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Application Snapshot

Project Title: Breathing Easy, Riding Green: Powering BEBs for a More Equitable and Sustainable Future

Applicant: Research Triangle Regional Public Transportation Authority (GoTriangle)

Contact: Jay Heikes, GoTriangle

(O) 919.485.7481, (E) jheikes@gotriangle.org

GoTriangle Employer Identification Number (EIN): 56-1718037

Unique Entity Identifier (UEI): RV6CKH6QRJ36

DUNS No. 801047812

Website: [www.gotriangle.org/BOMF](http://www.gotriangle.org/BOMF)

## Introduction

This GHG Technical Appendix explains the methodology and assumptions for developing the estimated GHG emission reductions for Measures 1 and 2 of this application. The attached GHG Emission Reduction Calculations spreadsheet (GHGcalcs\_GoTriangle.xlsx) demonstrates the specific formulas and assumptions used to determine the anticipated emissions reductions. “GHG 00 – Summary” (Sheet 1) provides an overview of estimated metric tons of CO<sub>2</sub>e avoided in 2025-2030 and 2025-2050, requested funding, and cost effectiveness. “GHG 01 – BEB” (Sheet 2) details the inputs, assumptions, and calculations for annual and cumulative emissions reductions estimated for Measure 1. “GHG 02 – PV” (Sheet 3) details the inputs, assumptions, and calculations for annual and cumulative emissions reductions estimated for Measure 2.

Reduction Measure	2025-2030 MT CO <sub>2</sub> e Emissions Avoided	2025-2050 MT CO <sub>2</sub> e Emissions Avoided	Estimated Costs
Measure #1: BEBs	2,544.48	10,481.65	\$ 13,215,200
Measure #2: PVs	1,913.05	15,047.30	\$ 6,659,120
<b>Totals</b>	<b>4,457.54</b>	<b>25,528.95</b>	<b>\$ 19,874,320</b>
Less 20% Applicant Match			\$ 3,974,864
<b>Total CPRG Request</b>			<b>\$ 15,899,456</b>
<b>Cost Effectiveness (\$/MT CO<sub>2</sub>e)</b>	<b>\$ 3,566.87</b>	<b>\$ 622.80</b>	

## 1 Measure 1: Battery Electric Buses and Charging Infrastructure

### Reference Case Scenario

To determine the estimated emissions reductions for Measure 1: Battery-Electric Buses (BEBs) and Charging Infrastructure, the calculations were performed based on projected “business as usual” emissions of 10 diesel buses operating plus diesel fuel deliveries for 10 buses.

Sheet “GHG 01 – BEB” of the Calculations spreadsheet demonstrates projected future GHG emissions in the absence of this implemented measure. As seen below under *Table 1B: Emissions Factors and Associated Emissions*, estimated CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions are converted to MT CO<sub>2</sub>e/year and projected for 10 diesel-powered buses. GoTriangle is seeking to replace 10 diesel buses with 10 BEBs and various chargers as we work to electrify our fleet.

### 1.a Tables 1A: Measure-Specific Activity Data

Table 1A establishes the measure-specific activity data—as well as the estimate methods, tools, and assumptions needed to establish this measure-specific activity data—utilized to calculate annual and cumulative emissions reductions for 10 buses.

#### GoTriangle and Nelson Road BOMF Site Data:

- There are 2 underground diesel fuel tanks storing 20,000 gallons of diesel fuel each, for a total of 40,000 gallons.
- 10 diesel buses are being replaced with 10 battery-electric buses (BEBs).
- As a regional public transit provider, GoTriangle is operational 365 days a year.

#### Measure Implementation Assumptions:

- Total miles in a year for 1 bus averaged around 28,000 post-COVID. For years 2025-2050, an assumed 20%-50% increase has been factored into the calculation, which led to an average of 35% increased mileage. In total, 37,800 miles have been used to inform the calculations.

- The diesel fuel supplier is located in Selma, North Carolina which is 46 miles away from the Bus Operations and Maintenance Facility (BOMF), making a round trip of 92 miles.

#### Tools Used:

- AFLEET Tool<sup>1</sup> was used to quantify miles per gallon for two vehicle types:
  - A transit bus with a mileage of 37,800 miles/year (28,000 miles x 35% increased mileage) amounts to 4.4 miles/gallon.
  - A combination short-haul truck was selected in the AFLEET Tool for the diesel fuel truck. The standard input for the tool reflected 65,000 miles/year, which amounts to 4.5 miles/gallon.

**AFLEET Online**

Home Payback On-road Payback Off-road TCO

Vehicle Info Fuel Prices Fuel Options

Vehicle Type **Transit Bus**

State North Carolina

Quantity 1 vehicle(s)

Vehicle Mileage 37,800 mi/year

Powertrains to Compare

Powertrain	Fuel Economy (MPDGE)	Purchase Price (\$/vehicle)	Maintenance (\$/mi)
<input type="checkbox"/> Gasoline	3.7	0	0.00
<input checked="" type="checkbox"/> Diesel	4.4	500,000	1.00
<input type="checkbox"/> EV	11.2	900,000	0.60
<input type="checkbox"/> FCV	7.4	1,125,000	0.60

**AFLEET Online**

Home Payback On-road Payback Off-road TCO

Vehicle Info Fuel Prices Fuel Options

Vehicle Type **Combination Short-Haul Truck**

State North Carolina

Quantity 1 vehicle(s)

