEVATED	5,343	167	912	/mi
		AT-GRADE	695	110	460	/mi
	CATENARY		3,161	-	-	/mi
	STATION	UNDERGROUND	209,486	5,964	2,085	/facility
		ELEVATED	194,969	5,573	1,442	/facility
		AT-GRADE	119,188	3,433	581	/facility
MAINTENANCE	TRACK MILE	UNDERGROUND	-	-	4.42	/mi/yr
		ELEVATED	-	-	4.42	/mi/yr
		AT-GRADE	-	-	4.42	/mi/yr
	VEHICLE		-	-	0.00098	/veh-mile/yr
OPERATIONS	VEHICLE	ELECTRIC	See region-specific table below	-	-	
		DIESEL	-	-	0.02803	/veh-mile/yr
	STATION	ELECTRICITY	-	-	0.00739	/sqft/yr
	MAINTENANCE/ STORAGE FACILITY	ELECTRICITY	-	-	0.00559	/sqft/yr
		HEAT	-	-	0.00179	/sqft/yr

TABLE 4: LIGHT RAIL OR STREETCAR EMISSON FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
CONSTRUCTION	TRACK MILE	UNDERGROUND	163,642	4,592	See state-specific table below	/mi
		ELEVATED	4,901	146	793	/mi
		AT-GRADE	348	77	138	/mi
		CONVERTED OR UPGRADED	201	68	95	/mi
	CATENARY		3,161	-	-	/mi
	STATION	UNDERGROUND	52,253	1,487	782	/facility
		ELEVATED	8,337	2,399	383	/facility
		AT-GRADE	3,674	112	11	/facility
MAINTENANCE	TRACK MILE	UNDERGROUND	-	-	4.42	/mi/yr
		ELEVATED	-	-	4.42	/mi/yr
		AT-GRADE	-	-	4.42	/mi/yr
		CONVERTED OR UPGRADED	-	-	4.42	/mi/yr
	VEHICLE		-	-	-	/veh-mile/yr
OPERATIONS	VEHICLE	ELECTRIC	See region-specific table below	-	-	
	STATION	ELECTRICITY	-	-	0.00739	/sqft/yr
	MAINTENANCE/ STORAGE FACILITY	ELECTRICITY	-	-	0.00559	/sqft/yr

TABLE 5: BUS/BRT EMISSON FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
CONSTRUCTION	TRACK MILE	AT-GRADE	196	24	250	/mi
		CONVERTED OR UPGRADED	98	13	89	/mi
	CATENARY		902	-	-	/mi
	STATION	UNDERGROUND	3,674	112	11	/facility
		ELEVATED	3,674	112	11	/facility
		AT-GRADE	3,674	112	11	/facility
MAINTENANCE	TRACK MILE	AT-GRADE	-	-	0.50632	/mi/yr
	VEHICLE		-	-	0.00005	/veh-mile/yr
OPERATIONS	VEHICLE	DIESEL	0.00051	-	0.00250	/veh-mile/yr
		CNG	0.00057	-	0.00256	/veh-mile/yr
		HYBRID DIESEL	0.00037	-	0.00179	/veh-mile/yr
		GAS	0.00023	-	0.00098	/veh-mile/yr
		ELECTRIC	See Region-Specific Table	-	-	/veh-mile/yr
	STATION	ELECTRICITY	-	-	0.00739	/sqft/yr
		HEAT	-	-	0.00165	/sqft/yr
	MAINTENANCE/ STORAGE FACILITY	ELECTRICITY	-	-	0.00977	/sqft/yr
		HEAT	-	-	0.00103	/sqft/yr

TABLE 6: VANPOOL EMISSON FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
OPERATIONS	VEHICLE	DIESEL	0.00024	-	0.00119	/veh-mile/yr
		GAS	0.00023	-	0.00098	/veh-mile/yr

TABLE 7: SCHOOL BUS EMISSION FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
OPERATIONS	VEHICLE	DIESEL	0.00027	-	0.00133	/veh-mile/yr
		CNG	0.00030	-	0.00136	/veh-mile/yr

TABLE 8: DEMAND RESPONSE BUS EMISSION FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
OPERATIONS	VEHICLE	DIESEL	0.00024	-	0.00119	/veh-mile/yr
		CNG	0.00027	-	0.00121	/veh-mile/yr

