Draft Standard 242P

Standard Methods for Quantifying Greenhouse Gas Emissions Factors for Building Operations

Advisory Public Review (September 2025)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication.

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FOREWORD

Standard 242P establishes a single reference and methodologies for evaluating both historical and projected GHG emissions associated with a building, site or region. It provides a common quantification and documentation framework, emissions values for generating sources, and emissions factor data tables. It provides methods for calculating electricity grid emissions based on measured data or using computer simulation. The standard is intended to provide flexibility for AHJs, regulators, and the authors of related standards to calculate emissions, even while data resolution and data availability vary across locations.

To allow adaptability for users, data tables for both GWP20-year values and ASHRAE-recommended GWP100-year values are provided. Similarly, to accommodate the needs of various users, site and region boundaries are not specified, though users are required to identify the region for which emissions factors are calculated.

Use of region-specific data with month-hour resolution is recommended where such data is available; however, the standard provides methodologies for any time resolution for which data is available or for which a computer simulation is developed. Calculating grid imports and exports to and from nearby regions is recommended to properly account for on-grid and on-site generation, load reduction, and load-shifting impacts. Given that data availability can vary significantly across countries and regions, the data-based electricity emissions factor calculation methodology (Section 6.2) provides flexibility in how emissions factors are calculated, provided the user documents the parameters of their calculation.

Due to evolving evaluation and modeling of electricity grid emissions, the committee intends to place the document on continuous maintenance once published. The large quantity of data tables requires that the standard be made available online, with periodically updated data tables published as addenda. This will allow the document to be updated and utilized with minimal delay in the future.

The term AHJ (authority having jurisdiction) is used throughout to indicate the user of this standard. AHJ conventionally refers to the entity responsible for enforcing construction codes such as building or energy codes, but this standard might be referenced by:

- *Development committees for other codes and standards, including ASHRAE standards, that require quantification of GHG emissions*
- *AHJs, for adopted codes and standards that limit GHG emissions*
- *Owners, for campuses and building portfolios*
- *Utilities, for emissions analyses and incentive programs*
- *State and local governments, for legislation and tax issues*
- *Manufacturers, for determining GHG emissions for their products*
- *Researchers*

1. PURPOSE

To establish standard methods for quantifying emissions factors for use in calculating greenhouse gas emissions associated with the energy usage of buildings and sites.

2. SCOPE

2.1 This standard provides:

a. Methods for quantifying emissions factors for use in calculating greenhouse gas emissions associated with building energy usage and onsite generation,
b. Identification of data requirements for calculations and projections, and
c. Labeling requirements through which emissions factors can be uniformly identified.

2.2 This standard does not provide:

a. Methods of measurement or verification,
b. Greenhouse gas emission goals or limits, or
c. Design guidance or requirements for buildings.

3. DEFINITIONS

authority having jurisdiction (AHJ): the governmental unit, agency, agent or code official responsible for enforcing this standard.

calculation period: the time period for which emissions factors are calculated, which may be a single hour, a year, multiple years or any other period defined for the calculation.

carbon dioxide equivalent (CO2e): The mass of carbon dioxide that provides a global warming effect equal to the global warming effect, over a specific averaging period, of emissions of one or more specific pollutants.

electricity demand: all electric energy supplied to all end users in a specific region.

emissions factor: a value that relates the quantity of a pollutant released to the atmosphere with the consumption of a specific form of energy or an activity associated with the release of that pollutant. These factors are usually expressed as the mass of *CO2e* of pollutants per unit of consumed energy or per unit weight, volume, distance, or duration of the activity emitting the pollutant.

> ***emissions factor, average***: the total electricity system emissions allocated to the study region divided by the total amount of electricity demand at a given timestep and all *nodes* within the study region.
>
> ***emissions factor, location-based***: an emissions factor that reflects the operations of the physical systems supplying an energy source to a building or site, primarily used for electricity-related greenhouse gas emission calculations and distinguished from a *market-based emissions factor*.
>
> ***emissions factor, market-based***: an emissions factor that reflects the purchased electricity for a building or site that accounts for *procured electricity*, primarily used for electricity-related greenhouse gas emission calculations and distinguished from a *location-based emissions factor*. Market-based emissions factors are sometimes referred to as residual emissions factors.
>
> ***emissions factor, marginal***: the difference in total electricity system emissions allocated to the study region that is caused by an intervention shifting *electricity demand* divided by the total amount of *electricity demand* shifted at a given timestep and all *nodes* within the study region.

exported energy: Energy that is delivered from a site or grid region for use off-site. Examples include on-site renewable energy generation conversions of non-renewable energy .

fuel**:** a material that may be used to produce heat or generate power by combustion.

> ***fuel, bulk***: an imported energy source that is stored and used on-site for the purpose of energy services, heating, or other amenities. Examples include propane, fuel oil, other petroleum products, hydrogen, coal, wood, and biofuel or biomass products.

***fuel, fossil*:** *fuel* derived from a hydrocarbon deposit, such as petroleum, coal, or natural gas derived from living matter of a previous geologic time.

greenhouse gas (GHG): Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths emitted by the Earth's surface, the atmosphere itself and by clouds. Absorption of emitted infrared radiation causes the greenhouse effect. Carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), ozone (O3), and water vapor (H2O) are the primary *GHGs* in the Earth's atmosphere.

greenhouse gas emissions: The release of *greenhouse gases* into the atmosphere.

global warming potential (GWP): an index describing the global warming effect over a specific time period of a pollutant relative to the global warming effect over the same time period of an equal mass of carbon dioxide (CO2).

global warming potential time horizon: A length of time used for calculating the global warming effect of emissions of pollutants which have effects that vary over a relatively short period. Examples include 20 years and 100 years.

grid operator: an entity responsible for the reliable operation of an electricity grid region and any associated markets, including balancing authorities, regional transmission operators (RTOs) and independent system operators (ISOs)

imported electricity: electricity that is generated off-site and is delivered for use at the site.

imported energy: an energy source that is delivered for use on-site. *Imported energy* includes *imported electricity*.

node: A mathematical representation of a region within an electricity grid, generally combining physical characteristics of the grid, such as generators, loads, and transmission constraints, in a manner that simplifies computation of a *production cost model* while maintaining accuracy of the simulated performance.

***procured electricity*:** electricity supply allocated to specific end users or aggregations of end users through market instruments, including but not limited to direct contracts and power purchase agreements, Energy Attribute Certificates (EACs) and renewable energy certificates (RECs) and green tariffs, verified through contracts, government databases, utilities*, grid operators*, Regional Generation Attribute Tracking Systems, clean energy and carbon offset certification programs or other entities that are not party to the market instruments.

***production cost model*:** a mathematical optimization program that solves a unit commitment problem for a *study region* and adjacent regions in order to minimize total costs to meet *electricity demand* at each *node* over a simulation period given constraints on operation of each generator assigned to each *node* in the model regions and on transmission flows between each *node* in the model regions.

study region: region for which the final emissions factor is being determined. Broadly defined as grouping of electricity generating stations, energy-using buildings, transmission and distribution infrastructure, inflow connections and outflow connections.

verified data: measured data required for emissions factor calculations from government agencies, system operators, power plant operators or otherwise required by the provisions of this standard or *the authority having jurisdiction*.

4. ADMINISTRATION

4.1 Compliance. Emissions factors shall comply with one of the following:

a. *Fuel* emissions factors shall comply with section 5
b. Electricity emissions factors shall comply with section 6.
c. District thermal emissions factors shall comply with section 7.

4.2 Emissions Factor Identification. The emissions factors shall be identified in accordance with the following as applicable:

a. The *calculation period* shall be identified by the following:
    i. Start date and time,
    ii. End date and time,
    iii. Multiple year averaging.
b. The emissions factor time granularity shall be identified by the calculation time step. Example: minutes, hours, month-hours, or years.
c. The *study region* shall be identified using a publicly available term for a geographic region or a user defined geographic boundary.
d. The emissions factor units shall be identified in unit of mass per unit energy (e.g. kg/MWh, lb/MWh, lb/MMBtu)
e. The emissions representation shall be identified by the specific *greenhouse gas* (e.g. CO_2, CH_4 or N_2O) or *carbon dioxide equivalent* of multiple constituent gases (e.g. *CO_2e)*.
f. The *global warming potential time horizon* shall be identified as either 100-yr or 20-yr.
g. The electricity emissions calculation procedure shall be identified as one of the following:
    i. As-measured with the following additional identifiers as applicable
        1. Net Import/Export Alternative
        2. Average Efficiency Alternative
        3. Neighboring Region – Alternative Timestep
        4. Neighboring Region – Alternative Year
        5. Generation-only Method
    ii. Computer simulation Data; identified as S-P
h. The emissions factor type shall be identified as one of the following:
        i. Average emissions factors
        ii. Marginal emissions factors
i. Projected emissions factors shall be identified as one of the following:
    i. N/A (i.e. emissions factors are not projected)
    ii. Historical annual trend
    iii. Utility data basis

iv. Simulated scenario

j. The emissions factor basis shall be identified as one of the following:
   i. Location-based, or
   ii. Market-based

Informative note*:* In the current version of the standard, items (g-j) only apply to electricity.

Informative note: *An example acceptable emissions factor identifier is:*

a. *Calculation period*: Jan 1, 2023- Dec 31, 2023. No averaging.
b. Emissions factor time granularity: month-hours.
c. *Study region*: Lansing, Michigan.
d. Emissions factor units: kg/MWh
e. Emissions representation: CO_2e.
f. *Global warming potential time horizon*: 100-yr
g. Electricity emissions calculation procedure: As-measured, Neighboring Region – Alternative Timestep
h. Emissions factor type: Average
i. Projected emissions factor: N/A
j. Emissions factor basis: Market-based

5. FUEL EMISSIONS FACTORS

5.1 General. *Greenhouse gas emissions factors* for *fuel* usage shall comply with Section 5.2 in accordance with the selections made in Section 4.2.

5.2 Calculating Fuel Emissions Factors. All *fuel emissions factors* shall include emissions from both upstream (precombustion) and on-site (combustion) activities in accordance with Sections 5.2.1 and 5.2.2. *Emissions factors* for liquified natural gas shall comply with Section 5.2.3. *Emissions factors* for *fuels* other than *fossil fuels* are permitted to comply with Section 5.2.4.

Where the building or site where the *fuel* is combusted is in a geographic region in Figure 5.2, the appropriate *emissions factor* for the *fuel*, region and facility type from the following tables shall be permitted:

a. Table 5.2a for *CO2e* for *fuels* used in buildings
b. Table 5.2b for *CO2e* for *fuels* used in power plants
c. Table 5.2c for component gases for *fuels* used in buildings
d. Table 5.2d for component gases for *fuels* used in power plants

5.2.1 Combustion Emissions. All *emissions factor* calculations shall include combustion *greenhouse gas emissions* associated with the burning of a *fuel*, either within the building or site or to generate electricity or thermal energy used within the building or site.

5.2.2 Upstream Emissions. All *emissions factor* calculations shall include *greenhouse gas emissions* associated with all processes prior to combustion within the building or site or to generate electricity or thermal energy used within the building or site, including all of the following applicable to the *fuel* and end use:

a. Extraction
b. Gathering and boosting
c. Processing
d. Transmission station
e. Storage
f. Transmission pipeline
g. Liquefaction
h. Transport
i. Regassification
j. Delivery
k. Emissions from post-meter leakage

Informative Note. Appendix A provides detailed information on component upstream (pre-combustion) natural gas emissions.

a

5.2.3 Liquified Natural Gas. For liquified natural gas, the *emissions factor* shall include component *emissions factors* for liquefaction, transport, and regassification. A default factor for these components shall be determined from equation 5.2.

$$LNG\ Adder\ = a + b(Distance) + c \tag{5.2}$$

Where:

LNG Adder	= Additional component *emissions factor* for LNG (kg/MWh)
a	= 38 kg/MWh for *GWP*100 or 53 kg/MWh for *GWP* 20
b	= 0.0031 kg/MWh-km for *GWP*100 or 0.0036 kg/MWh-km for *GWP*20
Distance	= transportation distance (km)
c	= 4 kg/MWh

5.2.4 Alternative Fuels. Where applicable, *emissions factors* are permitted to be calculated in accordance with one of the following, provided they comply with Sections 5.2.1 and 5.2.2:

a. the carbon intensity methodology of the California Air Resources Board Low Carbon Fuel Standard, excluding credits for avoided emissions, or
b. the net *greenhouse gas emissions* methodology in the U.S. Environmental Protection Agency Renewable Fuel Standard.

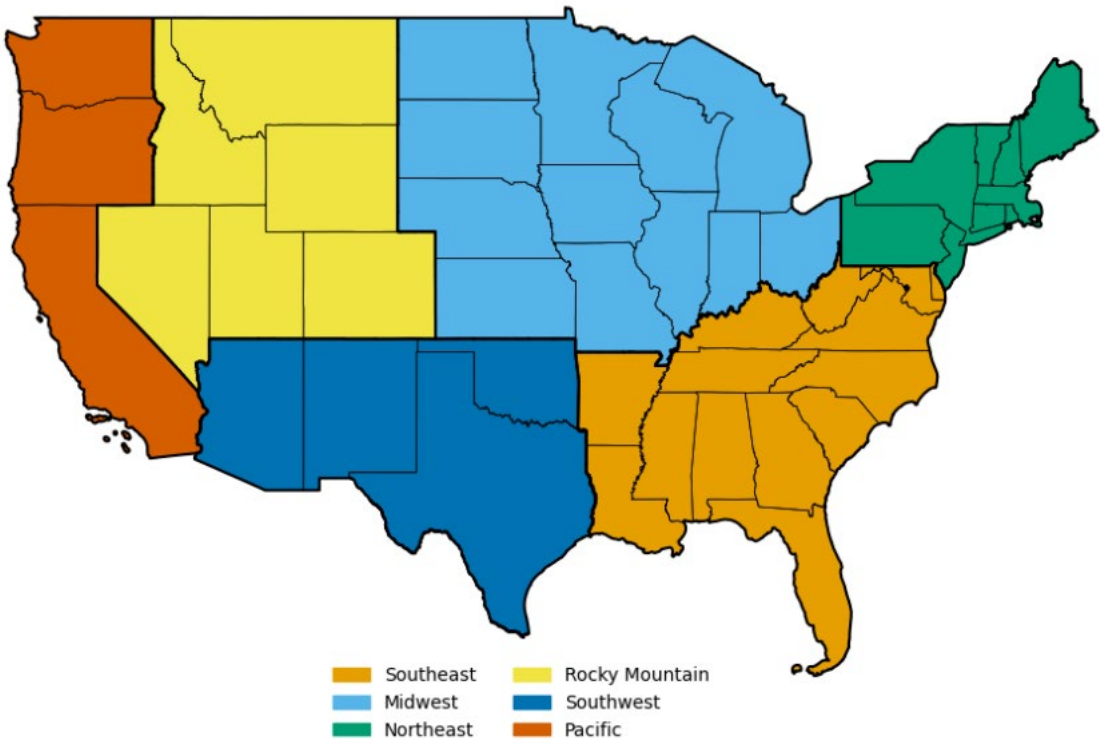

Figure 5.2 - Geographic Regions for Table 5.2a and Table A.1

Table 5.2a - CO_2e Emissions for Fossil Fuels Used in Buildings

		CO2e Emissions (GWP20) (kg/MWh)			CO2e Emissions (GWP100) (kg/MWh)		
		Combustion	Pre-Combustion[1]	Total	Combustion	Pre-Combustion[1]	Total
Natural Gas	Midwest	184	59	243	184	33	217
	Northeast	184	44	228	184	24	208
	Pacific	184	69	253	184	43	227
	Rocky Mtn.	184	68	252	184	40	224
	Southeast	184	70	254	184	37	221
	Southwest	184	65	249	184	35	219
	US Average[1]	184	52	236	184	30	214
LPG or propane		229	66	295	229	46	275
Fuel oil (residual)		265	70	334	264	49	313
Fuel oil (distillate)		255	69	324	255	48	303
Coal		332	51	382	329	23	352
Gasoline		255	82	337	255	57	312
Other fuels not specified		332	51	382	329	23	352

1. Pre-combustion emissions for U.S. National Average are permitted to be used as a default for Alaska, Hawaii, and other locations outside of the U.S. For *study regions* in the continental U.S., it is recommended to use the regional values instead of the US Average.

Table 5.2b - CO_2e Emissions for Fossil Fuels Used at Power Plants

Fuel		CO2e Emissions (GWP20) (kg/MWh) Combustion	Pre-Combustion	Total	CO2e Emissions (GWP100) (kg/MWh) Combustion	Pre-Combustion	Total
Coal		332	51	382	329	23	352
Petroleum		263	82	345	262	53	315
Natural Gas and Other Gases	Midwest	184	54	238	184	31	215
	Northeast	184	39	223	184	22	206
	Pacific	184	64	248	184	42	225
	Rocky Mtn.	184	56	240	184	36	220
	Southeast	184	64	248	184	35	218
	Southwest	184	60	244	184	33	217
	US Average[1]	184	47	231	184	28	212
Nuclear		0	0	0	0	0	0
Pumped Storage		0	0	0	0	0	0
Hydroelectric		0	0	0	0	0	0
Wood		165	29	194	164	18	183
Waste		165	29	194	164	18	183
Geothermal[5]		0	9	9	0	9	9
Solar		0	0	0	0	0	0
Wind		0	0	0	0	0	0

1. Pre-combustion emissions for U.S. National Average are permitted to be used as a default for Alaska, Hawaii, and other locations outside of the U.S. For study regions in the continental U.S., it is recommended to use the regional values instead of the US Average.

Table 5.2c - GHG Emission Rates for Fuels used Directly in Buildings[1,2,3]

	Combustion Emissions (kg/MWh)			Pre-Combustion Emissions (kg/MWh)				Total Emissions (kg/MWh)		
Fuel	CO2	CH4	N20		CO2	CH4	N20	CO2	CH4	N20
				Midwest	17.99	0.4954	0.0001	201.58	0.4989	0.0005
				Northeast	13.01	0.3795	0.0001	196.59	0.3829	0.0005
				Pacific	28.75	0.4830	0.0003	212.34	0.4864	0.0006
Natural Gas	183.59	0.0035	0.0003	Rocky Mtn.	24.59	0.5311	0.0002	208.18	0.5345	0.0006
				Southeast	18.23	0.6288	0.0001	201.82	0.6323	0.0005
				Southwest	18.53	0.5614	0.0001	202.12	0.5648	0.0004
				US Average[4]	16.97	0.4285	0.0001	200.56	0.4319	0.0005
LPG or propane	224.50	0.0037	0.0166		34.86	0.3708	0.0006	259.36	0.3744	0.0173
Fuel oil (residual)	263.98	0.0024	0.0012		36.96	0.3944	0.0007	300.94	0.3968	0.0019
Fuel oil (distillate)	254.41	0.0026	0.0013		36.60	0.3894	0.0007	291.01	0.3920	0.0020
Coal	326.81	0.0385	0.0056		7.39	0.5232	0.0001	334.20	0.5617	0.0057
Gasoline	254.41	0.0026	0.0013		43.33	0.4612	0.0008	297.74	0.4638	0.0021
Other fuels not specified[3]	326.81	0.0385	0.0056		7.39	0.5232	0.0001	334.20	0.5617	0.0057

1. Combustion and pre-combustion emissions for *fossil fuels* are taken from the National Renewable Energy Laboratory LCI database. Values were first published in Michael Deru and Paul Torcellini, Source Energy and Emission Factors for Energy Use in Buildings, National Renewable Energy Laboratory, Technical Report NREL/TP-550-38617, Revised June 2007. These data were updated by NREL in 2021.
2. Pre-combustion emissions for natural gas are taken from DOE/NETL-2024/4862, Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile, December 2024. Data is taken from Appendix F of the NETL document.
3. Values for coal are used for "other fuels not specified"
4. Pre-combustion emissions for U.S. National Average are permitted to be used as a default for Alaska, Hawaii, and other locations outside of the U.S. For *study regions* in the continental U.S., it is recommended to use the regional values instead of the US Average.

Table 5.2d - GHG Emission Rates for Fuels used in Power Plants[1,2]

	Combustion Emissions (kg/MWh)				Pre-Combustion Emissions (kg/MWh)			Total Emissions (kg/MWh)		
Fuel	CO2	CH4	N20		CO2	CH4	N20	CO2	CH4	N20
Coal	326.81	0.0385	0.0056		7.39	0.5232	0.0001	334.20	0.5617	0.0057
Petroleum	261.37	0.0109	0.0022		35.93	0.5571	0.0006	297.30	0.5680	0.0028
Natural Gas and Other Gases	183.59	0.0035	0.0003	Midwest	17.97	0.4308	0.0001	201.56	0.4343	0.0005
				Northeast	13.00	0.3177	0.0001	196.58	0.3212	0.0005
				Pacific	28.74	0.4256	0.0003	212.33	0.4291	0.0006
				Rocky Mtn.	24.59	0.3788	0.0002	208.18	0.3822	0.0006
				Southeast	18.18	0.5511	0.0001	201.76	0.5546	0.0005
				Southwest	18.53	0.4972	0.0001	202.12	0.5007	0.0004
				US Average[1]	16.96	0.3696	0.0001	200.54	0.3731	0.0005
Nuclear	0	0	0		0	0	0	0	0	0
Pumped Storage	0	0	0		0	0	0	0	0	0
Hydroelectric	0	0	0		0	0	0	0	0	0
Wood[3]	163.72	0.0136	0.0000		12.59	0.1953	0.0002	176.32	0.2089	0.0002
Waste[3]	163.72	0.0136	0.0000		12.59	0.1953	0.0002	176.32	0.2089	0.0002
Geothermal[4]	0	0	0		9.07	0	0	9.07	0	0
Solar	0	0	0		0	0	0	0	0	0
Wind	0	0	0		0	0	0	0	0	0

1. Combustion and pre-combustion emissions for coal (bituminous assumed), petroleum, and natural gas are taken from the National Renewable Energy Laboratory LCI database. Values were first published in Michael Deru and Paul Torcellini, Source Energy and Emission Factors for Energy Use in Buildings, National Renewable Energy Laboratory, Technical Report NREL/TP-550-38617, Revised June 2007. These data were updated by NREL in 2021.
2. Pre-combustion emissions for natural gas are taken from DOE/NETL-2024/4862, Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile, December 2024. Data is taken from Appendix F of the NETL document.
3. Biomass emissions were determined from the U.S. Energy Information Agency (EIA), Monthly Energy Reports (MER). Biomass emissions are taken from Table 12.7. Electric generation from biomass is taken from Table 10.2c. A net *emissions factor* of 0.5 is applied to the CO_2 combustion emissions to account for the counterfactual emissions.
4. Pre-combustion emissions for U.S. National Average are permitted to be used as a default for Alaska, Hawaii, and other locations outside of the U.S. For *study regions* in the continental U.S., it is recommended to use the regional values instead of the US Average.
5. Emissions at geothermal plants are small, but not zero. A value of 20 lb of CO_2 per MWh (9.07 kg/MWh) of electricity production is assumed based on geothermal plants in the western United States.

6. ELECTRICITY EMISSIONS FACTORS

6. Methods for Calculating Electricity Emissions Factors

6.1 General. *Greenhouse gas emissions* factors for *electricity demand* shall comply with Sections 6.1.1 through 6.1.3 in accordance with the selections made in Section 4.2.

6.1.1 Calculation procedure. Emissions factors for electricity supply in the *study region* shall comply with one of the following:

a. Where identified as "as-measured" in accordance with Section 4.2, emissions factor calculations shall comply with Section 6.2.

b. Where identified as "computer simulation" in accordance with Section 4.2, emissions factor calculations shall comply with Section 6.3.

6.1.2 Projected emissions factors. Where identified as projected emissions factors in accordance with Section 4.2, emissions factors for electricity supply in the *study region* shall comply with Section 6.4.

6.1.3 Market-based emissions factors. Where identified as *market-based emissions factors* in accordance with Section 4.2, emissions factors for electricity supply in the *study region* shall comply with Section 6.5

Informative notes:

1. Where quantifying *greenhouse gas emissions* for buildings includes accounting for *procured electricity* by the building, *market-based emissions factors* (sometimes referred to as residual emissions factors) should be used for all electricity usage that is not *procured electricity*.
2. *Location-based emissions factors* do not separately account for *procured electricity* and should not comply with Section 6.5.

6.2. Calculating electricity emissions factors based on measured data. Emissions factors for electricity supply in the *study region* shall comply with Sections 6.2.1 and 6.2.2.

6.2.1 Data-Based Calculations. Emissions factors for electricity supply, $EF\_elec_{R,t}$, shall be calculated in accordance with Equation 6.2.1, for *study region*, *R*, documented in accordance with Section 4.2 and for the timestep, *t*, documented in accordance with Section 4.2.

$$EF\_elec_{R,t} = \frac{\left[\sum_f \sum_g \left(fuel\_gen_{f,g\in R,t} \times EF\_fuel_{f,R,t}\right)\right] \times \left(1 - \frac{\sum_r elec\_exp_{r,t}}{\sum_g elec\_gen_{g\in R,t}}\right) + \sum_r \left(elec\_imp_{r,t} \times EF\_elec_{r,t}\right)}{elec\_dem_{R,t}} \quad (6.2.1)$$

Where:

$fuel\_gen_{f,g\in R,t}$ = *fuel* usage for electricity generation of *fuel* type, *f*, used by generator, *g*, within study region, *R*, at timestep, *t* , determined in accordance with Section 6.2.2.1

$EF\_fuel_{f,R,t}$ = emissions factor for *fuel* type, *f*, in *study region*, *R*, for timestep, *t*, determined in accordance with Section 6.2.2.2

$elec\_exp_{r,t}$ = exports of electricity from *study region* to adjacent region, *r*, for timestep, *t*, in units of energy, determined in accordance with Section 6.2.2.3

$elec\_gen_{g \in R,t}$ = electricity generated by generator, *g*, at timestep, *t*, in units of energy, determined in accordance with Section 6.2.2.4

$elec\_imp_{r,t}$ = imports of electricity into *study region* from adjacent region, *r*, for timestep, *t*, in units of energy, determined in accordance with Section 6.2.2.3

$EF\_elec_{r,t}$ = electricity emissions factor for adjacent region, *r*, for timestep, *t*, in units of mass of *greenhouse gas emissions* per unit electric energy used, determined in accordance with Section 6.2.2.5

$elec\_dem_t$ = *electricity demand* within the *study region* for timestep, *t*, in units of energy used, determined in accordance with Section 6.2.2.6

6.2.2Data Inputs for Electricity Emissions Factor Calculations. All calculations of emissions factors for electricity supply based on measured data shall comply with Sections 6.2.2.1 through 6.2.2.7.

6.2.2.1 Fuel Usage for Electricity Generation. All calculations shall use *verified data* for *fuel* usage for electricity generation at the defined timestep in energy units corresponding to the *fuel*, *study region* and generator. Alternative methods that comply with Sections 6.2.2.1.1 and 6.2.2.1.2 shall be permitted.

6.2.2.1.1 Total Fuel Usage by Fuel Type Alternative. Calculations in accordance with Section 6.2.1, shall be permitted to use the total *fuel* usage for the *fuel* for electricity generation within the *study region*, $fuel\_gen_{f,R,t}$, in accordance with the following substitution in Equation 6.2.1:

$$\sum_f \sum_g \left(fuel\_gen_{f,g \in R,t} \times EF\_fuel_{f,R,t}\right) = \sum_f fuel\_gen_{f,R,t} \times EF\_fuel_{f,R,t}$$

6.2.2.1.2 Average Efficiency Alternative. Where the emissions factor is identified as "average efficiency alternative" in accordance with Section 4.2, the value for *fuel* usage for electricity generation is permitted to be calculated in accordance with the following:

$$fuel\_gen_{f,g,t} = elec\_gen_{f,g,t} \times \frac{1}{\eta_G} = elec\_gen_{f,g,t} \times \frac{\sum_{g \in G} fuel\_gen_{f,g,\tau}}{\sum_{g \in G} elec\_gen_{f,g,\tau}}$$

Where:

G = a set of one or more generators with the same *fuel* type and generator type as generator, *g*, and τ is permitted to be a timestep greater than timestep, *t*

η_G = average efficiency of generator type, *G*, defined as the ratio of electricity generated to fuel usage using *verified data* for not more than three years before or after the timestep

6.2.2.2 Fuel Emissions Factor Associated with Electricity Generation. All calculations shall use *fuel* emissions factors, in units of mass of *greenhouse gas emissions* per unit energy usage, associated with electricity generation within the *study region* in accordance with Section 5.1.

6.2.2.3 Electricity Imports and Exports. All calculations shall comply with Sections 6.2.2.3.1 and 6.2.2.3.2.

Exception to 6.2.2.3: Where the emissions factor is identified as "generation-only" in accordance with Section 4.2 and the calculation is in accordance with Section 6.2.2.3.3.

6.2.2.3.1 Electricity Imports. All calculations shall use *verified data* for electricity imports into the *study region* from adjacent regions at each point of import, in energy units and at the same timestep as the emissions factor calculation, unless otherwise permitted by Section 6.2.2.3.1.1. All values for electricity imports shall be no less than zero.

6.2.2.3.1.1 Net Imports-Based Calculation. Where the calculation is identified as "Net Import/Export" in accordance with Section 4.2, the value of the import of electricity into the *study region* from an adjacent region in Equation 6.2.1 shall be permitted to be the greater of:

i.zero or

ii.the sum of all imports from the adjacent region minus the sum of all exports to the adjacent region over all timesteps within the calculation timestep that are shorter than the calculation timestep, based on *verified data.*

6.2.2.3.2 Electricity Exports. All calculations shall use *verified data* for electricity exports from the *study region* to adjacent regions at each point of export, in energy units and at the same timestep as the emissions factor calculation, unless otherwise permitted by Section 6.2.2.3.2.1. All values for electricity exports shall be no less than zero.

6.2.2.3.1.1. Net Exports-Based Calculation. Where the calculation is identified as "Net Import/Export" in accordance with Section 4.2, the value of the export of electricity from the *study region* to an adjacent region in Equation 6.2.1 shall be permitted to be the greater of:

i. zero or

ii. the sum of all exports from the adjacent region minus the sum of all imports to the adjacent region over all timesteps within the calculation timestep that are shorter than the calculation timestep, based on *verified data*.

6.2.2.3.3 Generation-Only Calculations. Where the emissions factor is identified as "generation-only" in accordance with Section 4.2, the values for imports and exports of electricity shall be permitted to be set to zero and the emissions factor shall be permitted to be calculated in accordance with the following:

$$EF\_elec_{R,t} = \frac{\left[\sum_f \sum_g \left(fuel\_gen_{f,g\in R,t} \times EF\_fuel_{f,R,t}\right)\right]}{elec\_dem_{R,t}}$$

6.2.2.4 Electricity Generation. All calculations shall use *verified data* for electricity generation at the defined timestep in energy units corresponding to the *study region* and generator unless otherwise permitted by Sections 6.2.2.4.1 through 6.2.2.4.3.

6.2.2.4.1 Total Electricity Generation Alternative. Calculations in accordance with Section 6.2.1, shall be permitted to use verified data for the total electricity generation in the *study region* at the timestep in accordance with the following substitution in Equation 6.2.1:

$$\sum_g elec\_gen_{g\in R,t} = elec\_gen_{R,t}$$

6.2.2.4.2 Net Import/Export-Based Calculation. Where the calculation is identified as "Net Import/Export" in accordance with Section 4.2, the value of the electricity generation in the *study region* is permitted to be the sum of all *verified data* for electricity generation over all timesteps within the calculation timestep that are shorter than the calculation timestep. (Example: If hourly import and export data is available and the emissions factor calculation is for a one year timestep, the hourly import and export data is permitted to be summed to net imports or net exports for use in Equation 6.2.1.)

6.2.2.4.3 Estimating Electricity Generation from Other Data. Where *verified data* for electricity generation is not available, calculations shall be permitted to estimate the electricity generation based on *verified data* for the *electricity demand* at the timestep and a transmission and distribution loss factor, in accordance with the following:

$$elec\_gen_{R,t} = \frac{elec\_dem_{R,t} - \sum_r \left(elec\_imp_{r,t} - elec\_exp_{r,t}\right)}{\left(1 - TDL_{R,t}\right)}$$

Where *TDL* is calculated in accordance with Section 6.2.2.7 using *verified data* for no more than three years before or after the timestep.

6.2.2.5 Emissions Factor of Imported Electricity. All calculations with electricity imports from an adjacent region into the *study region* shall use adjacent region emissions factors that comply with Sections 6.2.2.5.1 and 6.2.2.5.2.

6.2.2.5.1 Adjacent Region Emissions Factor – Methods. Adjacent region emissions factors for electricity supply shall be calculated in accordance with Section 6.2.1 or 6.3.

6.2.2.5.2 Adjacent Region Emissions Factors – Timestep. The timestep for the adjacent region emissions factor calculations shall be the same as that for the *study region* emissions factor calculation unless otherwise permitted by Sections 6.2.2.5.2.1 and 6.2.2.5.2.2.

6.2.2.5.2.1 Allowance for Longer Timesteps for Adjacent Region Data. Where identified as "Neighboring Region – Alternative Timestep" in accordance with Section 4.2, emissions factor for the adjacent region shall be permitted to be calculated for a longer timestep than the timestep for the *study region* calculation, provided that the timestep for the adjacent region calculation is no longer than one year and includes within it the timestep for the *study region* calculation.

6.2.2.5.2.2 Allowance for Adjacent Region Data from Other Years. Where approved by the *AHJ* and where identified as "Neighboring Region – Alternative Year" in accordance with Section 4.2, the emissions factor for the adjacent region shall be permitted to be calculated for a timestep no more than two years before or after the timestep for the *study region* calculation.

6.2.2.6 Electricity Demand. All calculations shall use *verified data* for *electricity demand* in the *study region* in energy units at the defined timestep unless otherwise permitted by Section 6.2.2.6.1.

6.2.2.6.1 Estimating Electricity Demand from Other Data. Where *verified data* for *electricity demand* is not available, calculations shall be permitted to estimate the *electricity demand* based on *verified data* for the *electricity demand* at the timestep and a transmission and distribution loss factor, in accordance with the following:

$$elec\_dem_{R,t} = \left(\sum_g elec\_gen_{R,t} + \sum_r \left(elec\_imp_{r,t} - elec\_exp_{r,t}\right)\right) \times \left(1 - TDL_{R,t}\right)$$

Where *TDL* is calculated in accordance with Section 6.2.2.7 using *verified data* for no more than three years before or after the timestep.

6.2.2.7 Transmission and Distribution Loss Factor. The transmission and distribution loss factor, TDL_τ, shall be calculated for a timestep, τ, permitted by the other requirements of Section 6.2 and in accordance with Equation 6.2.2.7. Calculations shall be permitted to use a timestep, τ, that is greater than the emissions factor calculation timestep, *t*.

$$TDL_{R,\tau} = 1 - \frac{elec\_dem_{R,\tau}}{\sum_g elec\_gen_{R,\tau} + \sum_r \left(elec\_imp_{r,\tau} - elec\_exp_{r,\tau}\right)} \quad (6.2.2.7)$$

6.3. Calculating electricity emissions factors based on computer simulation. Emissions factors for electricity supply in the *study region* shall comply with Sections 6.3.1 and 6.3.2.

6.3.1 Production Cost Model. Emissions factors shall be calculated using a *production cost model* of the *study region* and adjacent regions. The *production cost model* shall include all of the following based on *verified data*:

a. For each generator:
   1. *Fuel* type and cost per unit energy
   2. Heat rate, efficiency or *fuel* usage as a function of electricity generation
   3. Minimum and maximum electricity generation limits
   4. Minimum up and down time for each generator
   5. Startup cost
   6. Electricity generation based on weather data, where applicable (e.g. intermittent electricity generation from wind and solar resources)
   7. *Node* to which the generator is connected.

b. For each connection between *nodes*:
   1. Maximum transmission limit
   2. Transmission and distribution loss factor

c. For each *node*, *electricity demand* at each timestep in the simulation

6.3.2 Emissions Factor Calculations. Emissions factor calculations shall comply with Section 6.3.2.1 and Section 6.3.2.2 based on the outputs of a *production cost model* complying with Section 6.3.1.

6.3.2.1 Calculating Study Region Emissions. Where the *study region* is all *nodes* in a *production cost model*, emissions shall be calculated in accordance with Section 6.3.2.1.1. Where the *study region* is a single *node* or a subset of *nodes* in a *production cost model*, emissions shall be calculated in accordance with Section 6.3.2.1.2.

6.3.2.1.1 Emissions for All Model Nodes. Where the *study region* is all *nodes* in a *production cost model*, *study region* emissions, $em_{R,t}$, at *calculation period* timestep, *t*, shall be calculated in accordance with Equation 6.3.2.1.1 based on a *production cost model* complying with Section 6.3.1 with simulation timestep, τ.

$$em_{R,t} = \sum_{\tau \in t} \sum_{f,g} \left(fuel\_gen_{f,g,\tau} \times EF\_fuel_{f,g,\tau}\right) \quad (6.3.2.1.1)$$

Where:

$fuel\_gen_{f,g,\tau}$ = *fuel* usage for electricity generation of *fuel* type, *f*, used by generator, g, at simulation timestep, τ, in units of energy used

$EF\_fuel_{f,g,\tau}$ = emissions factor for *fuel* type, *f*, at generator, g, for simulation timestep, τ, determined in accordance with Section 5 in units of mass of emissions per unit energy

6.3.2.1.2 Allocating Emissions to Study Region. Emissions allocated to the *study region*, $em_{R,t}$, at *calculation period* timestep, *t*, shall be calculated in accordance with Equation 6.3.2.1.2-1 based on a *production cost model* complying with Section 6.3.1 with simulation timestep, τ.

$$em_{R,t} = \sum_{i \in R} \sum_{\tau \in t} em_{i,\tau} \tag{6.3.2.1.2-1}$$

Where:

$em_{i,\tau}$ = emissions in units of mass allocated to *node*, *i*, calculated in accordance with Equation 6.3.2.1.2-2, where *i*, *j* and *k* designate *nodes* in a *production cost model* complying with Section 6.3.1.

$$em_{i,\tau} = elec\_dem_{i,\tau} \sum_{j} \frac{[\boldsymbol{A}_{\tau}^{-1}]_{j,i} \times \sum_{f} \sum_{g \in j} fuel\_gen_{f,g,\tau} \times EF\_fuel_{f,g,\tau}}{elec\_dem_{j,\tau} + \sum_{k} elec\_exp_{j-k,\tau}} \tag{6.3.2.1.2-2}$$

Where:

$elec\_dem_{i,\tau}$ = *electricity demand* at *node*, *i*, for simulation timestep, τ, in units of energy used
$\boldsymbol{A}_{\tau}$ = electricity allocation matrix formed in accordance with Equation 6.3.2.1.2-3 for simulation timestep, τ (dimensionless)
$fuel\_gen_{f,g,\tau}$ = *fuel* usage for electricity generation of *fuel* type, *f*, used by generator, g, at simulation timestep, τ, in units of energy used
$EF\_fuel_{f,g,\tau}$ = emissions factor for *fuel* type, *f*, at generator, g, for simulation timestep, τ, determined in accordance with Section 5 in units of mass of emissions per unit energy
$elec\_dem_{j,\tau}$ = *electricity demand* at *node*, *j*, for simulation timestep, τ, in units of energy used
$elec\_exp_{j-k,\tau}$ = exports of electricity from *node*, *j*, to *node*, *k*, for simulation timestep, τ, in units of energy. This value is zero when electricity flows from *k* to *j*.

$$[\boldsymbol{A}_{\tau}]_{j,i} = \begin{cases} 1 & , \quad j = i \\ \dfrac{-elec\_exp_{j-i,\tau}}{elec_{dem\,j,\tau} + \sum_{k} elec\_exp_{j-k,\tau}} & , \quad where\ j\ and\ i\ are\ connected\ nodes \\ 0 & , \quad else \end{cases} \tag{6.3.2.1.2-3}$$

Where:

$elec\_exp_{j-i,\tau}$ = exports of electricity from *node*, *j*, to *node*, *k*, for simulation timestep, *t*, in units of energy. This value is zero when electricity flows from *i* to *j*.

$elec\_dem_{j,\tau}$ = *electricity demand* at *node*, *j*, for timestep, *t*, in units of energy
$elec\_exp_{j-k,\tau}$ = exports of electricity from *node*, *j*, to *node*, *k*, for timestep, *t*, in units of energy. This value is zero when electricity flows from *k* to *j*.

6.3.2.2 Emissions Factor Type. Emissions factor calculations shall comply with one of Sections 6.3.2.2.1 or 6.3.2.2.2.

6.3.2.2.1 Average Emissions Factors. Where identified as an *average emissions factor* in accordance with Section 4.2, the emissions factor for *study region, R*, shall be calculated in accordance with Equation 6.3.2.2.1.

$$EF\_elec_{R,t} = \frac{em_{R,t}}{\sum_{i \in R} \sum_{\tau \in t} elec\_dem_{i,\tau}} \quad (6.3.2.2.1)$$

Where:

$em_{R,t}$ = emissions allocated to *study region*, *R*, calculated in accordance with Section 6.3.2.1, in units of mass
$elec\_dem_{i,\tau}$ = *electricity demand* at *node*, *i*, for simulation timestep, τ, in units of energy used

6.3.2.2.2 Marginal Emissions Factors. Where identified as a *marginal emissions factor* in accordance with Section 4.2, the emissions factor shall be calculated in accordance with Equation 6.3.2.2.2-1 using both of the following:

i. a base *production cost model* complying with Section 6.3.1, and
ii. a perturbed *production cost model* modifying the base *production cost model electricity demand* in accordance with Equation 6.3.2.1.2-2 for all *nodes*, *i*, in *study region*, *R*, for all simulation timesteps, τ, in *calculation period* timestep, *t*.

$$EF\_elec_{R,t} = \frac{\sum_{\tau \in t} em'_{R,\tau} - em_{R,\tau}}{\sum_{i \in R} \sum_{\tau \in t} \left(elec\_dem'_{i,\tau} - elec\_dem_{i,\tau} \right)} \quad (6.3.2.2.2\text{-}1)$$

$$elec\_dem'_{i,\tau} = (1 + \varepsilon) \times elec\_dem_{i,\tau} \ , \quad for\ all\ i \in R, \tau \in t \quad (6.3.2.1.2\text{-}2)$$

Where:

$em'_{R,\tau}$ = emissions allocated to *study region*, *R*, at simulation timestep, τ, calculated in accordance with Section 6.3.2.1 using a perturbed *production cost model* in accordance with Section 6.3.2.2.2(ii)
$em_{R,t}$ = emissions allocated to *study region*, *R*, at simulation timestep, τ, calculated in accordance with Section 6.3.2.1 for the base *production cost model* complying with Section 6.3.1.
$elec\_dem'_{i,t}$ = modified *electricity demand* at *node*, *i*, for timestep, *t*, calculated in accordance with Equation 6.3.2.1.2-2, in units of energy used
$elec\_dem_{i,t}$ = *electricity demand* at *node*, *i*, for timestep, *t*, in units of energy used
ε = perturbation factor of no less than 0.01 and no greater than 0.05

6.4 Calculating projected electricity emissions factors. Where identified as projected emissions factors in accordance with Section 4.2, emissions factors for electricity supply in the *study region* shall comply with Section 6.4.1, 6.4.2 or 6.4.3.

6.4.1 Projected Emissions Factors – Historical Annual Trend. Where identified as "Projected – Historical annual trend" in accordance with Section 4.2 and where the emissions factor timestep, *t*, is one year, *average emissions factors* shall be permitted to be calculated in accordance with Equation 6.4.1.

$$EF_t = \frac{a}{1 + e^{b(t-c)}} \tag{6.4.1}$$

Where the values of a, b and c minimize the sum of the squares of the deviation of emissions factors calculated in accordance with Section 6.2 or 6.3 and Equation 6.4.1 in accordance with the following:

$$\min_{a,b,c} \sum_{\tau=1}^{T} \left[EF_\tau - \frac{a}{1 + e^{b(\tau-c)}} \right]^2$$

Where T is no less than 10 and is permitted to include non-consecutive years.

6.4.2 Projected Emissions Factors – Utility Data. Where identified as "Projected – Utility data basis" in accordance with Section 4.2, emissions factors shall be permitted to be calculated in accordance with Section 6.3 using *verified data* for future electricity generators (Section 6.3.1(a)), internodal transmission interfaces (Section 6.3.1(b)), and *electricity demand* (Section 6.3.1(c)), from any of the following:

a. *Grid operators*, including generator and transmission capacity additions and retirements.

b. Electric utilities, including planned capacity additions and retirements, demand projections and integrated resource plans.

6.4.3 Projected Emissions Factors – Simulated Scenario. Where identified as "Projected – Simulated Scenario" in accordance with Section 4.2, emissions factors shall be permitted to be calculated in accordance with Section 6.3 using *verified data* for future electricity generators (Section 6.3.1(a)), internodal transmission interfaces (Section 6.3.1(b)), and *electricity demand* (Section 6.3.1(c)) based on a publicly available mathematical programming model of the electric power sector that makes investment and operational decisions to minimize the overall cost of the electricity system based on documented technology, market and policy inputs.

6.5 Calculating market-based emissions factors. Where identified as *market-based emissions factors* in accordance with Section 4.2, emissions factor calculations shall comply with Section 6.5.1. Where all *procured electricity* in the *study region* has an emissions factor of zero, emissions factor calculations shall be permitted to comply with Section 6.5.2.

6.5.1 Market-based emissions factors – general method. Emissions factor calculations shall comply with the following:

a. Where identified as "as-measured" in accordance with section 4.2, emissions factor calculations in accordance with Section 6.2 shall be adjusted in accordance with Equation 6.5 for any calculation input, *X*, applicable to *procured electricity* in the *study region*.
b. Where identified as "computer simulation" and as an *average emissions factor* in accordance with Section 4.2, emissions factor calculations in accordance with Section 6.3.2.1.1 shall be adjusted

in accordance with Equation 6.5 for any calculation input, X, applicable to *procured electricity* in the *study region* and adjacent regions in a *production cost model*.

c. Where identified as "computer simulation" and as a *marginal emissions factor* in accordance with Section 4.2, emissions factor calculations shall comply with Section 6.3 without adjustment in accordance with this section.

$$X = X^{(base)} - X^{(PE)} \tag{6.5.1}$$

Where:

X = an input for calculations in accordance with Section 6.2 or a *production cost model* in accordance with Section 6.3.1

$X^{(base)}$ = measured data in accordance with Section 6.2 and *verified data* in accordance with Section 6.3.1, corresponding to calculation input, X, as applicable for the emissions factor identified in accordance with Section 4.2

$X^{(PE)}$ = measured data in accordance with Section 6.2 and *verified data* in accordance with Section 6.3.1, attributed to *procured electricity* corresponding to calculation input, X, for the *study region*, any adjacent regions included in the analysis, and transmission interfaces between regions included in the analysis

6.5.2 Market-based emissions factors – simplified method. Where all *procured electricity* in *the study region* has an emissions factor of zero, *study region* emissions factor calculations based on measured data in accordance with Section 6.2 and *average emissions factor* calculations in accordance with Section 6.3.2.1.1 shall be permitted to be adjusted in accordance with Equation 6.5.1 without further adjustments in accordance with Section 6.5.1.

$$elec\_dem = elec\_dem^{(base)} - elec\_dem^{(PE)} \tag{6.5.2}$$

Where:

$elec\_dem$ = *electricity demand* for calculations in accordance with Section 6.2 or a *production cost model* in accordance with Section 6.3.1

$elec\_dem^{(base)}$ = *electricity demand* in a *study region* in accordance with Section 6.2.2.6 or at a *node* in a *production cost model* in accordance with Section 6.3.1(c)

$elec\_dem^{(PE)}$ = *electricity demand* attributed to *procured electricity* for a *study region* or *node* in a *production cost model* corresponding to the same *study region* or *node* in $elec\_dem^{(base)}$

Informative note: When calculating an *average emissions factor* based on computer simulation, the simplified *market-based emissions factor* in Section 6.5.2 does not require adjustment of a *production cost model* in accordance with Equation 6.5. Only after the output of the unadjusted *production cost model* does *electricity demand* need to be adjusted for the calculation in accordance with Section 6.3.2.1.1.

7. DISTRICT THERMAL ENERGY EMISSIONS FACTORS

7.1 General. Emissions factors for district thermal energy supplied to a *building* or *site*, including steam, hot water and chilled water, shall comply with Section 7.2 in accordance with the selections made in Section 4.2.

7.2 Calculating emissions factors for thermal energy supplied to buildings. Emissions factors for thermal energy supply shall comply with Sections 7.2.1 and 7.2.2.

Exception to 7.2: Where an alternative calculation method is approved by the *AHJ*.

7.2.1 Thermal energy emissions factors – general method. Thermal energy emissions factors shall be calculated in accordance with Equation 7.2.1 unless otherwise permitted by Section 7.2.1.1 or 7.2.1.2.

$$EF\_thermal_t = \frac{1}{1 - TDL\_thermal_t} \sum_s \frac{en\_input\_thermal_{s,t} \times EF\_source_{s,t}}{gen\_thermal_{s,t}} \quad (7.2.1)$$

Where:

$en\_input\_thermal_{s,t}$ = energy input of source, *s*, at time, *t*, to generate thermal energy, determined in accordance with Section 7.2.2.1, in units of energy

$EF\_source_{s,t}$ = emissions factor for energy source, *s*, at time, *t*, determined in accordance with Section 7.2.2.2

$gen\_thermal_{s,t}$ = thermal energy generated by source, *s*, at time, *t*, determined in accordance with Section 7.2.2.3, in units of energy

$TDL\_thermal_t$ = thermal transmission and distribution loss factor at time, t, determined in accordance with Section 7.2.2.5

7.2.1.1 Thermal energy emissions factors – average efficiency alternative. Where a single energy source is used and *verified data* are not available for energy input and thermal energy generated, thermal energy emissions factors are permitted to be calculated in accordance with Equation 7.2.1.1.

$$EF\_thermal_t = \frac{EF\_source_{s,t}}{\eta\_thermal_{s,t} \times (1 - TDL\_thermal_t)} \quad (7.2.1.1)$$

Where:

$\eta\_thermal_{s,t}$ = efficiency of thermal energy generation from source, s, at time, t, determined in accordance with Section 7.2.2.4

7.2.1.2 Thermal energy emissions factors – annual values. Where the timestep, *t*, is less than one year, thermal energy efficiency emissions factors are permitted to use average annual data for the same year in which timestep, *t*, occurs.

7.2.2 Data Inputs for Thermal Energy Emissions Factors. All calculations of emissions factors for thermal energy supply shall comply with Sections 7.2.2.1 through 7.2.2.5.

7.2.2.1 Energy Input for Thermal Energy Generation. All calculations shall use *verified data* for *fuel* or electricity usage by the facility generating the thermal energy at the defined timestep.

7.2.2.2 Thermal Energy Source Emissions Factors. Where the source energy for thermal energy generation is a *fuel*, emissions factor calculations shall use emissions factors complying with Section 5. Where the source energy for thermal energy generation is electricity, emissions factor calculations

shall use emissions factors complying with Section 6. All calculations shall use source energy emissions factors for a *study region* that includes the facility producing the thermal energy.

7.2.2.3 Thermal Energy Generated. Emissions factor calculations shall use *verified data* for thermal energy generated from a specified source at the defined timestep for the facility generating the thermal energy.

7.2.2.4 Thermal Energy Generation Efficiency. Where emissions calculations using average efficiencies are permitted by Section 7.2.1.1, calculations shall use *verified data* for the efficiency of thermal energy generated from a specified energy source at the defined timestep for the facility generating the thermal energy. Where efficiency values are not known for the specific facility, the default values in Table 7.2.2.4 shall be permitted.

Table 7.2.2.4 Default Thermal Energy Conversion Efficiency

Thermal Energy Output	Energy Input Source	Default Efficiency
Hot Water	Fuel	70%
	Electricity – Boiler	90%
	Electricity – Heat Pump	300%
Steam	Fuel	70%
	Electricity – Boiler	90%
Chilled Water	Electricity	440%

7.2.2.5 Thermal Energy Transmission and Distribution Loss Factor. The transmission and distribution loss factor, $TDL\_thermal_{\tau}$, shall be calculated for a timestep, τ, permitted by the other requirements of Section 7.2 and in accordance with Equation 7.2.2.5 for the facility generating the thermal energy. Calculations are permitted to use a timestep, τ, that is greater than the emissions factor calculation timestep, *t*. Where loss factor values are not known for the specific facility, the default values in Table 7.2.2.5 shall be permitted.

$$TDL\_thermal_{\tau} = 1 - \frac{delivered\_thermal_{\tau}}{gen\_thermal_{\tau}} \quad (7.2.2.5)$$

Where:

$delivered\_thermal_{s,t}$ = thermal energy delivered to all end users from the facility at time, *t*, in units of energy

Table 7.2.2.5 Default Thermal Energy Loss Factors

Thermal Energy Output	Default Loss Factor
Hot Water	10%
Steam	15%
Chilled Water	5%

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX A

NATURAL GAS PRE-COMBUSTION DATA USED IN SECTION 5

Table A.1 Pre-Combustion Fuel Emissions Factors for Natural Gas by U.S. Region (kg/MWh)

Region	Phase[a]	CO2	CH4	N2O	CO2e-20	CO2e100
Midwest	Production	1.59E+00	1.62E-01	8.44E-07	1.50E+01	6.42E+00
	Gathering and Boosting	3.46E+00	9.91E-02	2.04E-08	1.16E+01	6.42E+00
	Processing	7.96E+00	5.02E-02	4.65E-05	1.21E+01	9.46E+00
	Transmission Station	4.80E+00	1.11E-01	9.74E-05	1.40E+01	8.13E+00
	Storage	1.57E-01	7.85E-03	1.22E-06	8.05E-01	3.91E-01
	Transmission Pipeline	8.30E-06	9.64E-04	0.00E+00	7.96E-02	2.87E-02
	Distribution	2.01E-02	6.46E-02	0.00E+00	5.35E+00	1.94E+00
	Total - Power Plants	1.80E+01	4.31E-01	1.46E-04	5.36E+01	3.09E+01
	Total - Buildings	1.80E+01	4.95E-01	1.46E-04	5.89E+01	3.28E+01
Northeast	Production	8.42E-01	1.07E-01	4.06E-07	9.67E+00	4.03E+00
	Gathering and Boosting	2.70E+00	7.69E-02	1.76E-08	9.05E+00	5.00E+00
	Processing	4.83E+00	5.46E-02	1.62E-05	9.34E+00	6.46E+00
	Transmission Station	3.99E+00	6.49E-02	9.40E-05	9.37E+00	5.95E+00
	Storage	6.31E-01	1.35E-02	6.00E-06	1.74E+00	1.03E+00
	Transmission Pipeline	9.73E-06	7.37E-04	0.00E+00	6.08E-02	2.20E-02
	Distribution	1.01E-02	6.18E-02	0.00E+00	5.11E+00	1.85E+00
	Total - Power Plants	1.30E+01	3.18E-01	1.17E-04	3.92E+01	2.25E+01
	Total - Buildings	1.30E+01	3.79E-01	1.17E-04	4.43E+01	2.43E+01
Pacific	Production	9.50E-01	2.14E-01	1.50E-06	1.86E+01	7.33E+00
	Gathering and Boosting	3.26E+00	1.09E-01	2.19E-08	1.23E+01	6.52E+00
	Processing	1.80E+01	3.95E-02	1.43E-04	2.13E+01	1.92E+01
	Transmission Station	6.27E+00	5.34E-02	1.45E-04	1.07E+01	7.90E+00
	Storage	2.48E-01	7.99E-03	2.97E-06	9.08E-01	4.87E-01
	Transmission Pipeline	8.15E-06	1.27E-03	0.00E+00	1.05E-01	3.78E-02
	Distribution	8.54E-03	5.73E-02	0.00E+00	4.74E+00	1.72E+00
	Total - Power Plants	2.87E+01	4.26E-01	2.92E-04	6.39E+01	4.15E+01
	Total - Buildings	2.88E+01	4.83E-01	2.92E-04	6.87E+01	4.32E+01
Rocky Mtn.	Production	9.36E-01	2.10E-01	1.47E-06	1.83E+01	7.20E+00
	Gathering and Boosting	3.21E+00	1.08E-01	2.15E-08	1.21E+01	6.42E+00
	Processing	1.77E+01	3.88E-02	1.40E-04	2.10E+01	1.89E+01
	Transmission Station	2.25E+00	1.42E-02	5.53E-05	3.44E+00	2.69E+00
	Storage	4.74E-01	7.41E-03	8.50E-06	1.09E+00	6.97E-01
	Transmission Pipeline	2.74E-06	4.43E-04	0.00E+00	3.66E-02	1.32E-02
	Distribution	2.54E-03	1.52E-01	0.00E+00	1.26E+01	4.54E+00
	Total - Power Plants	2.46E+01	3.79E-01	2.06E-04	5.59E+01	3.59E+01
	Total - Buildings	2.46E+01	5.31E-01	2.06E-04	6.85E+01	4.05E+01
Southeast	Production	2.19E+00	1.81E-01	7.84E-07	1.71E+01	7.58E+00
	Gathering and Boosting	4.39E+00	1.10E-01	2.10E-08	1.34E+01	7.66E+00
	Processing	5.62E+00	5.03E-02	2.10E-05	9.78E+00	7.13E+00

	Transmission Station	5.69E+00	1.94E-01	1.19E-04	2.18E+01	1.15E+01
	Storage	2.89E-01	1.47E-02	2.75E-07	1.50E+00	7.28E-01
	Transmission Pipeline	6.06E-06	1.13E-03	0.00E+00	9.31E-02	3.36E-02
	Distribution	5.18E-02	7.77E-02	0.00E+00	6.46E+00	2.37E+00
	Total - Power Plants	1.82E+01	5.51E-01	1.41E-04	6.37E+01	3.46E+01
	Total - Buildings	1.82E+01	6.29E-01	1.41E-04	7.01E+01	3.70E+01
Southwest	Production	3.46E+00	2.28E-01	1.20E-06	2.23E+01	1.03E+01
	Gathering and Boosting	5.03E+00	1.33E-01	2.44E-08	1.60E+01	9.00E+00
	Processing	6.67E+00	4.88E-02	3.48E-05	1.07E+01	8.13E+00
	Transmission Station	3.04E+00	7.70E-02	6.79E-05	9.41E+00	5.36E+00
	Storage	3.29E-01	9.66E-03	0.00E+00	1.13E+00	6.17E-01
	Transmission Pipeline	3.35E-06	5.97E-04	0.00E+00	4.92E-02	1.78E-02
	Distribution	3.57E-04	6.41E-02	0.00E+00	5.29E+00	1.91E+00
	Total - Power Plants	1.85E+01	4.97E-01	1.04E-04	5.96E+01	3.34E+01
	Total - Buildings	1.85E+01	5.61E-01	1.04E-04	6.49E+01	3.53E+01
US Average[d]	Production	1.83E+00	1.61E-01	7.37E-07	1.51E+01	6.62E+00
	Gathering and Boosting	3.77E+00	1.01E-01	2.03E-08	1.21E+01	6.77E+00
	Processing	5.96E+00	5.14E-02	2.62E-05	1.02E+01	7.49E+00
	Transmission Station	5.16E+00	4.59E-02	1.12E-04	8.97E+00	6.55E+00
	Storage	2.36E-01	9.91E-03	1.10E-06	1.05E+00	5.32E-01
	Transmission Pipeline	1.13E-05	1.05E-03	0.00E+00	8.70E-02	3.14E-02
	Distribution	1.35E-02	5.89E-02	0.00E+00	4.87E+00	1.77E+00
	Total - Power Plants	1.70E+01	3.70E-01	1.40E-04	4.75E+01	2.80E+01
	Total - Buildings	1.70E+01	4.28E-01	1.40E-04	5.24E+01	2.98E+01

a. The physical boundaries of the geographic regions are defined in Figure 5.2
b. For phases up through "Distribution," the same *emissions factors* apply to both power plants and buildings. For "Distribution" the value listed is an average of the power plant and building distribution *emissions factors*.
c. Data Source: Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile, DOE/NETL-2024/4862, December 2024. Data is taken from Appendix F of the NETL document.
d. Pre-combustion emissions for U.S. National Average are permitted to be used as a default for Alaska, Hawaii, and other locations outside of the U.S. For *study regions* in the continental U.S., it is recommended to use the regional values instead of the US Average.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX B

EXAMPLE USE OF SECTION 5 TO DETERMINE ELECTRICITY EMISSIONS FACTORS

Informative Table B.1 includes electricity emissions factors calculated in accordance with Section 6 for the following parameters identified in accordance with Section 4.2:

a. *Calculation period*: Each column represents the start year of a 20-year *calculation period* (e.g. "2025" indicates a *calculation period* beginning January 1, 2025, and ending December 31, 2044); values are averaged over the 20-year *calculation period*.
b. Emissions factor granularity: Annual
c. *Study region*: As indicated by the "eGRID Subregion" column. Lookup tables that indicate eGRIDc subregions by zip code or county are included in the published Cambium 2024 LRMER workbooks available at https://data.nrel.gov/submissions/289.
d. Emissions factor units: kg/MWh
e. Emissions representation: CO_2e
f. *Global warming potential time horizon*: 100-year
g. Electricity emissions calculation procedure: Computer Simulation
h. Emissions factor type: Marginal
i. Projected emissions factor: Simulated scenario
j. Emissions factor: Location-based

Additional Notes:
1. The electricity *greenhouse gas emissions* factors are site end-use long-run marginal emissions rate (LRMER) values for the Cambium 2024 mid-case scenario.
2. The Cambium eGRID subregions are based on balancing area and do not completely align with EPA eGRID subregions, which are based on utility service territory.
3. More details on the Cambium input assumptions and methodology are described in the documentation report available at https://docs.nrel.gov/docs/fy25osti/93005.pdf.

Informative Table B.1

eGRID Subregion	Electricity Emissions Factor ($kgCO_2e/MWh$)[a]						
	First Year of Calculation Period[b]						
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
CAISO	208	199	199	199	202	206	211
ERCOT	60.1	48.0	41.4	34.2	30.4	26.6	24.2
FRCC	117	104	98	90	89	88	90
ISONE	310	314	320	328	339	350	360
MISO Central	290	285	285	285	287	290	293
MISO North	191	185	186	187	192	197	200
MISO South	294	284	276	267	262	256	252
Northern Grid East	144	128	119	110	106	103	103
Northern Grid South	95.2	76.8	61.0	45.1	34.6	24.2	18.1
Northern Grid West	412	409	409	408	411	414	416
NYISO	517	517	517	516	516	515	515
PJM East	449	443	439	433	430	426	423
PJM West	220	206	197	189	187	185	186
SERTP	196	187	185	184	190	195	201
SPP North	226	214	209	204	205	206	211
SPP South	437	424	413	400	390	379	370
West Connect North	285	272	264	252	246	239	235
West Connect South	248	235	227	217	211	205	199