Vehicle Mileage 65,000 mi/year

Powertrains to Compare

Powertrain	Fuel Economy (MPDGE)	Purchase Price (\$/vehicle)	Maintenance (\$/mi)
<input type="checkbox"/> Gasoline	3.7	0	0.00
<input checked="" type="checkbox"/> Diesel	4.5	130,000	0.60

#### Calculations for Diesel Consumption of Transit Buses:

- Total miles/year per 1 bus, plus 35% projected growth = 28,000 \* 1.35 = projecting 37,800 miles/year/bus
- Total miles/year per 1 bus ÷ days/year = 37,800 ÷ 365 = 103.56 miles/day/bus
- Total miles/day per 1 bus ÷ miles/gallon = 103.56 ÷ 4.4 miles/gallon (per AFLEET) = 23.54 gallons/day/bus
- Total gallons consumed per day for 10 buses = 23.54 gal/day/bus \* 10 buses = 235.37 gallons/day/10 buses

#### Calculations for Diesel Consumption of Delivery Trucks:

- Total gallons consumed per day for 10 buses = 23.54 gal/day/bus \* 10 buses = 235.37 gallons/day/10 buses
- Total days for 10 buses to empty tanks = 40,000 gallons/2 tanks ÷ 235.4 gal/day/10 buses = 169.95 days
- Number of fuel delivery trips to fuel 10 diesel buses = days in a year ÷ days for 10 buses to empty 40,000-gallon tanks in a year = 365 days/year ÷ 169.95 days/refuel = 2.15 fuel deliveries/year
- Total miles driven by fuel truck each year to site, to provide fuel for 10 diesel buses = 92 miles round trip \* 2.15 deliveries per year = 198 miles roundtrip

<sup>1</sup> Argonne National Lab, AFLEET Online Tool.  
<https://afleet.es.anl.gov/afleet/>.

- Total gallons consumed per year for fuel deliveries for 10 diesel buses = 198 miles/refill ÷ 4.50 miles/gallon (as per AFLEET for short haul truck) = 43.91 gallons/year
- Total gallons per day for fuel deliveries of 10 diesel buses = 43.91 gallons/year ÷ 365 days = 0.12 gallons/day for fuel deliveries
- Total gallons of diesel per day = 235.37 gallons/day (10 diesel buses) + 0.12 gallons/day (diesel refuel trucks) = 235.49 gallons/day total (10 buses + fuel deliveries for 10 buses)

## 1.b Table 1B: Emissions Factors and Associated Emissions

### GHG Reduction Estimate Assumptions:

- As per NOFO Appendix B: Global Warming Potentials (GWPs) for GHGs, as informed by the 2013 IPCC AR5 Fifth Assessment Report, the 100-year GWP for greenhouse gases referenced in the calculations are as follows:
  - Carbon dioxide (CO<sub>2</sub>) = 1
  - Methane (CH<sub>4</sub>) = 28
  - Nitrous Oxide (N<sub>2</sub>O) = 265
- The emissions factors for each of the greenhouse gases have been informed by the Emissions Factors for Transport Fuel Use by GHG Protocol.<sup>2</sup>
  - As per “Table 12. CO<sub>2</sub> Emission Factors by Fuel” below, the emission factor for US on-road diesel fuel is 10.15 kilograms/US gallon.

Fuel	Region	CO <sub>2</sub>	CO <sub>2</sub> - Biomass Fuel	CO <sub>2</sub> Unit - Numerator	CO <sub>2</sub> Unit - Denominator
Jet Fuel	Other	9.428		Kilogram	US Gallon
Aviation Gasoline	Other	8.333		Kilogram	US Gallon
Gasoline/Petrol	Other	8.5987		Kilogram	US Gallon
On-Road Diesel Fuel	Other	10.131		Kilogram	US Gallon
Residual Fuel Oil (3s 5 and 6)	Other	11.125		Kilogram	US Gallon
LPG	Other	6.1		Kilogram	US Gallon
CNG	Other	0.053		Kilogram	Standard Cubic Foot
LNG	Other	4.46		Kilogram	US Gallon
Ethanol	Other		5.56	Kilogram	US Gallon
100% Biodiesel	Other		9.46	Kilogram	US Gallon
E85 Ethanol/Gasoline	Other	1.2898	4.726	Kilogram	US Gallon
B20 Biodiesel/Diesel	Other	8.1044	1.892	Kilogram	US Gallon
Jet Fuel	UK	9.5461		Kilogram	US Gallon
Aviation Gasoline	UK	8.373		Kilogram	US Gallon
Gasoline/Petrol	UK	8.7133		Kilogram	US Gallon
On-Road Diesel Fuel	UK	9.9984		Kilogram	US Gallon
Residual Fuel Oil (3s 5 and 6)	UK	9.5767		Kilogram	US Gallon
LPG	UK	5.641		Kilogram	US Gallon
CNG	UK	0.0573		Kilogram	Standard Cubic Foot
LNG	UK	4.6455		Kilogram	US Gallon
Ethanol	UK		5.56	Kilogram	US Gallon
100% Biodiesel	UK		9.46	Kilogram	US Gallon
E85 Ethanol/Gasoline	UK	1.307	4.726	Kilogram	US Gallon
B20 Biodiesel/Diesel	UK	7.9987	1.892	Kilogram	US Gallon
Jet Fuel	US	9.57		Kilogram	US Gallon
Aviation Gasoline	US	8.32		Kilogram	US Gallon
Gasoline/Petrol	US	8.81		Kilogram	US Gallon
On-Road Diesel Fuel	US	10.15		Kilogram	US Gallon
Residual Fuel Oil (3s 5 and 6)	US	11.8		Kilogram	US Gallon
LPG	US	5.79		Kilogram	US Gallon
CNG	US	0.054		Kilogram	Standard Cubic Foot
LNG	US	4.46		Kilogram	US Gallon
Ethanol	US		5.56	Kilogram	US Gallon
100% Biodiesel	US		9.46	Kilogram	US Gallon
E85 Ethanol/Gasoline	US	1.3215	4.726	Kilogram	US Gallon
B20 Biodiesel/Diesel	US	8.12	1.892	Kilogram	US Gallon

