FTA

FEDERAL TRANSIT ADMINISTRATION

# Transit Bus Electrification Tool: User Guide

**APRIL 2022**

U.S. Department of Transportation

**Federal Transit Administration**

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# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | April 2022 | User Guide |

| 4. TITLE AND SUBTITLE | 5a. FUNDING NUMBERS |
|---|---|
| Transit Bus Electrification Tool User Guide | 69319519N200024 |

| 6. AUTHOR(S) | 5b. CONTRACT NUMBER |
|---|---|
| Gina Filosa, Billy Chupp, Carson Poe, and Abigail Raymond | |

| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) | 8. PERFORMING ORGANIZATION REPORT NUMBER |
|---|---|
| U.S. Department of Transportation<br>John A Volpe National Transportation Systems Center<br>55 Broadway<br>Cambridge, MA 02142-1093 | DOT-VNTSC-FTA-22-04 |

| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER |
|---|---|
| US Department of Transportation<br>Federal Transit Administration<br>Office of Environmental Programs<br>1200 New Jersey Avenue, SE<br>Washington, DC 20590 | |

11. SUPPLEMENTARY NOTES
Project Manager: Saadat Khan

| 12a. DISTRIBUTION/AVAILABILITY STATEMENT | 12b. DISTRIBUTION CODE |
|---|---|
| This document is available to the public on the FTA website at https://www.transit.dot.gov/regulations-and-programs/environmental-programs/climate-considerations | |

13. ABSTRACT (Maximum 200 words)

The Transit Bus Electrification Tool is a Microsoft Excel-based spreadsheet tool that allows users to estimate the partial lifecycle greenhouse gas emission savings associated with replacing standard bus fleets with low-emission or zero-emission transit buses.

| 14. SUBJECT TERMS | 15. NUMBER OF PAGES |
|---|---|
| Greenhouse gas emissions, bus electrification | 9 |
| | 16. PRICE CODE |

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| Unclassified | Unclassified | Unclassified | Unlimited |

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# 1 Introduction

The Transit Bus Electrification Tool is a Microsoft Excel-based spreadsheet that allows users to estimate the partial lifecycle greenhouse gas (GHG) emissions savings associated with replacing standard bus fleets with low-emission or zero-emission transit buses.

The tool includes two components:

- The **"Add or Modify Scenario" Module**: Allows the user enters information on the annual vehicle miles traveled by fuel-type for the existing bus fleet and a replacement scenario fleet to calculate the change in emissions for a single scenario. Section 3 of this User Guide provides detailed instructions on using the module.
- The **"Compare Scenarios" Module**: Allows the user to compare the GHG emissions savings across multiple replacement scenarios created in the Add or Modify Scenario Module. Section 4 of this User Guide provides detailed instructions on using the module.

The emissions factors used in the Transit Bus Electrification Tool are listed in Section 5.

# 2 Getting Started

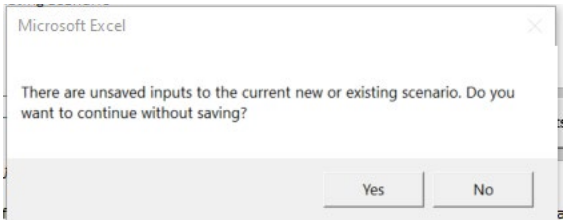
When opening the tool for the first time a user will need to enable macros. If an "Enable Content" Security Warning appears, click the "Enable Content" button. If the Security Warning does not appear when the tool is first opened, it may be necessary to change the security settings for macros. To change the setting, first exit out of the tool and re-launch Microsoft Excel without 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 Add or Modify a Scenario Component

The "Add or Modify Scenario" component allows users to estimate the partial lifecycle GHG emissions savings associated with replacing standard bus fleets with low-emission or zero-emission transit buses. The user will enter data for the existing bus fleet and a replacement scenario fleet, and the tool will calculate the change in emissions for the scenario. The user can save a scenario and then compare it to other scenarios the user creates using the "Compare Scenarios" component.

## Step 1: Select the "Add New Scenario" button

On the "Add or Modify Scenario" tab, select the "1. Add New Scenario" button. On the first use of the tool, you will receive the following message:




Click Yes. You will then be prompted to enter a name for the new scenario in the text field. Click OK.