TABLE 9: SEDAN / AUTOMOBILE EMISSION FACTORS

PHASE	GHG SOURCE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
OPERATIONS	VEHICLE	GAS	0.00008	-	0.00033	/veh-mile/yr
		DIESEL	0.00006	-	0.00029	/veh-mile/yr
		HYBRID ELECTRIC	0.00005	-	0.00024	/veh-mile/yr
		ALL ELECTRIC	See Region-Specific Table	-		
		PLUG-IN HYBRID ELECTRIC	See Region-Specific Table	-		

TABLE 10: PARKING EMISSION FACTORS

PHASE	GHG SOURCE	UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
CONSTRUCTION	LOT < 50	0.17000	0.07000	0.18000	/space
	LOT 50-500	0.21140	0.09120	0.20820	/space
	LOT > 500	0.22838	0.11280	0.20828	/space
	GARAGE < 50	5.3000	0.14000	1.00000	/space
	GARAGE 50-500	5.3688	0.14660	0.74740	/space
	GARAGE > 500	5.4149	0.15424	0.74222	/space

TABLE 11: CARBON STORAGE EMISSION FACTORS

PHASE		UPSTREAM MATERIALS	UPSTREAM TRANSPORT	DOWNSTREAM	MTCO2eq
CONSTRUCTION	Lost/gained carbon sequestration	-	-	0.83680	/tree/yr

State- and Region-Specific Emissions Factors

TABLE 12: STATE-SPECIFIC EMISSION FACTORS FOR DOWNSTREAM, UNDERGROUND TRACK MILE CONSTRUCTION FOR HEAVY RAIL, COMMUTER RAIL, AND LIGHT RAIL/STREETCAR

State	DOWNSTREAM	MTCO2eq
AL	4,967	/mi
AK	4,977	/mi
AZ	4,987	/mi
AR	5,165	/mi
CA	4,503	/mi
CO	5,520	/mi
CT	4,552	/mi
DC	4,352	/mi
DE	4,937	/mi
FL	5,076	/mi
GA	5,056	/mi
HI	5,570	/mi
ID	4,246	/mi
IL	4,868	/mi
IN	5,886	/mi
IA	5,046	/mi
KS	5,244	/mi
KY	6,004	/mi
LA	4,928	/mi
ME	4,404	/mi
MD	5,066	/mi
MA	4,878	/mi
MI	5,155	/mi
MN	5,066	/mi
MS	4,987	/mi
MO	5,738	/mi
MT	5,303	/mi
NE	5,333	/mi
NV	4,819	/mi
NH	4,374	/mi
NJ	4,612	/mi
NM	5,619	/mi
NY	4,523	/mi
NC	4,918	/mi
ND	5,718	/mi
OH	5,520	/mi
OK	5,096	/mi
OR	4,365	/mi
PA	4,908	/mi
RI	4,918	/mi
SC	4,681	/mi
SD	4,572	/mi
TN	5,046	/mi
TX	5,096	/mi

State	DOWNSTREAM	MTCO2eq
UT	5,678	/mi
VT	4,127	/mi
VA	4,868	/mi
WA	4,246	/mi
WV	6,024	/mi
WI	5,441	/mi
WY	6,073	/mi

TABLE 13: REGION-SPECIFIC UPSTREAM EMISSION FACTORS FOR OPERATION OF ELECTRIC HEAVY RAIL, COMMUTER RAIL, AND LIGHT RAIL/STREETCARS