- As per “Table 13. CH<sub>4</sub> and N<sub>2</sub>O Emission Factors by Fuel” below, the emissions factors for US diesel buses are 0.01887 grams/US gallon for CH<sub>4</sub> and 0.01776 grams/US gallon for N<sub>2</sub>O.

<sup>2</sup> GHG Protocol. “CO<sub>2</sub> Emissions Factor for Transport Fuel Use”, (March 2017).

[https://ghgprotocol.org/sites/default/files/Emission\\_Factors\\_from\\_Cross\\_Sector\\_Tools\\_March\\_2017.xlsx](https://ghgprotocol.org/sites/default/files/Emission_Factors_from_Cross_Sector_Tools_March_2017.xlsx)

**Table 13. CH<sub>4</sub> and N<sub>2</sub>O Emission Factors by Fuel**

Transport and Fuel	Region	CH <sub>4</sub>	CH <sub>4</sub> Unit - Numer.	CH <sub>4</sub> Unit - Denomin.	N <sub>2</sub> O	N <sub>2</sub> O Unit - Numer.	N <sub>2</sub> O Unit - Denomin.
Train - Diesel Fuel	UK	0.8	Gram	US Gallon	0.26	Gram	US Gallon
Other	UK	0	Gram	US Gallon	0	Gram	US Gallon
Agricultural Equipment - Gasoline	UK	1.26	Gram	US Gallon	0.22	Gram	US Gallon
Agricultural Equipment - Diesel Fuel	UK	1.44	Gram	US Gallon	0.26	Gram	US Gallon
Construction Equipment - Gasoline	UK	0.5	Gram	US Gallon	0.22	Gram	US Gallon
Construction Equipment - Diesel Fuel	UK	0.58	Gram	US Gallon	0.26	Gram	US Gallon
Other	UK	0	Gram	US Gallon	0	Gram	US Gallon
Ship and Boat - Residual Fuel Oil	UK	0.86	Gram	US Gallon	0.3	Gram	US Gallon
Ship and Boat - Diesel Fuel	UK	0.74	Gram	US Gallon	0.26	Gram	US Gallon
Ship and Boat - Gasoline	UK	0.64	Gram	US Gallon	0.22	Gram	US Gallon
Other	UK	0	Gram	US Gallon	0	Gram	US Gallon
Train - Diesel Fuel	US	0.8	Gram	US Gallon	0.26	Gram	US Gallon
Agricultural Equipment - Gasoline	US	1.26	Gram	US Gallon	0.22	Gram	US Gallon
Agricultural Equipment - Diesel Fuel	US	1.44	Gram	US Gallon	0.26	Gram	US Gallon
Construction Equipment - Gasoline	US	0.5	Gram	US Gallon	0.22	Gram	US Gallon
Construction Equipment - Diesel Fuel	US	0.58	Gram	US Gallon	0.26	Gram	US Gallon
Bus - CNG	US	4.784	Gram	US Gallon	0.42	Gram	US Gallon
Bus - Ethanol	US	0.885	Gram	US Gallon	0.875	Gram	US Gallon
Bus - Diesel	US	0.01887	Gram	US Gallon	0.01776	Gram	US Gallon
Bus - Gasoline	US	0.105	Gram	US Gallon	0.085	Gram	US Gallon

### Calculations for Estimated Annual Emissions:

- The emission factors are converted to unified units from grams/gallon and kilograms/gallon to metric tons of the respective gas/gallon of diesel:
  - $\text{CO}_2 = (10.15 \text{ kilograms/gallon}) \div 1,000 \text{ kg/MT} = 0.010150 \text{ MT CO}_2/\text{gallon}$
  - $\text{CH}_4 = (0.01887 \text{ grams/gallon}) \div 1,000,000 \text{ g/MT} = 1.89 \times 10^{-8} \text{ MT CH}_4/\text{gallon}$
  - $\text{N}_2\text{O} = (0.01776 \text{ grams/gallon}) \div 1,000,000 \text{ g/MT} = 1.78 \times 10^{-8} \text{ MT N}_2\text{O}/\text{gallon}$
- The emission rates for each gas are converted to equivalents of CO<sub>2</sub> (CO<sub>2</sub>e) by multiplying them with their respective 100-year GWPs:
  - $\text{CO}_2 = 0.010150 \text{ MT CO}_2/\text{gallon} * 1 = 0.010150 \text{ MT CO}_2\text{e}/\text{gallon}$
  - $\text{CH}_4 = 1.89 \times 10^{-8} \text{ MT CH}_4/\text{gallon} * 28 = 5.28 \times 10^{-7} \text{ MT CO}_2\text{e}/\text{gallon}$
  - $\text{N}_2\text{O} = 1.8 \times 10^{-8} \text{ MT N}_2\text{O}/\text{gallon} * 265 = 4.71 \times 10^{-6} \text{ MT CO}_2\text{e}/\text{gallon}$
- As calculated in Table 1a, the total diesel fuel for 10 buses = 235.49 gallons. The emissions/day for 10 buses is calculated as:
  - $\text{CO}_2 = 0.010150 \text{ MT CO}_2\text{e}/\text{gallon} * 235.49 \text{ gallons/day/bus} = 2.390 \text{ MT CO}_2\text{e}/\text{day}$
  - $\text{CH}_4 = 1.0 \times 10^{-5} \text{ MT CO}_2\text{e}/\text{gallon} * 235.49 = 1.24 \times 10^{-4} \text{ MT CO}_2\text{e}/\text{day}$
  - $\text{N}_2\text{O} = 5.0 \times 10^{-5} \text{ MT CO}_2\text{e}/\text{gallon} * 235.49 = 1.11 \times 10^{-3} \text{ MT CO}_2\text{e}/\text{day}$
  - Total = summation = 2.391433 MT CO<sub>2</sub>e/day = Total emissions per day for 10 buses
- The emissions generated per year for 10 buses:
  - $\text{CO}_2 = 2.390 \text{ MT CO}_2\text{e}/\text{day} * 365 \text{ days/year} = 872.422950 \text{ MT CO}_2\text{e}/\text{year}$
  - $\text{CH}_4 = 1.24 \times 10^{-4} \text{ MT CO}_2\text{e}/\text{day} * 365 \text{ days/year} = 0.045414 \text{ MT CO}_2\text{e}/\text{year}$
  - $\text{N}_2\text{O} = 1.11 \times 10^{-3} \text{ MT CO}_2\text{e}/\text{day} * 365 \text{ days/year} = 0.404529 \text{ MT CO}_2\text{e}/\text{year}$
  - Total = summation = 872.872893 MT CO<sub>2</sub>e/year = Total emissions per year for 10 buses

### 1.c Table 1C: Magnitude of Emissions Reductions Between Time Frames

#### Measure Implementation Assumptions:

- The BEBs are anticipated to be delivered around 2/1/2028.
- Considering the lifespans of BEBs are 12 years,<sup>3</sup> the useful life span of the buses will be until 2/1/2040.

#### Site Emissions Avoided for 2025-2030:

- The number of days from the delivery date (2/1/2028) through the end of 2030 (12/31/2030) is a total of

<sup>3</sup> NREL. "Financial analysis of battery electric transit buses", (June 2020) [https://afdc.energy.gov/files/u/publication/financial\\_analysis\\_be\\_transit\\_buses.pdf](https://afdc.energy.gov/files/u/publication/financial_analysis_be_transit_buses.pdf).

1,064 days, which informs the emissions avoided for this time frame.

- $1,064 \text{ days} \times 2.39 \text{ MT CO}_2\text{e/day emissions avoided for 10 buses} = 2,544.48 \text{ MT CO}_2\text{e/day site emissions avoided from 2025-2030}.$

**Site Emissions Avoided for 2025-2040 (Useful BEB Life):**

- Since the useful life span of the buses is until 2/1/2040, the calculations are informed from the delivery date (2/1/2028) through the useful life (2/1/2040) for a total of 4,383 days.
- $4,383 \text{ days} \times 2.39 \text{ MT CO}_2\text{e/day emissions avoided for 10 buses} = 10,481.65 \text{ MT CO}_2\text{e/day site emissions avoided from 2025-2040}.$

**Site Emissions Avoided for 2025-2050 (Maintenance/BEB Battery Replacement):**

- Recognizing that maintenance and repair efforts can maintain the BEBs, the following calculations project emissions reduced through 2050 in full.
- The number of days from the delivery date (2/1/2028) through the end of 2050 (12/31/2050) is a total of 8,369 days, which informs the emissions avoided for this time frame.
- $8,369 \text{ days} \times 2.39 \text{ MT CO}_2\text{e/day emissions avoided for 10 buses} = 20,013.90 \text{ MT CO}_2\text{e/day site emissions avoided from 2025-2050}.$

## 2 Measure 2: Solar Photovoltaic Canopies

### Reference Case Scenario

To calculate the estimated emissions reductions for Measure 2: Solar Photovoltaic (PV) Canopies, the calculations were performed based on projected “business as usual” emissions by calculating the amount of energy that can be generated within the available site footprint. This onsite energy generation is assumed to offset a portion of the BOMF’s grid (“source”) energy consumption.

Sheet “GHG 02 – PV” of the Calculations spreadsheet demonstrates projected future GHG emissions in the absence of this implemented measure. As seen below under *Table 2B: Emissions Factors and Associated Emissions*, estimated CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions (MT CO<sub>2</sub>e/year) are calculated for consumption of grid electricity.

### 2.a Table 2A: Measure-Specific Activity Data

Table 2A establishes the measure-specific activity data—as well as the estimate methods, tools, and assumptions needed to establish this measure-specific activity data—utilized to calculate annual and cumulative emissions reductions for approximately 3,278 PV panels.

