GHG Metrics for BTO Tools - Specification

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# Introduction

This document provides specifications for calculating two standardized greenhouse gas (GHG) metrics. The intent is to have all relevant BTO tools use consistent methods to calculate these metrics. Note that each tool may also have additional metrics or alternative calculation approaches. This document does not cover all metrics and calculation approaches for GHG metrics.

This document is primarily intended for the developers of BTO tools and resources that involve the calculation of building-level GHG metrics. It may also be useful for other organizations and stakeholders who are looking to standardize the calculation of building level GHG metrics in tools, guidelines, standards, etc. These specifications are not intended as a formal DOE Standard.

# Total CO2e Using Annual Average Emission Factors

Full name: Total CO2e using annual average emission factors  
Short name: Total CO2e  
Units: Metric tons (whole facility), kg/sq.ft (intensity)

## Description

This metric is a measure of the total equivalent CO2 emissions (CO2e) for a facility over the course of one year or multiple years. It is calculated using average annual emissions factors for delivered energy.

## Purpose

This metric is primarily intended for use cases involving total building emissions (e.g., benchmarking, stock analysis) or lower time resolution data.

## Emission Factors

Total CO2e is calculated by multiplying annual site energy use for various fuels by the relevant annual average emissions factors, as specified below. In general, these factors are consistent with those used in the ENERGY STAR Portfolio Manager, which itself is based on the Greenhouse Gas Protocol Corporate Accounting and Reporting Standard developed by the World Resources Institute (WRI) and World Business Council for Sustainable Development. Excerpts from the ENERGY STAR Greenhouse Gas Emissions technical reference[[1]](#footnote-1) are included below. However, a key difference is that the electricity factors described below include transmission and distribution (T&D) line losses, since they provide a more complete representation of the emissions due to grid electricity use by buildings. (The WRI protocol considers T&D losses as scope 3 emissions for the building sector to avoid double-counting with utility sector emissions).

### Grid Electricity

Annual electricity emission factors vary by both location and year (due to differences in generation plant fuel mix). Because different tools were used to generate the historical (current and older) year emission factors and the future year emission factors, there may be differences in the analysis method, assumptions, and subregion definitions.

**Historical Years**

Annual emissions factors for historical years are based on the annual CO2e total output emission rate (SRC2ERTA) from EPA’s Emissions & Generation Resource Integrated Database ([eGrid](https://www.epa.gov/egrid)[[2]](#footnote-2)). The eGrid emission factors do not include T&D losses so they are added based on the gross grid loss (GGRSLOSS) by interconnect region. Download the historical\_annual\_co2e.csv file from the [BTO Carbon Metrics download folder](https://drive.google.com/drive/folders/1QO5Tb_W8rlc9XTqoH7KtiD_MBk2GA_O5?usp=sharing)[[3]](#footnote-3). Use the emission factor (in kg/MWh) corresponding to the desired eGrid subregion and year. Data from eGrid is available for the following historical years: 2007, 2009, 2010, 2012, 2014, 2016, 2018, and 2019. If a year is not available use the later year (e.g., for 2015, use 2016). The desired eGrid subregion can be determined using one of three methods:

1. Use the [eGrid subregion map](https://www.epa.gov/egrid/maps)[[4]](#footnote-4).
2. Look up the subregion with a zip code using the eGrid [Power Profiler](https://www.epa.gov/egrid/power-profiler#/)[[5]](#footnote-5).
3. Use the zip-subregion mapping in the [Power Profiler Zip Code spreadsheet](https://www.epa.gov/sites/production/files/2020-11/power_profiler_zipcode_tool.xlsx)[[6]](#footnote-6).

Methods 2 and 3 can return more than one subregion. In this case, the emission factor should be calculated as the average of the returned subregions. The one exception is if you know the utility provider, in which case you can use the Power Profiler web page (method 2) to select the subregion corresponding to this utility provider.

**Future Years**

Annual emissions factors for future years are based on the average emission rate of generation induced by a region’s load (co2\_rate\_avg\_load\_enduse) from NREL’s [Cambium tool](https://cambium.nrel.gov/)[[7]](#footnote-7) LowRECost scenario. The Cambium emission factors are not CO2e so they are adjusted based on the ratio of CO2e to CO2 from eGrid for each subregion. Download the future\_annual\_co2e.csv file from the [BTO Carbon Metrics download folder](https://drive.google.com/drive/folders/1QO5Tb_W8rlc9XTqoH7KtiD_MBk2GA_O5?usp=sharing). Use the emission factor (in kg/MWh) corresponding to the desired Cambium subregion and year. Data from Cambium is available for every two years from 2020 to 2050. For odd years use the next year (e.g. for 2031 use 2032). The Cambium subregions are similar to the eGrid subregions, but are not identical. First, identify the eGrid subregion using one of the methods above. Then use the corresponding Cambium subregion except for the three New York subregions (NYCW, NYLI, NYUP), in which case use the NYSTc subregion.

