ANSI/ASHRAE/ICC/USGBC/IES Addendum ak to ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2017

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 ak adds an informative appendix that documents how the source energy conversion factors and the CO_2e emission factors in Table 7.5.2 were developed. This information is intended to provide guidance on how the values may be modified for other countries to suit the mix of generator types used to make electricity.

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 ak to Standard 189.1-2017

Add informative notes to Sections 7.5.2 and 7.5.3. (Note: Section 7.5.3 was previously added by Addendum ar.)

7.5.2 Annual Carbon Dioxide Equivalent (CO_2e). The *proposed design* shall have an annual CO_2e equal to or less than the annual *CO2e* of the *baseline building design* multiplied by the performance cost index target determined from 7.5.1. To determine the annual CO_2e for each energy source in the *baseline building design* and *proposed design*, the energy consumption shall be multiplied by the CO_2e emission factors from Table 7.5.2.

Informative Note: The values in Table 7.5.2 are derived from United States data. The procedures in Informative Appendix K may be used to develop CO_2e emission factors when conditions are different.

7.5.3 Zero Energy Performance Index. The proposed building zero energy performance index (zEPI2004) with consideration of renewables shall be less than the target (zEPI2004 Target). zEPI2004 and zEPI2004 Target shall be calculated as described below.

[. . .]

Informative Note: The values in Table 7.5.3 are derived from United States data. The procedures in Informative Appendix K may be used to develop source energy conversion factors when conditions are different.

Add new Informative Appendix K.

(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 K
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 7.5.2 and provides guidance on how the data can be modified for locations outside of the United States (U.S.). Example data used to illustrate the procedure are for the entire United States electric grid in 2017. A similar procedure was used to develop source energy conversion factors and CO_2e emission factors for the eGRID subregions, the only difference being the mix of electric generators and net generation.

K1. SOURCE ENERGY CONVERSION FACTORS

K1.1 Source-Site Conversion Factors for Fossil Fuels. For the United States, the source energy factors for fossil fuel delivered to buildings are listed in Table K1-1. These factors represent the energy required to extract, process, and deliver the fuel to the building per unit of

Table K1-1 Source Energy Conversion Factors for Fuel Delivered to Buildings[a]
(Source: 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, Table 5.)

Fuel	Source Energy Conversion Factor	Higher Heating Value	
Anthracite coal	1.029	12,700 Btu/lb	29,539 kJ/kg
Bituminous coal	1.048	12,155 Btu/lb	28,270 kJ/kg
Sub-bitumious coal	1.066	8818 Btu/lb	20,509 kJ/kg
Lignite coal	1.102	6465 Btu/lb	15,038 kJ/kg
Natural gas	1.092	1010 Btu/ft^3 [b]	37,631 kJ/m^3 [b]
Residual fuel oil	1.191	149,500 Btu/gal	41,666 kJ/L
Distillate fuel oil	1.158	138,700 Btu/gal	38,656 kJ/L
Gasoline	1.187	100,000 Btu/gal	27,870 kJ/L
LPG	1.151	91,000 Btu/gal	25,362 kJ/L
Kerosene	1.205	135,000 Btu/gal	27,870 kJ/L

a. These data were derived from the life-cycle inventory data from the United States LCI Database maintained by NREL.
b. Heating value for 60°F and 14.70 psia (15.6°C and 101325 Pa).

Table K1-2 Heat Rates for Electric Generation (2017)
(Source: Energy Information Administration, Monthly Energy Review, Table A6, except for biomass and non combustible renewables)

Fuel Used for Electricity Generation	Heat Rate	
	Btu/kWh	kWh/kWh
Coal	10,493	3.08
Petroleum	10,811	3.17
Natural Gas	7870	2.31
Total fossil fuels	9232	2.71
Nuclear	10,459	3.07
Biomass[a]	15,968	4.68
Noncombustible renewables	0	0

a. The heat rate for biomass is the 2017 consumption from Table 10.2c of the EIA Monthly Energy Review divided by the 2017 biomass net generation from Table 7.2b of the MER.

energy in the fuel assuming the heating values listed in the table. These same values are used for fuels delivered to power plants.