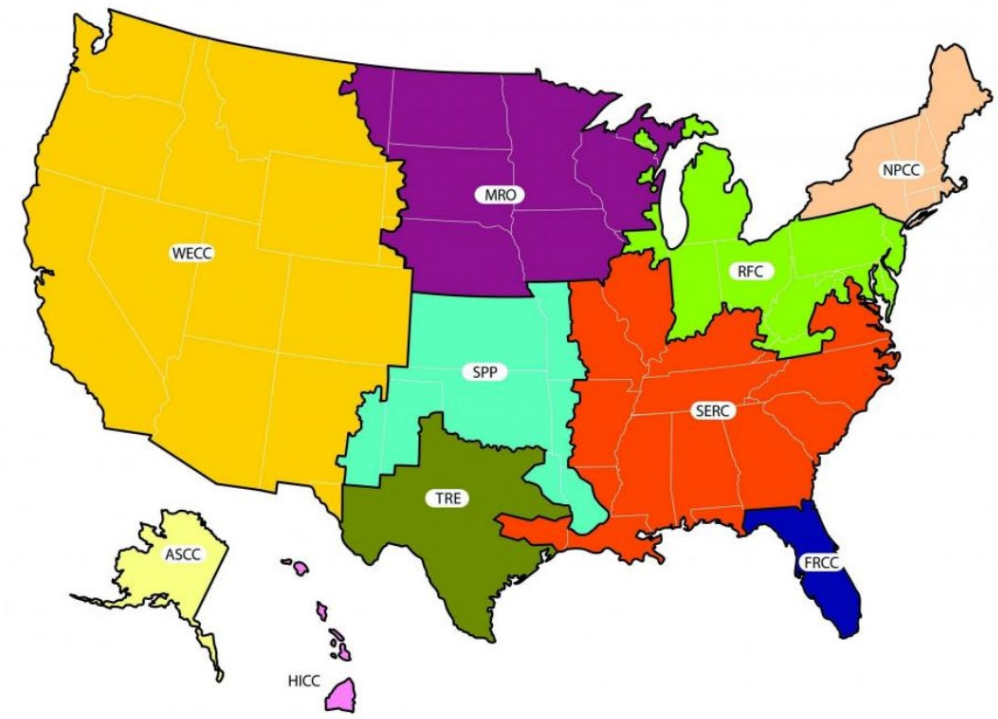
Note: In addition to adding a new scenario from scratch, users can choose a saved scenario from the drop-down menu and select the "Copy Scenario" button. The user will be prompted to enter a name from the new scenario. The user will then modify the inputs, as needed, and save the new scenario.

## Step 2: Select Electricity Generation Mix by Region

Select the applicable electricity generation mix by region 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;
- Regional electricity generation mix based on the North Atlantic Reliability Corporation (NERC) region, which reflects more region-specific electricity generation information. Refer to the map of NERC regions (see Figure 1) to identify the applicable region;
- 100%-renewable energy, which should be used in cases where the electricity used to charge the vehicle is entirely from renewable energy sources.

**FIGURE 1: ELECTRICITY REGIONS**




*Source: GREET 2021*

## Step 3: Enter Data for Baseline Fleet and Replacement Scenario (Future Bus Fleet)

Input the annual activity data (i.e., vehicle miles traveled) for the existing bus and the replacement scenario fleets by vehicle fuel-type. Users can enter the activity data by either 1) number of buses and average VMT per bus *OR* 2) annual VMT for the entire bus fleet of the fuel type(s) of choice.

**FIGURE 2: BASELINE AND REPLACEMENT SCENARIO INPUTS TABLE**

| | | Baseline: Existing Bus Fleet | | | Replacement Scenario: Future Bus Fleet | | |
|---|---|---|---|---|---|---|---|
| Fuel Type | Activity Input Type | Number of Buses | Average Annual VMT Per Bus | Annual Fleet VMT | Number of Buses | Average Annual VMT Per Bus | Annual Fleet VMT |
| | | | | | | | |
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For each row in the Baseline and Replacement Scenario Inputs table enter the following information:

- **Select Fuel Type:** From the drop-down menu select the fleet's fuel type:
  - Compressed Natural Gas (CNG)
  - Diesel
  - Hybrid Diesel