**GoTriangle and Nelson Road BOMF Site Data:**

- The square footage of the space available on site for solar photovoltaics (PVs) is 59,000 SF.

**GHG Reduction Estimate Assumptions:**

- The size for each photovoltaic panel is assumed at 18 SF.
- $\text{Total available site area} \div \text{estimated panel area} = 59,000 \text{ SF} \div 18 \text{ SF/panel} = 3,278 \text{ panels}$
- The anticipated potential output per panel is assumed to be 250 W = 0.25 kW.
- $\text{The total number of panels} \times \text{individual panel output} = 3,278 \text{ panels} \times 0.25 \text{ kW} = 819 \text{ kW total system energy generation} = \text{DC system size}$

**Tools Used:**

- The above assumptions and calculations were used to inform the National Renewable Energy Laboratory’s PVWatts tool to calculate the estimated annual energy generation of 1,134,004 kWh/year. Assuming a 2% loss in energy per year, this was rounded down to 1,100,000 kWh/year onsite energy generation.
- $1,100,000 \text{ kWh/year} \div 365 \text{ days/year} = 3,013.70 \text{ kWh/day} \div 1,000 \text{ kWh/MWh} = 3.0137 \text{ MWh/day onsite energy generation}$



Cautions: Photovoltaic system performance predictions calculated by PVWatts<sup>®</sup> include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts<sup>®</sup> inputs. For example, PV modules with better performance are not differentiated within PVWatts<sup>®</sup> from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at [sam.nrel.gov](http://sam.nrel.gov)) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

Disclaimer: The PVWatts<sup>®</sup> Model ("Model") is provided by the National Renewable Energy Laboratory ("NREL"), which is operated by the Alliance for Sustainable Energy, LLC ("Alliance") for the U.S. Department Of Energy ("DOE") and may be used for any purpose whatsoever.

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The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

## RESULTS

1,134,004 kWh/Year\*

System output may range from 1,086,036 to 1,157,251 kWh per year near this location.

Month	Solar Radiation ( kWh / m <sup>2</sup> / day )	AC Energy ( kWh )
January	3.79	77,288
February	4.36	79,250
March	5.00	97,484
April	5.94	108,532
May	6.00	110,957
June	6.33	110,057
July	6.34	113,022
August	5.99	108,662
September	5.38	96,290
October	4.49	86,117
November	4.21	80,537
December	3.22	65,809
Annual	5.09	1,134,005

### Location and Station Identification

Requested Location	27560, USA		
Weather Data Source	Lat, Lng: 35.81, -78.82	1.1 mi	
Latitude	35.81° N		
Longitude	78.82° W		

### PV System Specifications

DC System Size	819 kW					
Module Type	Standard					
Array Type	Fixed (open rack)					
System Losses	14.08%					
Array Tilt	20°					
Array Azimuth	180°					
DC to AC Size Ratio	1.2					
Inverter Efficiency	96%					
Ground Coverage Ratio	0.4					
Albedo	From weather file					
Bifacial	No (0)					
Monthly Irradiance Loss	Jan	Feb	Mar	Apr	May	June
	0%	0%	0%	0%	0%	0%
	July	Aug	Sept	Oct	Nov	Dec
	0%	0%	0%	0%	0%	0%

### Performance Metrics

DC Capacity Factor	15.8%
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## 2.b Table 2B: Emissions Factors and Associated Emissions

### GHG Reduction Data:

- As per NOFO Appendix B: Global Warming Potentials (GWPs) for GHGs, as informed by the 2013 IPCC AR5 Fifth Assessment Report, the 100-year GWP for greenhouse gases referenced in the calculations are as follows:
  - Carbon dioxide (CO<sub>2</sub>) = 1
  - Methane (CH<sub>4</sub>) = 28
  - Nitrous Oxide (N<sub>2</sub>O) = 265
- The emissions factors for each of the greenhouse gases have been identified from the EPA Emission Factors for GHG Inventories
- The emissions factors for each of the greenhouse gases have been informed by the Emissions Factors for Transport Fuel Use by GHG Protocol.<sup>4</sup>
  - As per Table 6: Electricity, the eGRID subregion is SERC Virginia/Carolina based on the location of the BOMF, identified with the acronym SRVC
    - The non-baseload emission factor for CO<sub>2</sub> is 1308.8 pounds/MWh
    - The non-baseload emission factor for CH<sub>4</sub> is 0.099 pounds/MWh
    - The non-baseload emission factor for N<sub>2</sub>O is 0.014 pounds/MWh

Blue text indicates an update from the 2023 version of this document.

Emission Factors for Greenhouse Gas Inventories  
Last Modified: 13 February 2024