eGRID Region	HEAVY RAIL OPERATIONS, UPSTREAM	COMMUTER RAIL OPERATIONS, UPSTREAM	LIGHT RAIL/STREETCAR OPERATIONS, UPSTREAM	MTCO2eq
US MIX	0.00249	0.00617	0.00358	/veh-mile/yr
AKGD	0.00285	0.00707	0.00411	/veh-mile/yr
AKMS	0.00140	0.00348	0.00202	/veh-mile/yr
AZNM	0.00243	0.00603	0.00350	/veh-mile/yr
CAMX	0.00116	0.00287	0.00167	/veh-mile/yr
ERCT	0.00222	0.00550	0.00320	/veh-mile/yr
FRCC	0.00220	0.00545	0.00317	/veh-mile/yr
HIMS	0.00304	0.00754	0.00438	/veh-mile/yr
HIOA	0.00434	0.01077	0.00625	/veh-mile/yr
MROE	0.00384	0.00954	0.00554	/veh-mile/yr
MROW	0.00281	0.00698	0.00405	/veh-mile/yr
NEWE	0.00125	0.00311	0.00181	/veh-mile/yr
NWPP	0.00183	0.00454	0.00264	/veh-mile/yr
NYCW	0.00141	0.00350	0.00203	/veh-mile/yr
NYLI	0.00310	0.00769	0.00446	/veh-mile/yr
NYUP	0.00059	0.00147	0.00085	/veh-mile/yr
PRMS	0.00392	0.00973	0.00565	/veh-mile/yr
RFCE	0.00177	0.00440	0.00256	/veh-mile/yr
RFCM	0.00304	0.00755	0.00438	/veh-mile/yr
RFCW	0.00273	0.00677	0.00394	/veh-mile/yr
RMPA	0.00318	0.00788	0.00458	/veh-mile/yr
SPNO	0.00274	0.00679	0.00395	/veh-mile/yr
SPSO	0.00256	0.00635	0.00369	/veh-mile/yr
SRMV	0.00206	0.00510	0.00297	/veh-mile/yr
SRMW	0.00406	0.01006	0.00585	/veh-mile/yr
SRSO	0.00247	0.00614	0.00357	/veh-mile/yr
SRTV	0.00243	0.00602	0.00350	/veh-mile/yr
SRVC	0.00173	0.00428	0.00249	/veh-mile/yr

TABLE 14: REGION-SPECIFIC UPSTREAM EMISSION FACTORS FOR OPERATION OF ELECTRIC BUS, SEDAN/AUTO, AND PHEV-GAS VEHICLES

NERC REGION	ELECTRIC BUS OPERATIONS UPSTREAM	ALL ELECTIC SEDAN/ AUTO OPERATIONS UPSTREAM	PHEV-GAS OPERATIONS UPSTREAM	MTCO2eq
US MIX	0.001222	0.000157	0.000106	/veh-mile/yr
ASCC	0.00157	0.000201	0.000128	/veh-mile/yr
FRCC	0.001363	0.000175	0.000114	/veh-mile/yr
HICC	0.002462	0.000316	0.000184	/veh-mile/yr
MRO	0.0018	0.00023	0.000141	/veh-mile/yr
NPCC	0.000704	0.00009	0.000072	/veh-mile/yr
RFC	0.001281	0.000164	0.000109	/veh-mile/yr
SERC	0.001253	0.000161	0.000107	/veh-mile/yr
SPP	0.001503	0.000193	0.000123	/veh-mile/yr
TRE	0.001285	0.000165	0.000109	/veh-mile/yr
WECC	0.001031	0.000127	0.00009	/veh-mile/yr

APPENDIX B. Transit Mode Definitions

Heavy rail: Heavy rail is a mode of transit service (also called metro or subway) operating on an electric railway with the capacity for a heavy volume of traffic. It is characterized by high speed and rapid acceleration passenger rail cars operating singly or in multi-car trains on fixed rails and separated rights-of-way. Heavy rail passenger cars are driven by electric power taken from overhead lines or third rails.

Commuter rail: Commuter rail is a mode of transit service characterized by an electric or diesel-propelled railway for urban passenger train service consisting of local short distance travel operating between a central city and adjacent suburbs

Light rail: Light rail is a mode of transit service operating passenger rail cars singly (or in short, usually two-car or three-car trains) on fixed rails in right-of-way that often is separated from other traffic for part or much of the way. Light rail vehicles are typically driven electrically with power being drawn from an overhead catenaries.

Streetcar: Streetcar is a mode of rail transit that operates predominantly on streets in mixed traffic. This service typically operates with single-car trains powered by overhead catenaries.

Bus: Bus is a transit mode comprised of rubber-tired passenger vehicles operating on fixed routes and schedules over roadways. Vehicles are powered by diesel, gasoline, battery, or alternative fuel engines contained within the vehicle.

Bus Rapid Transit (BRT): BRT is a fixed-route bus mode in which the majority of the line operates in a separated right-of way. The BRT vehicles are roadway vehicles powered by diesel, gasoline, battery, or alternative fuel engines contained within the vehicle.