- Gas
- Hydrogen Fuel Cell
- Electric
- Liquified Natural Gas (LNG)

- **Select Activity Input Type**: From the drop-down menu select how activity data will be entered:
  - VMT by Bus: User will be prompted to enter the number of buses and the average annual VMT per bus.
  - Annual Fleet VMT: User will be prompted to enter the annual VMT for the fleet of buses of the chosen fuel type.
- **Enter Activity Data for Baseline Fleet.** Users enter the activity data for the existing bus fleet. The National Transit Database (NTD) is one source for agency-specific data for the existing bus fleet. Two useful NTD data reports are:
  - Fuel and Energy Table: The Fuel and Energy NTD Report provides information on the total number of vehicles operated in maximum service (VOMS) broken down by fuel/propulsion type and the total annual vehicle miles traveled for each fleet type. [1]
  - Annual Database Vehicle Revenue Inventory: The Annual Database Revenue Vehicle Inventory contains more granular information on revenue vehicles by mode and type of service (TOS) and provides data on total miles for active vehicles during the reporting period. This dataset may be useful for agencies seeking to model replacing a subset of their fleet, such as older vehicles. [2]
- **Enter Activity Data for Replacement Scenario.** User will enter the activity data for the fuel-based fleet under the replacement scenario/future condition. See the Example Data Entry section below for an example data entry of a replacement scenario.
- Continue to add rows to the table until the agency's fleet for each different fuel type is fully represented.

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**Example Data Entry**

In this example, the agency's existing bus fleet includes both diesel and CNG buses. The agency is considering replacing half of its diesel bus fleet with new electric buses. The agency does not plan to make any changes to its CNG bus fleet. In Example A, the user has chosen to enter data on the VMT for the annual fleet. In Example B, the user has chosen to enter data on the average annual VMT per bus.

**Example A: Annual Fleet VMT Data Entry Option**

The agency's current fleet of diesel buses has an annual fleet VMT of 560,000 miles. In this example, the agency does not plan to make any changes to the overall VMT of its fleet and thus the VMT used for the existing baseline fleet and the replacement scenario future bus fleet will be the same. Under the replacement scenario, half of the diesel fleet (and by default half of the fleet VMT) will be replaced with

[1] The 2020 Fuel and Energy Report is available at https://www.transit.dot.gov/ntd/data-product/2020-fuel-and-energy
[2] The 2020 Annual Database Revenue Vehicle Inventory is available at https://www.transit.dot.gov/ntd/data-product/2020-annual-database-revenue-vehicle-inventory

electric vehicles. Under the replacement scenario section, the VMT for the diesel fleet is reduced by half (to 280,000 miles), and the annual VMT for the electric fleet is increased by 280,000 miles. Since the agency does not plan to make any changes to its CNG bus fleet, (in terms of number of buses and per-bus VMT), the annual VMT for the CNG fleet is the same for the baseline and replacement scenario. See Figure 3.

**FIGURE 3: ANNUAL FLEET VMT DATA ENTRY EXAMPLE**

| | | Baseline: Existing Bus Fleet | | | Replacement Scenario: Future Bus Fleet | | |
|---|---|---|---|---|---|---|---|
| Fuel Type | Activity Input Type | Number of Buses | Average Annual VMT Per Bus | Annual Fleet VMT | Number of Buses | Average Annual VMT Per Bus | Annual Fleet VMT |
| Diesel | Annual Fleet VMT | | | 560,000 | | | 280,000 |
| CNG | Annual Fleet VMT | | | 250,000 | | | 250,000 |
| Electric | Annual Fleet VMT | | | 0 | | | 280,000 |
| | | | | | | | |

**Example B: VMT By Bus Data Entry Option**

In Example B, the user has chosen to enter data on the average annual VMT per bus. The agency's current fleet of diesel buses includes 25 buses that travel an average of 22,400 miles annually. Under the replacement scenario, the agency plans to replace 13 of the diesel buses with new electric buses. Under the replacement scenario section, the number of diesel buses is reduced by 13 (to 12 buses), and the number of electric buses is increased by 13. The agency assumes that both the diesel and new electric buses will continue to operate 22,400 miles per year. Since the agency does not plan to make any changes to its CNG bus fleet (in terms of number of buses and per-bus VMT), the number of buses and average annual VMT per CNG bus is the same for the baseline and replacement scenario. See Figure 4.