Table 6 Electricity

eGRID Subregion Acronym	eGRID Subregion Name	Total Output Emission Factors			Non-Baseload Emission Factors		
		CO <sub>2</sub> Factor (lb CO <sub>2</sub> / MWh)	CH <sub>4</sub> Factor (lb CH <sub>4</sub> / MWh)	N <sub>2</sub> O Factor (lb N <sub>2</sub> O / MWh)	CO <sub>2</sub> Factor (lb CO <sub>2</sub> / MWh)	CH <sub>4</sub> Factor (lb CH <sub>4</sub> / MWh)	N <sub>2</sub> O Factor (lb N <sub>2</sub> O / MWh)
AKGD	ASCC Alaska Grid	1,052.1	0.088	0.012	1,224.5	0.123	0.017
AKMS	ASCC Miscellaneous	495.8	0.023	0.004	1,587.9	0.069	0.012
AZNM	WECC Southwest	776.0	0.051	0.007	1,205.2	0.065	0.009
CAMX	WECC California	497.4	0.030	0.004	1,055.0	0.049	0.006
ERCT	ERCOT All	771.1	0.049	0.007	1,194.9	0.067	0.009
FRCC	FRCC All	813.8	0.048	0.006	1,044.4	0.056	0.007
HIMS	HICC Miscellaneous	1,155.5	0.124	0.019	1,619.2	0.157	0.025
HIOA	HICC Ohio	1,575.4	0.163	0.025	1,810.3	0.177	0.028
MROE	MRO East	1,479.6	0.133	0.019	1,672.9	0.147	0.021
MROW	MRO West	936.5	0.102	0.015	1,794.7	0.183	0.026
NEWB	NPCC New England	536.4	0.063	0.008	923.3	0.073	0.010
NWPP	WECC Northwest	602.1	0.056	0.006	1,515.7	0.134	0.019
NYCW	NPCC NYC/Westchester	885.2	0.023	0.003	971.8	0.021	0.002
NYLI	NPCC Long Island	1,200.7	0.135	0.019	1,316.7	0.098	0.005
NYUP	NPCC Upstate NY	274.5	0.015	0.002	920.1	0.043	0.005
PRMS	Puerto Rico Miscellaneous	1,593.5	0.087	0.014	1,870.9	0.074	0.013
RFCE	RFC East	657.4	0.045	0.006	1,278.7	0.097	0.013
RFCM	RFC Michigan	1,216.4	0.116	0.016	1,597.3	0.149	0.021
RFCW	RFC West	1,000.1	0.087	0.012	1,843.6	0.178	0.026
RMFA	WECC Rockies	1,124.9	0.101	0.014	1,676.4	0.129	0.018
SPNO	SPP North	952.8	0.100	0.014	1,943.0	0.198	0.029
SPSO	SPP South	970.4	0.072	0.010	1,528.2	0.105	0.015
SRMV	SERC Mississippi Valley	801.0	0.040	0.006	1,220.7	0.073	0.010
SRMW	SERC Midwest	1,369.9	0.151	0.022	1,808.6	0.186	0.027
SRSO	SERC South	893.3	0.064	0.009	1,354.8	0.092	0.013
SRTV	SERC Tennessee Valley	933.1	0.062	0.012	1,671.0	0.152	0.022
SRVC	SERC Virginia/Carolina	623.0	0.047	0.007	1,308.8	0.099	0.014
US Average	US Average	823.1	0.066	0.009	1,405.3	0.107	0.015

Source: EPA eGRID2022, January 2024 (Summary Tables - Table 1. Subregion Output Emission Rates)

[https://www.epa.gov/system/files/documents/2024-01/eGRID2022\\_summary\\_tables.xlsx](https://www.epa.gov/system/files/documents/2024-01/eGRID2022_summary_tables.xlsx)

Notes:  
Total output emission factors can be used as default factors for estimating GHG emissions from electricity use when developing a carbon footprint or emissions inventory. Annual non-baseload output emission factors should not be used when developing a carbon footprint or emissions inventory, but can be used to estimate GHG emissions reductions on the grid from changes in electricity use.

For technical information, reference the EPA's eGRID Technical Guide

[https://www.epa.gov/system/files/documents/2024-01/eGRID2022\\_technical\\_guide.pdf](https://www.epa.gov/system/files/documents/2024-01/eGRID2022_technical_guide.pdf)

The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

### Calculations for Estimated Annual Emissions:

- The emissions factors are converted to unified units from pounds/MWh to metric tons (MT) of the respective gas/MWh:
  - CO<sub>2</sub> = 1,308.8 lb/MWh ÷ 2,204.62 lb/MT = 0.59366 MT CO<sub>2</sub>/MWh
  - CH<sub>4</sub> = 0.099 lb/MWh ÷ 2,204.62 lb/MT = 4.49 x 10<sup>-5</sup> MT CH<sub>4</sub>/MWh
  - N<sub>2</sub>O = 0.014 lb/MWh ÷ 2,204.62 lb/MT = 6.35 x 10<sup>-6</sup> MT N<sub>2</sub>O/MWh
- The emission rates for each gas are converted to equivalents of CO<sub>2</sub> (CO<sub>2</sub>e) by multiplying them with their

<sup>4</sup> EPA. "Emissions Factor for Greenhouse Inventories" (September, 2023)

[https://www.epa.gov/system/files/documents/2023-03/ghg\\_emission\\_factors\\_hub.pdf](https://www.epa.gov/system/files/documents/2023-03/ghg_emission_factors_hub.pdf)



respective 100-year GWPs:

- $\text{CO}_2 = 0.59366 \text{ MT CO}_2/\text{MWh} * 1 = 0.593662 \text{ MT CO}_2\text{e}/\text{MWh}$
- $\text{CH}_4 = 0.00004491 \text{ MT CH}_4/\text{MWh} * 28 = 0.001257 \text{ MT CO}_2\text{e}/\text{MWh}$
- $\text{N}_2\text{O} = 0.00000635 \text{ MT N}_2\text{O}/\text{MWh} * 265 = 0.001683 \text{ MT CO}_2\text{e}/\text{MWh}$
- As calculated in Table 2a, the daily energy offset by the PVs at the BOMF is 3.01 MWh/day. The emissions/day to be offset by PVs is calculated as:
  - $\text{CO}_2 = 0.59366 \text{ MT CO}_2\text{e}/\text{MWh} * 3.01 \text{ MWh}/\text{day} = 1.789120 \text{ MT CO}_2\text{e}/\text{day}$
  - $\text{CH}_4 = 0.001257 \text{ MT CO}_2\text{e}/\text{MWh} * 3.01 \text{ MWh}/\text{day} = 0.003789 \text{ MT CO}_2\text{e}/\text{day}$
  - $\text{N}_2\text{O} = 0.001683 \text{ MT CO}_2\text{e}/\text{MWh} * 3.01 \text{ MWh}/\text{day} = 0.005072 \text{ MT CO}_2\text{e}/\text{day}$
  - Total = summation = 1.797980 MT CO<sub>2</sub>e/day = Total BOMF emissions avoided per day with PVs
- The emissions avoided per year with the PVs is calculated as:
  - $\text{CO}_2 = 1.789120 \text{ MT CO}_2\text{e}/\text{day} * 365 \text{ days}/\text{year} = 653.029 \text{ MT CO}_2\text{e}/\text{year}$
  - $\text{CH}_4 = 0.003789 \text{ MT CO}_2\text{e}/\text{day} * 365 \text{ days}/\text{year} = 1.383 \text{ MT CO}_2\text{e}/\text{year}$
  - $\text{N}_2\text{O} = 0.005072 \text{ MT CO}_2\text{e}/\text{day} * 365 \text{ days}/\text{year} = 1.851 \text{ MT CO}_2\text{e}/\text{year}$
  - Total = summation = 656.263 MT CO<sub>2</sub>e/year = Total BOMF emissions avoided per year with PVs

## 2.c Table 2C: Magnitude of Emissions Reductions Between Time Frames

### Measure Implementation Assumptions:

- The PVs are anticipated to be delivered around 2/1/2028.
- Considering the lifespan of the PV canopies are 33 years,<sup>5</sup> the useful life span of the PVs will be until 2/1/2061. Both 2030 and 2050 occur before the end of the useful life of 2061; therefore, both calculations account for 2030 and 2050 respectively.

### Source Emissions Avoided for 2025-2030:

- The number of days from the delivery date (2/1/2028) through the end of 2030 (12/31/2030) is a total of 1,064 days, which informs the emissions avoided for this time frame.
- 1,064 days \* 1.80 MT CO<sub>2</sub>e/day emissions avoided with PVs = 1,913.05 MT CO<sub>2</sub>e/day source emissions avoided from 2025-2030.

### Source Emissions Avoided for 2025-2050:

- The number of days from the delivery date (2/1/2028) through the end of 2050 (12/31/2050) is a total of 8,369 days, which informs the emissions avoided for this time frame.
- 8,369 days \* 1.80 MT CO<sub>2</sub>e/day emissions avoided with PVs = 15,047.30 MT CO<sub>2</sub>e/day source emissions avoided from 2025-2050.

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<sup>5</sup> Forbes. "How Long Do Solar Panels Last?" (September, 2023) <https://www.forbes.com/home-improvement/solar/how-long-do-solar-panels-last/>

# ESTIMATED GREENHOUSE GAS (GHG) REDUCED EMISSIONS

## #1 BEBs] GHG Reduction Measure 1: BEBs and Electric Charging Infrastructure

Tables 1A: Measure-Specific Activity Data

#1] Systems (Site)	Fuel Source	Total Tank Sizes (Gallons)	Gallons/Day Used for 10 Buses	Days for 10 Buses to Empty Tank	Fuel Deliveries per Year (# Trips)	Miles from Fuel Source to Site (Roundtrip)	Miles/Year to Site to Fuel 10 Buses	Miles/Gallon per 1 Diesel Truck	Gallons/Year for Fuel Deliveries	Gallons/Day for Fuel Deliveries
Diesel Deliveries to Site for 10 Buses	Diesel	40,000	235.37	169.95	2.15	92	198	4.50	43.91	0.12
Notes		two 20,000 gallon tanks	calculated from below Cell 112	operational 365 days		Supplier in Selma, NC (46 miles away)	AFLEET Tool, Short-Haul Truck			

#1] Systems (Site)	Fuel Source	Number of Diesel Buses	Operational Days/Year	Miles/Year per 1 Bus	Miles/Day per 1 Bus	Miles/Gallon per 1 Bus	Gallons/Day per 1 Bus	Gallons/Day per 10 Buses
Diesel Bus	Diesel	10	365	37,800	103.56	4.40	23.54	235.37
Diesel Deliveries to Site for 10 Buses	(see above)							0.12
Notes				averaged 28,000 miles past-COVID; assume +20% to +50% growth	AFLEET Tool, Transit Bus		Total Gallons/Day (10 buses + fuel deliveries):	235.49

Table 1B: Emissions Factors and Associated Emissions

#1] Systems (Site)	Greenhouse Gas	100-Year GWP	Emissions Factor	Source of Emissions Factor	Conversions	Emissions Factor	Emissions Rate	Gallons/Day for 10 Buses	Emissions/Day for 10 Buses (MT CO <sub>2</sub> e/day)	Emissions/Year for 10 Buses (MT CO <sub>2</sub> e/year)
Diesel	Carbon Dioxide CO <sub>2</sub>	1	10.150000 kilogram/gallon	On-Road Diesel Fuel (US region)	1,000 kg = 1 metric ton (MT)	0.010150000 MT CO <sub>2</sub> /gallon	0.010150 MT CO <sub>2</sub> e/gallon	235.49	2.390200	872.422950
	Methane CH <sub>4</sub>	28	0.018870 gram/gallon	Diesel bus (US region)	1,000,000 g = 1 MT	1.89E-08 MT CH <sub>4</sub> /gallon	5.28E-07 MT CO <sub>2</sub> e/gallon		1.24E-04	0.045414
	Nitrous Oxide N <sub>2</sub> O	265	0.017760 gram/gallon	Diesel bus (US region)		1.78E-08 MT N <sub>2</sub> O/gallon	4.71E-06 MT CO <sub>2</sub> e/gallon		1.11E-03	0.404529
Totals							0.010155235		2.391433	872.872893
							SITE EMISSIONS			
Notes	Source: EPA NOFO, Appendix B		Source: GHG Protocol Emission Factors, Transport Fuel Use, Tables 12 and 13			Convert to final numerator	Multiply by GWP for CO <sub>2</sub> e			

Table 1C: Magnitude of Emissions Reductions between Time Frames

#1] Systems (Site)	Operational By	BEB Useful Lifespan (12 yr)	Days From Delivery to 2030 (in 2025-2030)	MT CO <sub>2</sub> e Site Emissions Avoided w/10 BEBs (2025-2030)	Days From Delivery to 2040 Useful Life (in 2025-2040)	MT CO <sub>2</sub> e Site Emissions Avoided w/10 BEBs (2025-2040)	Days From Delivery to 2050 and Replaced Batteries (in 2025-2050)	MT CO <sub>2</sub> e Site Emissions Avoided w/10 BEBs (2025-2050)
Measure #1: BEBs	2/1/2028	2/1/2040	1064	2,544.48	4,383	10,481.65	8,369	20,013.90
Notes		short of 2050 (use 2040)			Reduced by BEB's 12-year useful life	Through 2040 (useful life)	Through 2050 (replace batteries)	Through 2050 (replace batteries)

# ESTIMATED GREENHOUSE GAS (GHG) REDUCED EMISSIONS

## #2 PVs] GHG Reduction Measure 2: Solar Photovoltaic (PV) Canopies

Table 2A: Measure-Specific Activity Data

#2] Systems (Source)	Fuel Source	Site Availability (SF)	Panel Size (SF)	Approx. Number of Panels	Individual Panel Output (kW)	DC System Size (kW)	Annual Energy Generation (kWh/Year)	Annual Energy Generation with Losses (kWh/Year)	Daily Energy Generation (kWh/Day)	Daily Energy Generation (MWh/Day)
Photovoltaics	Solar	59,000	18.00	3,278	0.25	819	1,134,004	1,100,000	3,013.70	3.0137
Notes							round down as conservative PVWatts			

Table 2B: Emissions Factors and Associated Emissions

#2] Systems (Source)	Greenhouse Gas	100-Year GWP	Emissions Factor	Source of Emissions Factor	Conversions	Emissions Factor	Emissions Rate	BOMF Daily Energy Offset by PVs (MWh/Day)	Emissions/Day for BOMF, to be Offset by PVs (MT CO <sub>2</sub> e/day)	Emissions/Year for BOMF, to be Offset by PVs (MT CO <sub>2</sub> e/year)
eGRID: SRVC SERC Virginia/Carolina	Carbon Dioxide CO <sub>2</sub>	1	1308.8 pounds/MWh	Non-Baseload Grid	2,204.62 lb = 1 MT	(metric ton) 0.59366240 MT CO <sub>2</sub> /MWh	0.593662 MT CO <sub>2</sub> e/MWh	3.01	1.789120	653.029
	Methane CH <sub>4</sub>	28	0.099 pounds/MWh	Non-Baseload Grid		4.49E-05 MT CH <sub>4</sub> /MWh	0.001257 MT CO <sub>2</sub> e/MWh		0.003789	1.383
	Nitrous Oxide N <sub>2</sub> O	265	0.014 pounds/MWh	Non-Baseload Grid		6.35E-06 MT N <sub>2</sub> O/MWh	0.001683 MT CO <sub>2</sub> e/MWh		0.005072	1.851
Totals							0.596602589		1.797980	656.263
SOURCE EMISSIONS										
Notes		Source: EPA NOFO, Appendix B		EPA Emission Factors for GHG Inventories (Table 6: Electricity)		Convert to final numerator for CO <sub>2</sub> e		Multiply by GWP for CO <sub>2</sub> e		

Table 2C: Magnitude of Emissions Reductions between Time Frames

#2] Systems (Source)	Operational By	PV Useful Lifespan (33 yr)	Days From Delivery to 2030 (in 2025-2030)	MT CO <sub>2</sub> e Source Emissions Avoided w/PV Canopy (2025-2030)	Days From Delivery to 2050 (in 2025-2050)	MT CO <sub>2</sub> e Source Emissions Avoided w/PV Canopy (2025-2050)
Measure #2: PV Canopies for BOMF	2/1/2028	2/1/2061	1064	1,913.05	8,369	15,047.30
Notes		extends beyond 2050 (use 2050)			PV useful life is beyond 2050 - OK	