### Fuels

Table 1 shows the emissions factors for various fuels. Fuel emission factors are assumed not to vary by either location or time so there is only one factor for each fuel.

| Table . CO2e emissions factors for fuels burned on site | |
| --- | --- |
| Fuel Type | CO2e Emissions (kg/MBtu) |
| Natural Gas | 53.11 |
| Propane | 64.25 |
| Fuel Oil (No. 1) | 73.50 |
| Fuel Oil (No. 2) | 74.21 |
| Fuel Oil (No. 4) | 75.29 |
| Fuel Oil (No. 5,6) | 75.35 |
| Diesel Oil | 74.21 |
| Kerosene | 77.69 |
| Gasoline[[8]](#footnote-8) | 71.30 |
| Coal (anthracite) | 104.44 |
| Coal (bituminous) | 94.03 |
| Coke | 114.42 |
| Wood | 95.05 |
| Source: ENERGY STAR technical reference. Greenhouse Gas Emissions (except where noted). | |

### District Utilities

Table 2 shows the factors to be used for district utilities. District utility emission factors are assumed not to vary by either location or time so there is only one factor for each district utility.

| Table 2. Indirect CO2e emissions factors for district fuels | |
| --- | --- |
| Fuel Type | CO2e Emissions (kg/MBtu) |
| District steam | 66.40 |
| District hot water | 66.40 |
| District chilled water - electric-driven chiller | 52.70 |
| District chilled water - absorption chiller using natural gas | 73.89 |
| District chilled water - engine-driven chiller using natural gas | 49.31 |
| *Source: ENERGY STAR technical reference. Greenhouse Gas Emissions.* | |

## Calculation

Total emissions is the sum of emissions from grid electricity, fuels burned on site, and district utilities:

Where

Ei is the annual energy use of each delivered energy *i*

Cfi is the annual average emission factor for each delivered energy *i*

If a 12-month period straddles two calendar years, use a weighted average value for the two years, weighted by the number of days in each calendar year. An alternative is to use hourly or monthly data, with relevant emission factors for the time period.

## Versioning and Alternative Emissions Factors

Note that emissions factors may change in future versions of these sources. In general, a tool should use the latest version of these sources and identify which version is being used.

While the emissions factors specified above should be used as the “default,” tools should be designed to easily add the option to use alternative emission factors for states and other jurisdictions. As the need arises, BTO will amend this specification to include such alternative emissions factors. Tools may assume that the emissions factor data will be available as a csv file with a single value for each year and region.

## Reporting

Use the full name, short name, and units as indicated above when reporting the emissions for a site.

If using emission factors for an alternative jurisdiction, it should clearly state that as follows:

e.g., Total CO2e using annual average emission factors for <jurisdiction>

Notes:

* The site boundary may be defined in any form based on the purpose and scope of the analysis—a building, part of a building, or multiple buildings. The same site boundary must be used for all fuels.
* On-site vs. off-site green power: follow the protocol as specified in the Portfolio Manager technical reference.
* This metric does not account for energy consumed for on-site vehicle use, industrial or manufacturing processes, or fugitive refrigerant emissions from refrigeration or air conditioning equipment.

# Marginal CO2e Using Hourly Marginal Emission Factors

Full name: Marginal CO2e using hourly marginal emission factors  
Short name: Marginal CO2e  
Units: Metric tons (whole facility), kg/sq.ft (intensity)

## Description

This metric is a measure of the marginal equivalent CO2 emissions (CO2e) due to changes in energy use at a site over the course of one year or multiple years. It is calculated using hourly marginal emissions factors for delivered energy.

## Purpose

This metric is primarily intended for use cases related to analyzing the impact of changes in building energy use (e.g., due to energy efficiency, demand flexibility, or electrification) using time-dependent valuation and higher resolution data.

## Emission Factors

Marginal CO2e is calculated by multiplying the hourly change in site energy use for various fuels by the relevant hourly marginal emissions factors.

### Grid electricity

Hourly marginal electricity emission factors vary by location, time, and year (due to differences in generation plant fuel mix). Because different tools were used to generate the historical (current and older) year emission factors and the future year emission factors, there may be differences in the analysis method, assumptions, and subregion definitions.

**Historical Years**

Hourly marginal emissions factors for historical years are based on data from EPA’s AVoided Emissions and geneRation Tool ([AVERT](https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert)[[9]](#footnote-9)). The AVERT emission factors are not CO2e and do not include T&D losses, so they are adjusted based on the eGrid gross grid loss (GGRSLOSS) by interconnect region and the ratio of CO2e to CO2 from eGrid for each subregion. Download the historical\_hourly\_co2e\_[year].csv file from the [BTO Carbon Metrics download folder](https://drive.google.com/drive/folders/1QO5Tb_W8rlc9XTqoH7KtiD_MBk2GA_O5?usp=sharing), where [year] is the desired historical year. Use the column of 8,760 hourly emission factors (in kg/MWh) corresponding to the desired AVERT subregion. Data are currently only available for 2019. Instructions on determining the desired AVERT subregion is available on the [AVERT website](https://www.epa.gov/statelocalenergy/avert-tutorial-getting-started-identify-your-avert-regions)[[10]](#footnote-10).

**Future Years**

Hourly marginal emissions factors for future years are based on the long-run marginal emission rates for a region’s load (co2\_lrmer\_enduse) from NREL’s [Cambium tool](https://cambium.nrel.gov/)[[11]](#footnote-11) LowRECost scenario. The Cambium emission factors are not CO2e, so they are adjusted based on the ratio of CO2e to CO2 from eGrid for each subregion. Download the future\_hourly\_co2e\_[year].csv file from the [BTO Carbon Metrics download folder](https://drive.google.com/drive/folders/1QO5Tb_W8rlc9XTqoH7KtiD_MBk2GA_O5?usp=sharing), where [year] is the desired future year. Use the column of 8,760 hourly emission factors (in kg/MWh) corresponding to the desired Cambium subregion. Year and subregion information is the same as for annual future years. Note that these long-run marginal emission rates are best used if you can levelize them across some assumed measure lifetime.

### Fuels and District Utilities

For fuel and district utilities use the annual average factors.

## Calculation

Because the emission factors for electricity vary with time the calculation is different than for fuels.

Electrical emissions:

Where

is the hourly electrical energy change at hour *h*

is the hourly marginal electrical emission factor at hour *h*

Fuel emissions:

Where

is the annual energy change of each delivered fuel *f*

is the annual average emission factor for each delivered fuel *f*

## Versioning and Alternative Emissions Factors

As for annual average, use the latest version of these sources and identify which version is being used.

While the emissions factors specified above should be used as the “default,” tools should be designed to easily add the option to use alternative emission factors for states and other jurisdictions. As the need arises, BTO will amend this specification to include such alternative emissions factors. Tools may assume that the emissions factor data will be available as a csv file with hourly values for each year and subregion.

## Reporting

Use the full name, short name and units as indicated above when reporting the emissions for a site.

If using emission factors for an alternative jurisdiction, it should clearly state that as follows:

e.g., Marginal CO2e using hourly marginal emission factors for <jurisdiction>

Notes:

If reductions are for a large portfolio or stock of buildings, custom factors may need to be used.



For more information, visit: energy.gov/eere

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1. https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf [↑](#footnote-ref-1)
2. https://www.epa.gov/egrid [↑](#footnote-ref-2)
3. https://drive.google.com/drive/folders/1QO5Tb\_W8rlc9XTqoH7KtiD\_MBk2GA\_O5 [↑](#footnote-ref-3)
4. https://www.epa.gov/egrid/maps [↑](#footnote-ref-4)
5. https://www.epa.gov/egrid/power-profiler#/ [↑](#footnote-ref-5)
6. https://www.epa.gov/sites/production/files/2020-11/power\_profiler\_zipcode\_tool.xlsx [↑](#footnote-ref-6)
7. https://cambium.nrel.gov/ [↑](#footnote-ref-7)
8. From EIA Carbon Dioxide Emissions Coefficients by Fuel - https://www.eia.gov/environment/emissions/xls/co2\_vol\_mass.xls [↑](#footnote-ref-8)
9. https://www.epa.gov/avert [↑](#footnote-ref-9)
10. https://www.epa.gov/statelocalenergy/avert-tutorial-getting-started-identify-your-avert-regions [↑](#footnote-ref-10)
11. https://cambium.nrel.gov/ [↑](#footnote-ref-11)