**FIGURE 4: VMT BY BUS ENTRY EXAMPLE**

| | | Baseline: Existing Bus Fleet | | | Replacement Scenario: Future Bus Fleet | | |
|---|---|---|---|---|---|---|---|
| Fuel Type | Activity Input Type | Number of Buses | Average Annual VMT Per Bus | Annual Fleet VMT | Number of Buses | Average Annual VMT Per Bus | Annual Fleet VMT |
| Diesel | VMT By Bus | 25 | 22,400 | | 12 | 22,400 | |
| CNG | VMT By Bus | 20 | 12,500 | | 20 | 12,500 | |
| Electric | VMT By Bus | 0 | 0 | | 13 | 22,400 | |
| | | | | | | | |

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## Step 4: Calculate Results

Once all inputs associated with the replacement scenario click the "2. Calculate Results" button. The tool will generate estimates of the GHG emissions for the baseline fleet and the replacement scenario fleet in metric tons of carbon dioxide equivalent ($MTCO_2eq$). The results section calculates the total change and percent change in GHG emissions between the baseline and replacement scenario. A negative number/percentage indicates that the replacement scenario would be expected to reduce GHG emissions, while a positive number indicates the that the replacement scenario would be expected to increase GHG emissions.

## Step 5: Save Scenario

Press the "3. Save Scenario" button to save the scenario. Saving a scenario will allow the user to view this scenario in comparison with other saved scenarios on the "Compare Scenarios" tab.

# 4 Compare Scenarios

The "Compare Scenarios" tab allows a user to compare the GHG emissions savings across multiple replacement scenarios.

To compare scenarios, a user will select a saved scenario from the scenario name drop-down menu. The tool will populate the fleet VMT and total GHG emissions for the baseline fleet and the replacement scenario and tabulate the change in VMT and change in annual GHG emissions (see Figure 5).

The user can continue to add scenarios to the table by selecting a saved scenario from the scenario name drop-down menu. The user can sum the results for the selected scenarios by selecting yes from the drop-down menu below the scenario comparison table.

To remove a scenario from the comparison table, click on the scenario name and press the delete button.

**FIGURE 5: SCENARIO COMPARISON EXAMPLE**

Select scenarios to compare using the drop down menu below.

| | Baseline: Existing Bus Fleet | | Replacement Scenario: Future Bus Fleet | | | | |
|---|---|---|---|---|---|---|---|
| Scenario Name | Total Fleet VMT (miles) | Total GHG Emissions (MTCO2eq) | Total Fleet VMT (miles) | Total GHG Emissions (MTCO2eq) | Change in VMT (Before-After, miles) | Annual Change in GHG Emissions (MTCO2eq) | Annual Percent Change in GHG Emissions |
| 25% Scenario | 10,000,000 | 19,540.0 | 10,000,000 | 17,255.0 | 0 | -2,285.0 | -11.69% |
| 50% Scenario | 10,000,000 | 19,540.0 | 10,000,000 | 14,970.0 | 0 | -4,570.0 | -23.39% |

| | |
|---|---|
| Sum results for all selected scenarios? | Yes |

| | Baseline: Existing Bus Fleet | | Replacement Scenario: Future Bus Fleet | | | | |
|---|---|---|---|---|---|---|---|
| | Total Fleet VMT (miles) | Total GHG Emissions (MTCO2eq) | Total Fleet VMT (miles) | Total GHG Emissions (MTCO2eq) | Total Change in VMT (Before-After, miles) | Total Change in GHG Emissions (MTCO2eq) | Percent Change in Total GHG Emissions |
| Totals for all scenarios | 20,000,000 | 39,080 | 20,000,000 | 32,225 | 0 | -6,855 | -18% |

# 5 Data Sources and Data Limitations

## 5.1 Built-In Emissions Factors

The Transit Bus Electrification Tool uses the upstream and downstream[3] GHG emissions factors listed in Table 2 to generate the GHG emissions by bus fuel source. These factors are derived from the Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, 2021 release (October 11, 2021). The vehicles included in the Bus Transit Electrification Tool map to GREET vehicle types as summarized in Table 1. The bus emission data is based on a 40-foot bus.

