ANSI/ASHRAE/ICC/USGBC/IES Addendum m to ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2020

Standard for the Design of High-Performance Green Buildings

Except Low-Rise Residential Buildings

The Complete Technical Content of the International Green Construction Code®

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FOREWORD

Addendum m updates Section 7.5 (Performance Option) by making the following changes:

- *The source energy conversion factors and greenhouse gas (GHG) emission factors are updated, based on the latest prepandemic data from the U.S. Energy Information Agency (EIA) and Environmental Protection Agency (EPA).*
- *The global warming potential (GWP) for methane and nitrous oxide are updated based on the 2021 AR6 draft of from the IPCC (pp. 7-125).*
- *A separate building performance factor table is added for GHG emissions. Previously, a single BPF table was used for both cost and GHG.*
- *Methane leaks from the natural gas system are reduced by about 23% based on a 2019 NETL report. Previously, data were from a 2016 NETL report.*
- *Combustion and precombustion emission rates for CO_2, N_2O and CH_4 were updated from NREL's latest life-cycle inventory (LCI) database.*
- *The GHG metric is modified to be a ratio of the emissions of the rated building to the emissions of the baseline building and a new definition is added for "zero carbon emissions factor" (zCEF).*
- *Various editorial changes are made for clarification.*
- *The informative note to Section 7.5.2.1 was relocated and modified to clarify that local jurisdictions in the U.S. can use the procedures in Informative Appendix J to derive emission rates appropriate for the local electric generation mix.*
- *An informative note in the caption to Table 7.5.3 clarifies that the emission rates are based on GWP20 but that emission rates for GWP100 are included in Informative Appendix J for use when appropriate.*
- *The I-P values in Table 7.5.3 are deleted leaving only the SI values (kg/MWh).*
- *Separate emission rates are published for combustion at the power plant and precombustion emissions.*

Informative Appendix J is replaced in its entirety by an updated version. The original version is omitted for brevity.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum m to Standard 189.1-2020

Add new definition to Section 3.2.

zero carbon emissions factor (zCEF): *CO_2e* emissions of the proposed building compared to the *CO_2e* of the baseline building, as defined in by the performance rating method of ASHRAE Standard 90.1.

Modify Section 7.5 and 7.5.1 as shown. Lightly shaded text is relocated from another section.

7.5 Performance Option. Buildings shall comply with 7.5.1, 7.5.2 and 7.5.3 using the baseline building definition and modeling procedures as defined in Standard 90.1, Normative Appendix G, and modified by Appendix C.

On-site renewable energy systems in the *proposed design* shall be calculated using the procedures in Normative Appendix C. For mixed-use buildings, the building performance factor (BPF) shall be determined by weighting each building type by floor area. A *building project* served in whole or in part by a district energy plant shall follow the modeling requirements contained in Normative Appendix C, Section C1.3, in order to comply with this section.

7.5.1 Annual Energy Cost. The proposed building performance cost index (PCI) shall be equal to or less than the target performance cost target, as determined from the following equation:

$$\cancel{PCI_t = \frac{[BBUEC + (BBREC \times BPF)] \times (1 - RF)}{BBUEC + BBREC}}$$

$$\underline{PCI_{target} = \frac{[EC_{UBB} + (EC_{RBB} \times PBF_c)] \times (1 - RF_c)}{EC_{UBB} + EC_{RBB}}}$$

where

PCI_{target} = target PCI required for achieving compliance with ~~the~~ Section 7.5.1 of the standard, unitless

~~BBUEC~~ EC_{UBB} = ~~the~~ annual energy cost ~~component~~ of the baseline building ~~*baseline building* performance that is due to~~ resulting from *unregulated energy use*, \$

~~BBREC~~ EC_{RBB} = ~~the~~ annual energy cost ~~component~~ of the baseline building ~~*baseline building* performance that is~~ resulting from *unregulated energy use*~~, or baseline building performance minus BBUEC~~, \$

BPF_c = building performance factor for cost taken from Table 7.5.1, unitless

RF_c = renewable energy production fraction for cost from Table 7.5.1, unitless

~~On-site renewable energy systems in the proposed design shall be calculated using the procedures in Normative Appendix C. For mixed-use buildings, the building performance factor (BPF) shall be determined by weighting each building type by floor area. A building project served in whole or in part by a district energy plant shall follow the modeling requirements contained in Normative Appendix C, Section C1.3, in order to comply with this section.~~

[. . .]

Modify Section 7.5.2 as shown. Add new sections 7.5.2.1 and 7.5.2.2.

7.5.2 Zero ~~Annual~~ Carbon ~~Dioxide Equivalent~~ Emissions Factor (zCEF) ~~(CO_2e)~~. The *proposed design* *zCEF* shall ~~have annual CO_2e emissions~~ be equal to or less than the ~~annual CO_2e emissions~~ target *zCEF* as follows: ~~of the baseline building design multiplied by PCI target determined from 7.5.1.~~

$$zCEF_{proposed} \le zCEF_{target}$$

where

$$zCEF_{target} = \frac{[GHG_{UBB} + (GHG_{RBB} \times BPF_{energy})] \times (1 - RF_{energy})}{GHG_{UBB} + GHG_{RBB}}$$

and

$$zCEF_{proposed} = \frac{GHG_{proposed} - AE}{GHG_{UBB} + GHG_{RBB}}$$

and

$zCEF_{target}$ = target *zCEF* required for achieving compliance with the standard, unitless

$zCEF_{proposed}$ = proposed building *zCEF*, unitless

GHG_{UBB} = baseline building annual CO_2e emissions resulting from unregulated energy (see 7.5.2.1), CO_2e

GHG_{RBB} = baseline building annual CO_2e emissions resulting from regulated energy (see Section 7.5.2.1), CO_2e

BPF_{energy} = building performance factor for emissions taken from Table 7.5.2, unitless

RF_{energy} = renewable energy production fraction for emissions from Table 7.5.2, unitless

$GHG_{proposed}$ = proposed building annual CO_2e emissions resulting from regulated and unregulated energy (see Section 7.5.2.1), CO_2e

AE = avoided CO_2e emissions resulting from the purchase of off-site renewable energy (see Section 7.5.2.1)

7.5.2.1 Annual Average GHG Emissions. To determine the annual CO_2e for each energy source in the baseline building ~~design~~ and *proposed design* (GHG$_{UBB}$, GHG$_{RBB}$, GHG$_{proposed}$), the energy consumption for each fuel shall be multiplied by the CO_2e emission factors from Table 7.5.~~2~~3. U.S. locations shall use values for eGRID subregions from Table 7.5.~~2~~3 and Figure 7.5.~~2~~3 for electricity. Locations outside the U.S. shall use the value for "All other electricity" or locally derived values. ~~A building project served in whole or in part by a district energy plant shall follow the modeling requirements contained in Normative Appendix C, Section C1.3, in order to comply with this section.~~

Informative Note: The values in Table 7.5.~~2~~3 are based on eGRID subregions and delivery of fossil fuels for U.S. locations. ~~derived from United Stated data.~~ Some jurisdictions use locally derived values based on procedures in Informative Appendix J. ~~The procedures in Informative Appendix J may be used to develop CO_2e emission factors when conditions are different.~~

$$\text{GHG}_x = \sum_i (Q_i \times e_i)$$

where

GHG$_x$ = annual CO_2e emissions for GHG$_{UBB}$, GHG$_{RBB}$, and GHG$_{proposed}$ from Section 7.5.2, kg

Q_i = annual energy consumption, MWh

e_i = CO_2e emissions rate taken from Table 7.5.3 for fuel type i; eGRID values shall be used for electricity when applicable, kg/MWh

i = index for fuel used at the baseline or proposed building

The avoided emissions from off-site renewable energy procurement shall be calculated as follows:

$$\text{AE} = \sum_k (Q_k \times \text{REPF}_k \times e_e)$$

where

Q_k = annual renewable energy (electricity) purchased through procurement method k, MWh

REPF$_k$ = renewable energy procurement factor from Table 7.4.1.2 for renewable energy procurement method k, unitless

e_e = CO_2e emissions rate for electricity taken from Table 7.5.3. eGRID values shall be used when applicable

k = index for off-site renewable energy procurement method

Modify Table 7.5.1 as shown. (Note: This table has been reorganized for usability. Only the title includes changes; table values are unchanged.)

Table 7.5.1 ~~Energy Cost and CO_2e~~ Building Performance Factors for Cost (BPF_c) and Renewable Fraction (RF_c)

		Building Type								
	Climate Zone	Multifamily	Health Care/Hospital	Hotel/Motel	Office	Restaurant	Retail	School	Warehouse	All others
Building Performance Factor for Cost	0A and 1A	0.61	0.56	0.51	0.48	0.62	0.48	0.37	0.36	0.51
	0B and 1B	0.62	0.55	0.49	0.52	0.62	0.51	0.45	0.40	0.53
	2A	0.58	0.53	0.49	0.45	0.58	0.46	0.36	0.38	0.46
	2B	0.58	0.50	0.47	0.51	0.59	0.52	0.41	0.40	0.48
	3A	0.61	0.53	0.49	0.49	0.58	0.48	0.36	0.41	0.46
	3B	0.59	0.50	0.48	0.51	0.60	0.52	0.41	0.42	0.50
	3C	0.50	0.50	0.48	0.42	0.57	0.48	0.39	0.40	0.47
	4A	0.66	0.51	0.48	0.47	0.61	0.48	0.36	0.42	0.50
	4B	0.66	0.49	0.48	0.47	0.56	0.52	0.39	0.41	0.48
	4C	0.67	0.50	0.47	0.45	0.60	0.51	0.38	0.44	0.50
	5A	0.63	0.53	0.45	0.47	0.62	0.47	0.36	0.47	0.47
	5B	0.65	0.47	0.47	0.47	0.59	0.50	0.39	0.44	0.47
	5C	0.66	0.49	0.46	0.44	0.63	0.51	0.36	0.45	0.45
	6A	0.62	0.54	0.46	0.49	0.65	0.47	0.35	0.51	0.47
	6B	0.65	0.49	0.47	0.48	0.62	0.48	0.36	0.48	0.47
	7	0.61	0.55	0.46	0.46	0.66	0.46	0.35	0.54	0.47
	8	0.65	0.55	0.47	0.49	0.69	0.47	0.36	0.53	0.43
Renewable Fraction		0.50	0.35	0.50	0.50	0.10	0.50	0.50	0.50	0.50

Insert new Table 7.5.2 as shown.

Table 7.5.2 Building Performance Factors for Emissions (BPF_e) and Renewable Fraction (RF_e)

		Building Type								
	Climate Zone	**Multifamily**	**Health Care/Hospital**	**Hotel/Motel**	**Office**	**Restaurant**	**Retail**	**School**	**Warehouse**	**All others**
Building Performance Factor for Greenhouse Gas Emissions	0A/1A	0.64	0.57	0.55	0.53	0.49	0.50	0.39	0.38	0.51
	0B/1B	0.64	0.57	0.55	0.53	0.49	0.50	0.39	0.38	0.51
	2A	0.63	0.58	0.54	0.50	0.50	0.47	0.37	0.40	0.50
	2B	0.65	0.52	0.54	0.55	0.48	0.47	0.43	0.40	0.51
	3A	0.63	0.56	0.54	0.51	0.51	0.49	0.38	0.43	0.50
	3B	0.66	0.55	0.57	0.55	0.53	0.50	0.45	0.42	0.53
	3C	0.61	0.55	0.57	0.48	0.54	0.50	0.38	0.37	0.50
	4A	0.60	0.56	0.52	0.48	0.53	0.51	0.35	0.49	0.50
	4B	0.65	0.55	0.52	0.51	0.52	0.51	0.42	0.44	0.52
	4C	0.60	0.56	0.54	0.47	0.57	0.53	0.44	0.47	0.52
	5A	0.57	0.56	0.51	0.49	0.56	0.53	0.37	0.53	0.52
	5B	0.62	0.53	0.49	0.51	0.53	0.52	0.45	0.48	0.52
	5C	0.62	0.55	0.54	0.48	0.57	0.54	0.37	0.45	0.51
	6A	0.55	0.55	0.52	0.49	0.59	0.54	0.38	0.57	0.52
	6B	0.57	0.53	0.53	0.50	0.57	0.54	0.37	0.53	0.52
	7	0.53	0.55	0.51	0.46	0.60	0.50	0.37	0.53	0.51
	8	0.56	0.55	0.52	0.48	0.65	0.50	0.41	0.53	0.52
Renewable Fraction		0.50	0.35	0.50	0.50	0.10	0.50	0.50	0.50	0.50

Replace old Table 7.5.2 with new Table 7.5.3 as shown. The deleted table is omitted for brevity.

Table 7.5.3 Source Energy Conversion Factors and CO_2e Emission Factors

		CO_2e Emissions, kg/MWh		
	Source Energy Conversion Factor	Combustion	Precombustion	Total
Fossil fuels delivered to buildings				
Natural gas	1.092	184	93	277
Liquefied petroleum gas or propane	1.151	229	66	295
Fuel oil (residual)	1.191	265	70	334
Fuel oil (distillate)	1.158	255	69	324
Coal	1.048	332	51	382
Gasoline	1.187	255	82	337
Other fuels not specified in this table	1.048	332	51	382
Electricity				
AKGD–ASCC Alaska Grid	2.47	514	159	673
AKMS–ASCC miscellaneous	1.35	289	93	383
AZNM –WECC Southwest	2.57	444	121	565
CAMX–WECC California	1.66	255	88	343
ERCT–ERCOT all	2.32	431	126	558
FRCC–FRCC all	2.78	442	155	596
HIMS–HICC miscellaneous	3.15	681	211	892
HIOA–HICC Oahu	3.87	895	233	1128
MROE–MRO East	2.92	770	150	920
MROW–MRO West	2.21	534	94	628
NEWE–NPCC New England	2.66	287	96	383
NWPP–WECC Northwest	1.48	349	76	426
NYCW–NPCC NYC/Westchester	2.89	269	110	379
NYLI–NPCC Long Island	2.84	481	169	650
NYUP–NPCC Upstate NY	1.81	132	48	180
PRMS–Puerto Rico Miscellaneous	3.27	731	214	944
RFCE–RFC East	2.90	350	106	456
RFCM–RFC Michigan	2.93	594	133	727
RFCW–RFC West	2.97	532	113	645
RMPA–WECC Rockies	2.16	580	120	699
SPNO–SPP North	2.21	515	93	608
SPSO–SPP South	2.05	460	123	583
SRMV–SERC Mississippi Valley	2.84	418	137	555

Informative Note: The CO_2e emission factors presented in this table are based on U.S. data and a 20-year time horizon for methane (CH_4) and nitrous oxide (N_2O). When comparing or combining CO_2e values, care should be taken to ensure that a consistent time horizon is used for all estimates of CO_2e. Informative Appendix J, Table J-11, has emission rates based on a 100-year time horizon for use when the use of 100-year time horizons is necessary.

Table 7.5.3 Source Energy Conversion Factors and CO_2e Emission Factors *(Continued)*

		CO_2e Emissions, kg/MWh		
	Source Energy Conversion Factor	**Combustion**	**Precombustion**	**Total**
SRMW–SERC Midwest	3.09	779	134	913
SRSO–SERC South	2.89	496	133	629
SRTV–SERC Tennessee Valley	2.82	473	104	577
SRVC–SERC Virginia/Carolina	2.91	360	97	456
All other electricity	2.51	436	111	547
Thermal Energy				
Chilled water	0.60	104	26	131
Steam	1.84	309	157	466
Hot water	1.73	292	148	440

Informative Note: The *CO_2e* emission factors presented in this table are based on U.S. data and a 20-year time horizon for methane (CH_4) and nitrous oxide (N_2O). When comparing or combining *CO_2e* values, care should be taken to ensure that a consistent time horizon is used for all estimates of *CO_2e*. Informative Appendix J, Table J-11, has emission rates based on a 100-year time horizon for use when the use of 100-year time horizons is necessary.

Replace Informative Appendix J as shown. (Note: This addendum is a complete replacement of Informative Appendix J of Standard 189.1-2020. The replaced appendix is omitted for brevity.)

INFORMATIVE APPENDIX J
DERIVATION OF SOURCE ENERGY CONVERSION FACTORS AND CO_2e EMISSION FACTORS

This informative appendix documents the procedures used to develop the source energy conversion factors and *CO_2e* emission factors in Table 7.5.3 of Standard 189.1 and provides guidance on how the data can be modified for non-United States locations. Example data used to illustrate the procedure is for the entire United States electric grid in 2019. A similar procedure was used to develop source energy conversion factors and CO_2e emission factors for the eGRID subregions based on EPA eGRID data for 2019, the only difference being the mix of electric generators.

The greenhouse natural gas (GHG) emission rates in this appendix are applicable to the operation of the building and are keyed to building energy use. This appendix does not address the embodied carbon emissions related to building construction or demolition and recycling at the end-of-life.

J1. SOURCE ENERGY CONVERSION FACTORS

J1.1 Source Energy Conversion Factors for Fossil Fuels. For the U.S., the source energy conversion factors for fossil fuel delivered to buildings or power plants are listed in Table J-1. These factors represent the additional energy required to extract, process, and deliver the fuel to a building or power plant. The values for bituminous coal are assumed for all U.S. coal-fired power plants.

J1.2 Source Conversion Factors for Electricity. For electricity, the source energy conversion factors represent the energy required to extract, process, and deliver fuel to power plants plus the energy used at the power plant to generate electricity. Transmission and distribution losses are also accounted for.

J1.2.1 Distribution Efficiency. For 2019, the U.S. Energy Information Agency (EIA) reports that, 3,965 billion kWh were generated at domestic power plants in the U.S and that 211 billion kWh (5.3%) were lost through the transmission and distribution (T&D) system. This results in a distribution efficiency of 94.7%. These data are taken from the EIA Monthly Energy Report (MER), Table 7.1. The nationwide distribution efficiency is assumed for each of the eGRID subregions in the U.S. T&D losses in the U.S. have been fairly stable for approximately the last 30 years, averaging about 7.2%. When the procedure in this appendix is applied to the electric grid in other countries, the assumption on T&D losses should be updated based on local conditions.

J1.2.2 Heat Rates. The efficiency of power plants is commonly stated in terms of a heat rate, which represents the amount of fuel needed to generate a unit of electricity. The common units in the U.S. are Btu/kWh. The heat rate for coal, petroleum, and nuclear power plants has not changed much in the last 20 years, but the heat rate of natural gas power plants has significantly declined, mainly because new plants use more efficient combined-cycle technology. Heat rates are reported by EIA MER, Table A6, and are listed here in Table J-2. The heat rate for biomass plants is not directly reported by EIA but is calculated by dividing the heat input to wood and waste power plants from EIA MER, Table 10.2c, by the electricity generated by these plants, which is reported in EIA MER, Table 7.2b. The heat rate of noncombustible renewable power plants (wind, solar, hydro, and geothermal) is assumed to be zero.

The power plant efficiency is determined by dividing the heat content of a kWh of electricity (3412 Btu/kWh) by the heat rate.

J1.2.3 Source Energy Conversion Factor for Power Plant Types. The source energy conversion factor for each type of power plant is calculated as shown in Equation J-1. Calculated values for each type of power plant are shown in Table J-2

$$\mathrm{SECF}_{PowerPlant} = \frac{\mathrm{SECF}_{fuel}}{\mathrm{DeliveryEfficiency} \times \mathrm{PowerPlantEfficiency}} \quad \text{(J-1)}$$

where

$\mathrm{SECF}_{PowerPlant}$	=	source energy conversion factor for each power plant type, unitless
SECF_{fuel}	=	source energy conversion factor of the fuel used at the power plant, unitless, taken from Table J-1
DeliveryEfficiency	=	delivery efficiency (see Section J1.2.1)

Table J-1 Source Energy Conversion Factors for Fuel Delivered to Buildings

Fuel	Source Energy Conversion Factor ($SECF_{fuel}$)
Anthracite coal	1.029
Bituminous coal	1.048
Sub-bitumious coal	1.066
Lignite coal	1.102
Natural gas	1.092
Residual fuel oil	1.191
Distillate fuel oil	1.158
Gasoline	1.187
Liquefied petroleum gas	1.151
Kerosene	1.205

Data Source: Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were derived from the U.S. life-cycle inventory (LCI) database maintained by NREL.

Table J-2 Calculation of SECF for Power Plant Types

Power Plant Type	$HeatRate_{PowerPlant}$	Power Plant Efficiency	$SECF_{fuel}$	Delivery Efficiency	$SECF_{PowerPlant}$
Coal	10,551	32.3%	1.048	94.7%	3.42
Petroleum	11,135	30.6%	1.191	94.7%	4.11
Natural gas	7732	44.1%	1.092	94.7%	2.61
Other gases	7732	44.1%	1.092	94.7%	2.61
Nuclear	10,442	32.7%	1.000	94.7%	3.23
Pumped storage	8904	38.3%	1.000	94.7%	2.76
Hydroelectric	0	N/A	N/A	94.7%	0
Wood	16,682	20.5%	1.025	94.7%	5.29
Waste	15,388	22.2%	1.025	94.7%	4.88
Geothermal	0	N/A	N/A	94.7%	0
Solar	0	N/A	N/A	94.7%	0
Wind	0	N/A	N/A	94.7%	0

Notes:

a. Heat rates are taken from the 2019 Energy Information Administration (EIA) monthly energy review (MER), Table A6.

b. The heat rate for wood and waste is fuel consumption from the 2019 EIA MER, Table 10.2c, divided by the biomass net generation from of the 2019 MER, Table 7.2b.

PowerPlantEfficiency = power plant efficiency, determined by dividing 3412 Btu/kWh by the heat rate

$HeatRate_{PowerPlant}$ = heat rate (efficiency) of the power plant, Btu/kWh (see Table J-2)

J1.2.4 Source Energy Conversion Factors for Electric Generation Mix. The source energy conversion factor for the U.S. and for each eGRID subregion is calculated as the weighted average of the source energy conversion factors for each power plant type from Table J-2, based on the generation mix for each electric grid or subgrid (see Equation J-2).

$$SECF_{GenMix} = \sum_{i=1}^{n} SECF_i \times GenMix_i \qquad \text{(J-2)}$$

Table J-3 U.S. Electricity Generation Mix for 2019
(Source: Energy Information Agency, Monthly Energy Report, Table 7.2b)

Generator Type	Percent of Generation		Source Energy Conversion Factor for Generator Type			Product
Coal	24.2%	×	3.42		=	0.83
Petroleum	0.4%	×	4.11		=	0.02
Natural Gas	37.3%	×	2.61		=	0.97
Other Gases	0.1%	×	2.61		=	0.00
Nuclear	20.4%	×	3.23		=	0.66
Pumped Storage	-0.1%	×	2.76		=	(0.00)
Hydroelectric	7.2%	×	0		=	—
Wood	0.3%	×	5.29		=	0.02
Waste	0.4%	×	4.88		=	0.02
Geothermal	0.4%	×	0		=	—
Solar	1.8%	×	0		=	—
Wind	7.4%	×	0		=	—
				Sum product		2.51

Table J-4 Global Warming Potential (GWP) (unitless multipliers)

	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)
20-year cumulative forcing	1	82.5	273
100-year cumulative forcing	1	29.8	273

Source: These values are taken from the Intergovernmental Panel on Climate Change (IPCC) AR6 Draft, Table 7.15, released August 7, 2021 report (p. 7-125).

where

$SECF_{GenMix}$ = overall SECF for the mix of generator types in the electric grid

$SECF_i$ = source energy conversion factor of the *i*-th generator type

$GenMix_i$ = fraction of total electric generation provided by the *i*-th generator type

i = index for the *i*-th generator type

n = number of generator types in the electric grid

Table J-3 shows the mix of electricity generated in the U.S. in 2019 (from EIA MER, Table 7.2b) and illustrates how the source energy conversion factor is calculated as a weighted average. A similar process was used to calculate the SECF for each eGRID subregion, the only difference being the mix of generator types.

J2. CARBON DIOXIDE EQUIVALENT (CO_2e) EMISSIONS

J2.1 Fossil-Fuel Emissions. Fossil-fuel combustion results in the release of three significant greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). While the amount of CH_4 and N_2O are small compared to CO_2, these gases have a much larger impact on global warming than CO_2 for a given mass of emissions. The global warming potential (GWP) for 20-year (GWP_{20}) and 100-year (GWP_{100}) cumulative forcing as determined by the International Panel of Climate Change (IPCC) is used in the analysis (see Table J-4). These data are used to determine the CO_2e values and are used to calculate the CO_2e for both fuels delivered to power plants and directly to buildings.

Greenhouse gas emissions are released at the point of combustion (stack emissions), but emissions also result from the mining of coal, production of oil and gas, and refinement, pumping, trucking, rail transport, and/or piping of fuels. Table J-5 lists both the combustion and precombustion emission rates of CO_2, CH_4, and N_2O per unit of fuel consumed by power plants. Table J-6 lists the emission rates for fuels delivered to buildings. CO_2e is calculated for both GWP_{20} and GWP_{100}.

J2.2 CO_2e Emissions for Power Plant Types. The CO_2e emissions are calculated for each power plant type using Equation J-3. Table J-7 shows the emissions for each power plant type for both GWP_{20} and GWP_{100}.

$$\text{PowerPlantEmissions} = \frac{\text{Emissions}_{fuel}}{\text{DeliveryEfficiency} \times \text{PowerPlantEfficiency}} \tag{J-3}$$

where

PowerPlantEmissions	=	emission rate for each power plant type, CO_2e/MWh
Emissions_{fuel}	=	emissions per unit of fuel consumed at the power plant, lb/MWh, taken from Table J-5
DeliveryEfficiency	=	delivery efficiency (see Section J1.2.1)
PowerPlantEfficiency	=	power plant efficiency, determined by dividing 3412 Btu/kWh by the heat rate

J2.3 CO_2e Emissions for Electric Generation Mix. The CO_2e emissions rate for the U.S. grid or for an eGRID subregion is calculated as the weighted average of the power plant emissions calculated in Table J-7, using Equation J-4. Calculated values are shown in Table J-8 for the entire U.S. A similar procedure is used for each of the eGRID subregions.

$$\text{Emissions}_{GenMix} = \sum_{i=1}^{n} \text{PowerPlantEmissions}_i \times \text{GenMix}_i \tag{J-4}$$

where

$\text{Emissions}_{GenMix}$	=	total emissions for the mix of generator types in the electric grid, lb/MWh
$\text{PowerPlantEmissions}_i$	=	source energy conversion factor of the *i*-th generator
GenMix_i	=	fraction of total electric generation provided by the *i*-th generator type
i	=	index for the *i*-th power plant type
n	=	number of power plant types

Table J-8 shows the mix of electricity generated in the U.S. for 2019 and illustrates how the CO_2e emissions rate is calculated for the entire U.S. electric grid. A similar process was used to calculate the CO_2e emissions for each eGRID subregion, the only difference being the mix of generator types.

J3. DISTRICT ENERGY SYSTEMS

District energy systems are assumed to use electricity for cooling and natural gas for heating. Values in Table 7.5.3 were calculated based on the district energy efficiency assumptions shown in Table J-9. These or other assumptions appropriate for local conditions should be used when values in Table 7.5.3 are modified. Please note that the published values for district energy systems can be overridden through district energy modeling procedures in Normative Appendix C.

J4. CALCULATION RESULTS FOR THE UNITED STATES

The CO_2e emission rates published in Standard 189.1 are based on a GWP_{20} for CH_4 and N_2O. For comparison, emission rates are shown here for both GWP_{20} and GWP_{100}. Care must be taken to ensure that a consistent time-horizon is used when comparing or combining CO_2e values. Table J-11 has data for a 100-year time-horizon for this purpose.

J5. APPLYING THE CO_2E EMISSIONS PROCEDURE TO SPECIAL CASES

This section of the informative appendix shows how the assumptions used for the United States can be modified and how the procedure can be applied to other countries or special cases within the U.S. The inputs to the procedure that are most likely to change are as follows:

a. The mix of electric generators
b. Power plant efficiency
c. Delivery efficiency
d. Precombustion emissions, especially for imported liquefied natural gas (LNG) or coal

J5.1 Case Study #1: Community Choice Aggregator. A community choice aggregator in the U.S. buys electricity on behalf of the customers it serves. The mix of electricity purchased is 40% wind, 20% solar, and 40% natural gas. The emissions for each power plant type are assumed to be equal to the U.S. fleet average values shown in Table J-8. The GHG emissions for this special condition are 250 kg/MWh for GWP_{20} and 213 kg/MWh for GWP_{100} as calculated in Table J-12.

J5.2 Case Study #2: Hypothetical Electric Grid. Consider the following hypothetical electric grid:

a. Generation mix: 30% domestic coal, 50% domestic natural gas, and 20% wind
b. Power plant efficiency: coal fleet average 25% and natural gas fleet average 40%
c. Delivery efficiency: 92% (8% transmission and distribution losses)

The first step is to calculate the emissions for the fleet average coal and natural gas power plants. These calculations use Equation J-3 and are shown in Table J-13. Emission rates for coal and natural gas consumption are assumed to be the same as for the U.S., as documented in Table J-5.

The second step is to calculate the weighted average for the mix of electric generators. These calculations use Equation J-4 and are shown in Table J-14.

J5.3 Case Study #3: Liquefied Natural Gas to Europe or Asia. The precombustion emissions for liquefied natural gas (LNG) are significantly greater than for domestic production of natural gas or even foreign natural gas that arrives through a pipeline. The precombustion emissions in Tables J-5 and J-6 include emissions from extraction at the well, processing, and pipeline transport, including methane leaks. But these data do not include additional emissions that occur for LNG due to the following:

a. Liquefaction: The gas is further treated to remove CO_2, H_2S, water, and heavy hydrocarbons. It is then cooled to –162°C to reduce its volume and convert it to liquid form. After liquefaction, 0.02% to 0.1% of the gas boils off while in storage.
b. Tanker Transport: The LNG is loaded onto special tankers with pressurized containers and shipped to importing countries. Travel distances from the U.S. to foreign markets range from 9000 to 32,000 km. Boil-off gas during transport is used to help power the ship.
c. Regasification: When the LNG reaches its destination, it is regasified to make it suitable for power plants, industrial applications, and buildings.

Additional source energy and additional GHG emissions result at each of these steps. The top part of Table J-15 is an estimate of the additional CO_2e emissions related to LNG. These figures are normalized by the electricity delivered to power plants or customers.

The combustion emissions for LNG are the same as for domestic natural gas, but the precombustion emissions are greater by the values shown in Table J-15. Assuming the same natural gas power plant efficiency and delivery efficiency as the U.S., the second part of Table J-14 shows that total natural gas power plant emissions are increased about 13% for U.S. shipments to Europe and about 23% for shipments to Asia.

J5.4 Case Study #4—Imported Coal. The precombustion emissions for coal in Tables J-5 and J-6 do not include the emissions from transporting coal from one country to another, typically by ship. Based on the following assumptions, the additional precombustion emissions for coal transport are about 1.85 kg/MWh for each 1000 km of transport distance:

a. A Panamax size bulk carrier uses 240,000 L of fuel oil per day at a speed of about 40 km/h (21 knots). This works out to be 250,000 L per 1000 km traveled.
b. At 334 kg/MWh of carbon emissions per unit of fuel oil consumption (from Table J-6), ship emissions are 960,000 kg of CO_2e per 1000 km traveled.

c. This ship can carry 73,000 metric tons of coal with a heat content of about 520,000 MWh.
d. This works out to be 1.85 kg/MWh for a distance of 1000 km.

The distance from Sydney to Tokyo or Shanghai is about 8000 km, and the additional CO_2e emissions are 14.8 kg/MWh of coal delivered, a 29% increase in precombustion emissions. Note that this is a rough estimate that does not include the possibility that the ship will return to the coal destination empty, nor do the emissions include loading and unloading the coal at the ports.

Table J-5 Combustion and Precombustion Emissions for Fossil Fuels Used in Power Plants

Fuel	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	Emissions$_{fuel}$ CO_2e (20-year)	Emissions$_{fuel}$ CO_2e (100-year)
Combustion Emissions (kg/MWh of fuel consumption)					
Coal	326.90	0.0385	0.0056	331.61	329.58
Petroleum	261.44	0.0108	0.0022	262.93	262.36
Natural gas	183.64	0.0034	0.0004	184.02	183.84
Other gases	183.64	0.0034	0.0004	184.02	183.84
Nuclear	0.00	0.0000	0.0000	0.00	0.00
Pumped storage	0.00	0.0000	0.0000	0.00	0.00
Hydroelectric	0.00	0.0000	0.0000	0.00	0.00
Wood	161.09	0.0110	0.0188	167.13	166.55
Waste	161.09	0.0110	0.0188	167.13	166.55
Geothermal	0.00	0.0000	0.0000	0.00	0.00
Solar	0.00	0.0000	0.0000	0.00	0.00
Wind	0.00	0.0000	0.0000	0.00	0.00
Precombustion Emissions (kg/MWh of fuel consumption)					
Coal	7.40	0.5233	0.0001	50.60	23.02
Petroleum	35.94	0.5573	0.0006	82.08	52.72
Natural gas	16.47	0.7350	0.0000	77.13	38.40
Other gases	16.47	0.7350	0.0000	77.13	38.40
Nuclear	0.00	0.0000	0.0000	0.00	0.00
Pumped storage	0.00	0.0000	0.0000	0.00	0.00
Hydroelectric	0.00	0.0000	0.0000	0.00	0.00
Wood	7.53	0.0090	0.0000	8.28	7.81
Waste	7.53	0.0090	0.0000	8.28	7.81
Geothermal	9.07	0.0000	0.0000	9.07	9.07
Solar	0.00	0.0000	0.0000	0.00	0.00
Wind	0.00	0.0000	0.0000	0.00	0.00
Total Emissions (kg/MWh of fuel consumption)					
Coal	334.30	0.5618	0.0057	382.21	352.60
Petroleum	297.39	0.5681	0.0028	345.01	315.08
Natural gas	200.11	0.7385	0.0004	261.15	222.23

Sources of Data:

a. Combustion and precombustion emissions for coal (bituminous assumed), petroleum, and natural gas are taken from the National Renewable Energy Laboratory (NREL) LCI database. Values were first published in Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were updated by NREL in 2021.

b. Precombustion methane emissions for natural gas are based on total losses of 1.09% for gas delivered to power plants. These data were derived from DOE. 2019. *Life Cycle Analysis of Natural Gas Extraction and Power Generation*, Table ES-1. DOE/NETL-2019/2039. Washington, DC: U.S. Department of Energy.

d. Values for biomass were not reported in the NREL document. Data in this table were derived separately from EIA data and information from the California Air Resources Board (CARB). The cumulative net emissions for the 20-year and 100-year periods are adjusted by subtracting the estimated counterfactual emissions.

e. Emissions at geothermal plants are small but not zero. A value of 20 lb of CO_2 per MWh of production is assumed based on geothermal plants in the western United States.

Table J-5 Combustion and Precombustion Emissions for Fossil Fuels Used in Power Plants *(Continued)*

Fuel	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	$Emissions_{fuel}$ CO_2e (20-year)	$Emissions_{fuel}$ CO_2e (100-year)
Other gases	200.11	0.7385	0.0004	261.15	222.23
Nuclear	0.00	0.0000	0.0000	0.00	0.00
Pumped storage	0.00	0.0000	0.0000	0.00	0.00
Hydroelectric	0.00	0.0000	0.0000	0.00	0.00
Wood	168.62	0.0201	0.0188	175.41	174.36
Waste	168.62	0.0201	0.0188	175.41	174.36
Geothermal	9.07	0.0000	0.0000	9.07	9.07
Solar	0.00	0.0000	0.0000	0.00	0.00
Wind	0.00	0.0000	0.0000	0.00	0.00

Sources of Data:

a. Combustion and precombustion emissions for coal (bituminous assumed), petroleum, and natural gas are taken from the National Renewable Energy Laboratory (NREL) LCI database. Values were first published in Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were updated by NREL in 2021.

b. Precombustion methane emissions for natural gas are based on total losses of 1.09% for gas delivered to power plants. These data were derived from DOE. 2019. *Life Cycle Analysis of Natural Gas Extraction and Power Generation*, Table ES-1. DOE/NETL-2019/2039. Washington, DC: U.S. Department of Energy.

d. Values for biomass were not reported in the NREL document. Data in this table were derived separately from EIA data and information from the California Air Resources Board (CARB). The cumulative net emissions for the 20-year and 100-year periods are adjusted by subtracting the estimated counterfactual emissions.

e. Emissions at geothermal plants are small but not zero. A value of 20 lb of CO_2 per MWh of production is assumed based on geothermal plants in the western United States.

Table J-6 Combustion and Precombustion Emissions for Fossil Fuels Used in Buildings

Fuel	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	$Emissions_{Fuel}$ CO_2e (20-year)	$Emissions_{Fuel}$ CO_2e (100-year)
Combustion Emissions (kg/MWh of fuel consumption)					
Natural gas	183.64	0.0034	0.0004	184.02	183.84
Liquefied petroleum gas or propane	224.56	0.0037	0.0166	229.40	229.21
Fuel oil (residual)	264.06	0.0024	0.0012	264.59	264.46
Fuel oil (distillate)	254.48	0.0026	0.0013	255.06	254.92
Coal	326.90	0.0385	0.0056	331.61	329.58
Gasoline	254.48	0.0026	0.0013	255.06	254.92
Precombustion Emissions (kg/MWh of fuel consumption)					
Natural gas	16.47	0.9324	0.0001	93.42	44.28
Liquefied petroleum gas or propane	34.87	0.3709	0.0006	65.64	46.10
Fuel oil (residual)	36.97	0.3945	0.0007	69.70	48.91
Fuel oil (distillate)	36.61	0.3895	0.0007	68.93	48.40
Coal	7.40	0.5233	0.0001	50.60	23.02
Gasoline	43.35	0.4613	0.0008	81.62	57.31
Total Emissions (kg/MWh of fuel consumption)					
Natural gas	200.11	0.9358	0.0004	277.44	228.12
Liquefied petroleum gas or propane	259.43	0.3745	0.0172	295.05	275.31

Sources of Data:

a. Combustion and precombustion emissions for coal (bituminous assumed), petroleum, and natural gas are taken from the National Renewable Energy Laboratory (NREL) LCI database. Values were first published in Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were updated by NREL in 2021.

b. Data for liquefied petroleum gas, fuel oil, and gasoline are taken from Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were last revised June 2007.

c. Precombustion methane emissions for natural gas are based on total losses of 1.37% for gas delivered to buildings. These data were derived from DOE. 2019. *Life Cycle Analysis of Natural Gas Extraction and Power Generation*, Table ES-1. DOE/NETL-2019/2039. Washington, DC: U.S. Department of Energy.

Table J-6 Combustion and Precombustion Emissions for Fossil Fuels Used in Buildings *(Continued)*

Fuel	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	$Emissions_{Fuel}$ CO_2e (20-year)	$Emissions_{Fuel}$ CO_2e (100-year)
Fuel oil (residual)	301.03	0.3969	0.0019	334.29	313.37
Fuel oil (distillate)	291.09	0.3921	0.0020	323.99	303.32
Coal	334.30	0.5618	0.0057	382.21	352.60
Gasoline	297.83	0.4639	0.0021	336.68	312.23

Sources of Data:

a. Combustion and precombustion emissions for coal (bituminous assumed), petroleum, and natural gas are taken from the National Renewable Energy Laboratory (NREL) LCI database. Values were first published in Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were updated by NREL in 2021.

b. Data for liquefied petroleum gas, fuel oil, and gasoline are taken from Deru, M. and P. Torcellini. 2007. "Source Energy and Emission Factors for Energy Use in Buildings." Technical Report NREL/TP-550-38617, Table 5. Washington, DC: National Renewable Energy Laboratory. These data were last revised June 2007.

c. Precombustion methane emissions for natural gas are based on total losses of 1.37% for gas delivered to buildings. These data were derived from DOE. 2019. *Life Cycle Analysis of Natural Gas Extraction and Power Generation*, Table ES-1. DOE/NETL-2019/2039. Washington, DC: U.S. Department of Energy.

Table J-7 U.S. CO_2e Emissions for each Power Plant Type

Power Plant Type	Power Plant Efficiency	Emissions per Unit of Fuel Consumption, kg CO_2e/MWh		Delivery Efficiency	Power Plant Emissions, kg CO_2e/MWh	
		20-year	100-year		20-year	100-year
Coal	32.3%	382.21	352.60	94.7%	1248.45	1,151.74
Petroleum	30.6%	345.01	315.08	94.7%	1189.34	1,086.13
Natural gas	44.1%	261.15	222.23	94.7%	625.12	531.96
Other gases	44.1%	261.15	222.23	94.7%	625.12	531.96
Nuclear	32.7%	0.00	0.00	94.7%	—	—
Pumped storage	38.3%	0.00	0.00	94.7%	—	—
Hydroelectric	N/A	0.00	0.00	94.7%	—	—
Wood	20.5%	175.41	174.36	94.7%	905.92	900.46
Waste	22.2%	175.41	174.36	94.7%	835.65	830.61
Geothermal	N/A	9.07	9.07	94.7%	9.59	9.59
Solar	N/A	0.00	0.00	94.7%	—	—
Wind	N/A	0.00	0.00	94.7%	—	—

Table J-8 CO_2e Emissions for U.S. Electricity Generation Mix for 2019
(Source: Energy Information Agency, Monthly Energy Report, Table 7.2b)

Generator Type	Percent of Generation	CO_2e Emissions for Power Plant Type, kg/MWh		Power Plant Emissions Multiplied Times the Percent of Generation, kg/MWh	
		GWP_{20}	GWP_{100}	GWP_{20}	GWP_{100}
Coal	24.2%	1,248.45	1,151.74	301.90	278.51
Petroleum	0.4%	1,189.34	1,086.13	5.20	4.75
Natural gas	37.3%	625.12	531.96	232.89	198.19
Other gases	0.1%	625.12	531.96	0.64	0.54
Nuclear	20.4%	—	—	—	—
Pumped storage	–0.1%	—	—	—	—
Hydroelectric	7.2%	—	—	—	—
Wood	0.3%	905.92	900.46	2.75	2.73

Table J-8 CO_2e Emissions for U.S. Electricity Generation Mix for 2019 *(Continued)*
(Source: Energy Information Agency, Monthly Energy Report, Table 7.2b)

Generator Type	Percent of Generation	CO_2e Emissions for Power Plant Type, kg/MWh: GWP_{20}	CO_2e Emissions for Power Plant Type, kg/MWh: GWP_{100}	Power Plant Emissions Multiplied Times the Percent of Generation, kg/MWh: GWP_{20}	Power Plant Emissions Multiplied Times the Percent of Generation, kg/MWh: GWP_{100}
Waste	0.4%	835.65	830.61	3.39	3.37
Geothermal	0.4%	9.59	9.59	0.04	0.04
Solar	1.8%	—	—	0.00	0.00
Wind	7.4%	—	—	—	—
			Sum product	546.73	488.20

Table J-9 Efficiency Assumptions for District Energy Systems

Heating efficiency	70%	Overall efficiency
Cooling efficiency	4.4	Overall COP
Losses, chilled water	5%	
Losses, heating water	10%	
Losses, steam	15%	

Source: Defaults from LEED District Energy Guide, Section 2.4.1.2.3

Table J-10 Results for GWP_{20}

	Source Energy Conversion Factor	CO_2e Emission Rates, kg/MWh: Combustion	Precombustion	Total
Fossil Fuels Delivered to Buildings				
Natural gas	1.092	184	93	277
Liquefied petroleum gas or propane	1.151	229	66	295
Fuel oil (residual)	1.191	265	70	334
Fuel oil (distillate)	1.158	255	69	324
Coal	1.048	332	51	382
Gasoline	1.187	255	82	337
Other fuels not specified in this table	1.048	332	51	382
Electricity				
AKGD–ASCC Alaska grid	2.47	514	159	673
AKMS–ASCC miscellaneous	1.35	289	93	383
AZNM–WECC Southwest	2.57	444	121	565
CAMX–WECC California	1.66	255	88	343
ERCT–ERCOT all	2.32	431	126	558
FRCC–FRCC all	2.78	442	155	596
HIMS–HICC miscellaneous	3.15	681	211	892
HIOA–HICC Oahu	3.87	895	233	1128
MROE–MRO East	2.92	770	150	920
MROW–MRO West	2.21	534	94	628

Table J-10 Results for GWP_{20}

	Source Energy Conversion Factor	CO_2e Emission Rates, kg/MWh		
		Combustion	Precombustion	Total
NEWE–NPCC New England	2.66	287	96	383
NWPP–WECC Northwest	1.48	349	76	426
NYCW–NPCC NYC/Westchester	2.89	269	110	379
NYLI–NPCC Long Island	2.84	481	169	650
NYUP–NPCC Upstate NY	1.81	132	48	180
PRMS–Puerto Rico miscellaneous	3.27	731	214	944
RFCE–RFC East	2.90	350	106	456
RFCM–RFC Michigan	2.93	594	133	727
RFCW–RFC West	2.97	532	113	645
RMPA–WECC Rockies	2.16	580	120	699
SPNO–SPP North	2.21	515	93	608
SPSO–SPP South	2.05	460	123	583
SRMV–SERC Mississippi Valley	2.84	418	137	555
SRMW–SERC Midwest	3.09	779	134	913
SRSO–SERC South	2.89	496	133	629
SRTV–SERC Tennessee Valley	2.82	473	104	577
SRVC–SERC Virginia/Carolina	2.91	360	97	456
All other electricity	2.51	436	111	547
Thermal Energy				
Chilled water	0.60	104	26	131
Steam	1.84	309	157	466
Hot water	1.73	292	148	440

Table J-11 Results for GWP_{100}

	Source Energy Conversion Factor	CO_2e Emission Rates, kg/MWh		
		Combustion	Precombustion	Total
Fossil Fuels Delivered to Buildings				
Natural gas	1.092	184	44	228
Liquefied petroleum gas or propane	1.151	229	46	275
Fuel oil (residual)	1.191	264	49	313
Fuel oil (distillate)	1.158	255	48	303
Coal	1.048	330	23	353
Gasoline	1.187	255	57	312
Other fuels not specified in this table	1.048	330	23	353
Electricity				
AKGD–ASCC Alaska Grid	2.47	512	83	595
AKMS–ASCC miscellaneous	1.35	289	58	347

Table J-11 Results for GWP_{100}

	Source Energy Conversion Factor	CO_2e Emission Rates, kg/MWh		
		Combustion	Precombustion	Total
AZNM–WECC Southwest	2.57	443	59	501
CAMX–WECC California	1.66	255	44	299
ERCT–ERCOT all	2.32	430	62	491
FRCC–FRCC all	2.78	441	77	518
HIMS–HICC miscellaneous	3.15	679	134	814
HIOA–HICC Oahu	3.87	892	145	1,037
MROE–MRO East	2.92	766	72	838
MROW–MRO West	2.21	531	44	575
NEWE–NPCC New England	2.66	287	49	336
NWPP–WECC Northwest	1.48	348	37	384
NYCW–NPCC NYC/Westchester	2.89	269	55	324
NYLI–NPCC Long Island	2.84	481	87	568
NYUP–NPCC Upstate New York	1.81	132	24	156
PRMS–Puerto Rico miscellaneous	3.27	729	120	849
RFCE–RFC East	2.90	349	52	402
RFCM–RFC Michigan	2.93	591	64	655
RFCW–RFC West	2.97	530	54	584
RMPA–WECC Rockies	2.16	577	57	634
SPNO–SPP North	2.21	512	44	556
SPSO–SPP South	2.05	459	60	519
SRMV–SERC Mississippi Valley	2.84	417	68	485
SRMW–SERC Midwest	3.09	774	62	836
SRSO–SERC South	2.89	494	66	560
SRTV–SERC Tennessee Valley	2.82	471	49	520
SRVC–SERC Virginia/Carolina	2.91	358	47	406
All other electricity	2.51	434	54	488
Thermal Energy				
Chilled water	0.60	104	13	117
Steam	1.84	309	74	383
Hot water	1.73	292	70	362

Table J-12 CO_2e Emissions for Special U.S. Jurisdiction

Power Plant Type	Generation Mix	Power Plant Emissions per Unit of Delivered Electricity, kg CO_2e/MWh		Weighted Average Emissions for Power Grid, kg CO_2e/MWh	
		20-year	100-year	20-year	100-year
Natural gas	40%	625.12	531.96	250	213
Solar	20%	0	0	0	0

Table J-12 CO_2e Emissions for Special U.S. Jurisdiction *(Continued)*

Power Plant Type	Generation Mix	Power Plant Emissions per Unit of Delivered Electricity, kg CO_2e/MWh		Weighted Average Emissions for Power Grid, kg CO_2e/MWh	
		20-year	100-year	20-year	100-year
Wind	40%	0	0	0	0
			Sum product	250	213

Table J-13 CO_2e Emissions for Each Power Plant Type

	Power Plant Efficiency	Delivery Efficiency	Emissions per Unit of Fuel Consumption, kg CO_2e / MWh		Power Plant Emissions per Unit of Delivered electricity, kg CO_2e / MWh	
			20-year	100-year	20-year	100-year
Coal	25%	92%	382.21	352.60	1,662	1,533
Natural gas	40%	92%	261.15	222.23	710	604

Table J-14 CO_2e Emissions for Hypothetical Electric Grid

Power Plant Type	Generation Mix	Power Plant Emissions per Unit of Delivered Electricity, kg CO_2e/MWh		Weighted Average Emissions for Power Grid, kg CO_2e/MWh	
		20-year	100-year	20-year	100-year
Coal	30%	1,662	1533	499	460
Natural Gas	50%	710	604	355	302
Wind	20%	0	0	0	0
			Sum product	853	762

Table J-15 Additional CO_2e Emissions for Liquefied Natural Gas (kg CO_2e/MWh)

		From U.S. to Europe		From U.S. to Asia	
		GWP_{20}	GWP_{100}	GWP_{20}	GWP_{100}
Additional CO_2e emissions for liquefied natural gas (LNG) (kg CO_2e/MWh of delivered electricity)	Liquefaction	53	38	54	41
	Tanker transport	32	28	91	76
	Regasification	5	4	5	4
	Total LNG emissions	90	70	150	121
Emissions for natural gas power plant	Power plant emissions (Table J-7)	625	532	625	532
	Power plant emissions with LNG	715	602	775	653
	Percent increase	14%	13%	24%	23%

Source of Data: Data taken from NRDC. 2020. *Sailing to Nowhere: Liquefied Natural Gas is not an Effective Climate Strategy*, Table 1, p. 11. R: 20-08-A. New York: Natural Resources Defense Council. However, the data cited by NRDC are attributed to DOE. 2019. *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States*. DOE/NETL-2019/2041. Washington, DC: U.S. Department of Energy.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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Standard 189.1 and the International Green Construction Code

Standard 189.1 serves as the complete technical content of the International Green Construction Code® (IgCC). The IgCC creates a regulatory framework for new and existing buildings, establishing minimum green requirements for buildings and complementing voluntary rating systems. For more information, visit www.iccsafe.org.

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Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

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IMPORTANT NOTICES ABOUT THIS STANDARD

To ensure that you have all of the approved addenda, errata, and interpretations for this Standard, visit www.ashrae.org/standards to download them free of charge.

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11/22