K1.2 Source Conversion Factors for Electricity. For electricity, the source energy conversion factors represent the energy required to extract, process, and deliver fuel to the power plants plus the energy used at the power plant to generate electricity. This source energy is then divided by the net electricity generation in similar units. The net electricity generation is the power from domestic production that reaches customers, excluding transmission and distribution losses.

K1.2.1 Heat Rates. The source energy input into making electricity is calculated by multiplying the net electric generation for each generation source by the heat rate for that generation source. Table K1-2 shows the heat rates used to generate the source energy inputs for the United States. The source energy conversion factors from Table K1-1 are also applied to these values to account for the upstream energy used in extraction, processing and delivery.

K1.2.2 Electric Generation Mix. Table K1-3 shows the amount of electricity generated in the United States for 2017, broken down by the generator type. Data in this table will generally be the most significant change for locations outside of the U.S. The last column shows the source energy used for each generator. The source energy is calculated by multiplying the electric generation times the heat rate from Table K1-2 and the source energy conversion factor from Table K1-1.

Table K1-3 United States Electricity Generation Mix for 2017
(Source: Energy Information Agency, Monthly Energy Review, Table 7.2b)

Generator Type	Domestic Electric Generation, billions kWh	Source Energy, quads
Coal	1199	13.19
Petroleum	20	0.25
Natural Gas	1180	10.14
Nuclear	805	8.42
Hydroelectric	298	0
Biomass	32	0.52
Geothermal	16	0
Solar	52	0
Wind	254	0
Total	**3858**	**32.53**

Table K1-4 United States Net Generation for 2017
(Source: Energy Information Agency, Monthly Energy Review, Table 7.1)

	Net Electricity, billions kWh
Domestic generation (from Table K1-3)	3858
Pumped storage	–6
T&D losses	–245
Delivered to customers from domestic generation	3606
Delivered to customers from domestic generation (quads)	12.30

K1.2.3 Net Generation. The net electricity delivered to customers accounts for energy losses due to pumped or battery storage as well as transmission and distribution losses. Table K1-4 shows the net electricity generation in the United States for 2017. For 2017, transmission and distribution losses were about 6.1%.

K1.2.4 Source Energy Conversion Factor for Electricity. The source energy conversion factor is calculated as shown in Equation K1-1. For the U.S. national grid in 2017, the numerator is 32.53 quads from the last column of Table K1-3, and the denominator is the last row from Table K1-4. The result is 32.53 quads divided by 12.30 quads for a source energy conversion factor of 2.64. A similar process is used for each of the eGRID subregions.

$$r_e = \frac{\sum_{f=1}^{n} EG_f \times HR_f \times r_f}{NG} \quad \text{(K1)}$$

where

r_e = source energy conversion factor for electricity, unitless
EG_f = electric generation at the power plant for the f^{th} energy form, billions kWh (from Table K1-3)
HR_f = heat rate for the f^{th} energy form, kWh/kWh (from Table K1-2)
r_f = source energy conversion factor for the f^{th} energy form, unitless (from Table K1-1); a source energy conversion factor of 1.025 is used for biomass to account for the energy required for harvesting and transportation.
NG = net generation, e.g., power from domestic production that is delivered to customers, billions kWh (from Table K1-4)
f = index for the energy form
n = number of energy forms used to make electricity

Table K2-1 Direct and Indirect Emissions from Fossil Fuels Use[a]

(Source: 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, except as noted below.)

Fuel	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	CO_2e
Direct Emissions (lb/MWh of input)				
Natural gas (at the building)	412.14	0.0084	0.0084	415
Natural gas (at the power plant)	412.14	0.0084	0.0084	415
LPG (propane)	494.93	0.0081	0.0366	505
Residual fuel oil	581.98	0.0053	0.0027	583
Distillate fuel oil	560.88	0.0057	0.0029	562
Coal[b]	738.26	0.0323	0.1033	768
Gasoline	560.88	0.0057	0.0029	562
Biomass[c]	355.04	0.0243	0.0414	368
Indirect Emissions (lb/MWh of input)				
Natural gas (at the building)[d]	39.19	2.7000	0.0008	266
Natural gas (at the power plant)[d]	39.19	2.1000	0.0008	216
LPG or propane	76.86	0.8174	0.0014	146
Residual fuel oil	81.48	0.8695	0.0015	155
Distillate fuel oil	80.69	0.8585	0.0015	153
Coal[b]	26.16	1.1649	0.0005	124
Gasoline	95.54	1.0168	0.0018	181
Biomass[c]	16.60	0.0199	0.00008	18
Total Emissions (lb/MWh of input)				
Natural gas (at the building)	451.33	2.7084	0.0092	681
Natural gas (at the power plant)	451.33	2.1084	0.0092	631
LPG or propane	571.79	0.8255	0.0380	651
Residual fuel oil	663.46	0.8748	0.0042	738
Distillate fuel oil	641.56	0.8642	0.0044	715
Coal[b]	764.42	1.1972	0.1038	892
Gasoline	656.41	1.0225	0.0047	744
Biomass[c]	371.64	0.0442	0.0414	386

a. The NREL data in this report were derived from the United States Life Cycle Inventory (LCI) Database maintained by NREL.

b. The NREL report gives values for various types of coal, but bituminous is used for this analysis because it is most common form in the United States

c. Values for biomass were not reported in the NREL document. Figures 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 period are calculated by subtracting the estimated counterfactual emissions.

d. Indirect methane emissions for natural gas are based on total losses of 1.4% for gas delivered to power plants and 1.8% for gas delivered to buildings, per Table ES-1 of Life Cycle Analysis of Natural Gas Extraction and Power Generation, August 30, 2016, DOE/NETL-2015/1714.

Table K2-2 Global Warming Potential (unitless multipliers)

(Source: IPCC 2013, AR4 without climate carbon feedbacks)

	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)
20 year cumulative forcing	1	84	264
100 year cumulative forcing	1	28	265

Table K2-3 Efficiency Assumptions for District Energy Systems
(Source: Defaults from Section 2.4.1.2.3 of *LEED District Energy Guide*)

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

K2. CARBON DIOXIDE EQUIVALENT (CO_2E) EMISSIONS

K2.1 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). These gases are released at the point of combustion, but emissions also result from the mining of coal, production of oil and gas, refinement, pumping, trucking, rail transport and/or piping of fuels. These direct and indirect emission rates are used for both direct combustion in commercial boilers as well as in power plants, except as noted in Table K2-1. These values are not expected to change significantly for other locations or jurisdictions.

Small amounts of CH_4 and N_2O are released (mostly upstream), but these gases have a much larger impact on global warming than CO_2 for a given mass of emissions. The global warming potential for 20 year cumulative forcing, as determined by the International Panel of Climate Change (IPCC), is used in the analysis (emissions from noncombustible renewable energy generators—e.g. wind, solar and hydro—are assumed to be zero). 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 U.S. Table K2-2 and these 20 year weights are used to determine the CO_2e values in Table K2-1. The total emissions from Table K2-1 are used for fuels delivered directly to buildings or power plants.

Emissions from noncombustible renewable energy generators—e.g. wind, solar and hydro—are assumed to be zero. 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 U.S.

K2.2 Emissions from Electricity Generation. Emissions related to electricity generation are calculated by multiplying the total emissions from Table K2-1 for each CO_2e emitting fuel times the quantity of that fuel from Table K1-3 that is used to generate electricity. The sum is then divided by the net electricity generation from Table K1-4 as shown in Equation K2.1.

$$CO_2e = \frac{\sum_{f=1}^{n} F_f \times E_f \times C}{NG} \qquad \text{(K2)}$$

where

CO_2e = carbon dioxide equivalent emissions, lb/MWh

F_f = quantity of carbon emitting fuel used at the power plant for the f^{th} energy form, quads (from Table K1-3)

E_f = total emissions rate for the f^{th} energy form, kWh/kWh (from Table K2-1)

C = conversion factor to change quads to MWh

NG = net generation, e.g. power from domestic production delivered to the customers, billions kWh (from Table K1-4)

f = index for the energy form

n = number of energy forms used to make electricity

K2.3 District Energy Systems. *District energy systems* are assumed to use electricity for cooling and natural gas for heating. Values in Table 7.5.2 were calculated based on the district energy efficiency assumptions shown in Table K2-3. These or other assumptions appropriate for local conditions should be used when values in Table 7.5.2 are modified. Please note that the published values for *district energy systems* can be overridden through district energy modeling procedures recognized in Appendix C.

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7/20