**TABLE 1: GREET VEHICLE TYPE**

| ESTIMATOR VEHICLE TYPE | GREET2021 VEHICLE |
|---|---|
| **Diesel bus** | CIDI Transit Bus: Conventional and LS Diesel |
| **CNG bus** | SI Transit Bus: CNG, NA NG |
| **LNG bus** | SI Transit Bus: LNG, 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[4] |
| **Hydrogen Fuel Cell bus** | Fuel-Cell Vehicle: G.H2, Central Plants, NA NG |
| **Electric bus** | Transit Bus, Electricity |

The GREET model includes GHG emissions from the electric generation mixes for the national averaged electricity generation mix and for each major region, as defined by the North American Electric Reliability Corporation (NERC). NERC divides the North America electric utility system into eight major regions – Florida Reliability Coordinating Council (FRCC), Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability First Corporation (RFC), SERC Reliability Corporation (SERC), Southwest Power Pool, RE (SPP), Texas Reliability Entity (TRE), and Western Electricity Coordinating Council (WECC). Other than these regions, electric generation mixes for Hawaii (HICC) and Alaska (ASCC) are also included in GREET.[5]

The GHG emissions factors 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.

**TABLE 2: GHG EMISSION FACTORS**

| Fuel Type | GHG EMISSIONS | | |
|---|---|---|---|
| | Upstream Emissions | Downstream Emissions | Total Emissions |
| Diesel | 0.00034 | 0.00162 | 0.00195 |
| CNG | 0.00042 | 0.00151 | 0.00192 |
| LNG | 0.000485 | 0.00151 | 0.00200 |

[3] 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 the bus

[4] Emission factors for gas buses are from GREET Model, 2020 release. The 2021 version for GREET does not include data for gasoline-powered buses.

[5] Argonne National Laboratory. October 2021. Summary of Expansions and Updates in GREET® 2021. https://greet.es.anl.gov/files/greet-2021-summary

| Fuel Type | GHG EMISSIONS | | |
|---|---|---|---|
| | Upstream Emissions | Downstream Emissions | Total Emissions |
| HYBRID DIESEL | 0.00028 | 0.00134 | 0.00162 |
| GAS | 0.00023 | 0.00098 | 0.00121 |
| HYDROGEN FUEL CELL | 0.00135 | 0.00000 | 0.00135 |
| ELECTRIC - US MIX | 0.00104 | 0.00000 | 0.00104 |
| ELECTRIC - ASCC | 0.00143 | 0.00000 | 0.00143 |
| ELECTRIC - FRCC | 0.00115 | 0.00000 | 0.00115 |
| ELECTRIC - HICC | 0.00218 | 0.00000 | 0.00218 |
| ELECTRIC - MRO | 0.00148 | 0.00000 | 0.00148 |
| ELECTRIC - NPCC | 0.00060 | 0.00000 | 0.00060 |
| ELECTRIC - RFC | 0.00103 | 0.00000 | 0.00103 |
| ELECTRIC - SERC | 0.00098 | 0.00000 | 0.00098 |
| ELECTRIC - SPP | 0.00120 | 0.00000 | 0.00120 |
| ELECTRIC -TRE | 0.00098 | 0.00000 | 0.00098 |
| ELECTRIC -WECC | 0.00084 | 0.00000 | 0.00084 |
| ELECTRIC -100% renewable energy | 0.00000 | 0.00000 | 0.00000 |

## 5.2 User-Supplied GHG Emissions Factors

In some cases, users may have access to transit bus GHG emissions factors that are applicable to their specific locality, bus fleet, or analysis years. Users can replace the emission factors in the "Bus GHG Emissions Data" tab in the tool with more location or fleet-specific GHG emissions factors. Users should update values in the "Total Emissions" column of the table only for fuel types for which they have more accurate data. All GHG emissions factors should be input in terms of MTCO2eq per vehicle mile per year.

Location or fleet-specific GHG emissions factors may be available from several sources. Emissions models such as EPA's Motor Vehicle Emissions Simulator (MOVES) [6] consider factors like vehicle model years, local meteorology, and local average roadway grade when estimating downstream emissions factors for many fuel types. Other sources include on-vehicle emissions testing, and local instead of national standards.

[6] EPA, MOVES, https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves