Public Review Draft

Proposed Addendum ak to Standard 189.1-2017

Standard for the Design of High-Performance Green Buildings

Except Low-Rise Residential Buildings

First Public Review Draft (August 2019)
(Draft Shows Proposed Changes to Current Standard)

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Foreword

This addendum 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 to Reviewers: This addendum makes proposed changes to the current standard. These changes are indicated in the text by underlining (for additions) and strikethrough (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum ak to 189.1-2017

Add informative notes to Sections 7.5.2 and 7.5.3

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 CO_2e 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 ($zEPI_{2004}$) with consideration of renewables shall be less than the target ($zEPI_{2004\ Target}$). $zEPI_{2004}$ and $zEPI_{2004\ Target}$ shall be calculated as described below.

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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. Note: this informative appendix is entirely new. For ease of reading, material is not shown underlined

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 non-United States locations. Example data used to illustrate the procedure is 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. These factors represent the energy required to extract, process, and deliver the fuel to the building per unit of energy in the fuel assuming the heating values listed in the table. These same values are used for fuels delivered to power plants.

Table K1 – Source Energy Conversion Factors for Fuel Delivered to Buildings
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	8,818 Btu/lb	20,509 kJ/kg
Lignite Coal	1.102	6,465 Btu/lb	15,038 kJ/kg
Natural Gas	1.092	1,010 Btu/ft³ *	37,631 kJ/m^3 *
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

This data was derived from the life cycle inventory data from the U.S. LCI Database, maintained by NREL.
* Heating value for 60°F and 14.70 psia (15.6°C and 101325 Pa).

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 and excludes 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 K2 has the heat rates used to generate the

source energy inputs for the United States. The source-site multipliers from Table K1 are also applied to these values to account for the upstream energy used in extraction, processing and delivery.

Table K2 – Heat Rates for Electric Generation – 2017
Source: Energy Information Administration, Monthly Energy Review, Table A6, except for biomass and non-combustible renewables

	Heat Rate	
Fuel Used for Electricity Generation	*(Btu/kWh)*	*(kWh/kWh)*
Coal	10,493	3.08
Petroleum	10,811	3.17
Natural Gas	7,870	2.31
Total Fossil Fuels	9,232	2.71
Nuclear	10,459	3.07
Biomass[1]	15,968	4.68
Non-Combustible Renewables	0	0

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

K1.2.2 Electric Generation Mix

Table K3 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 non-United States locations. 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 K2 and the source energy conversion factor from Table K1.

Table K3 – United States Electricity Generation Mix for 2017
Source: Energy Information Agency, Monthly Energy Report, Table 7.2b

Generator Type	*Domestic Electric Generation (billions kWh)*	*Source Energy (quads)*
Coal	1,199	13.19
Petroleum	20	0.25
Natural Gas	1,180	10.14
Nuclear	805	8.42
Hydroelectric	298	0
Biomass	32	0.52
Geothermal	16	0
Solar	52	0
Wind	254	0
Total	3,858	32.53

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 K4 shows the net electricity generation in the United States for 2017. For 2017, transmission and distribution losses were about 6.1%.

Table K4 – United States Net Generation for 2017
Source: Energy Information Agency, Monthly Energy Report, Table 7.1

	Net Electricity (billions kWh)
Domestic Generation (from Table K3)	3,858
Pumped Storage	-6
T&D Losses	-245
Delivered to Customers from Domestic Generation	3,606
Delivered to Customers from Domestic Generation (quads)	12.30

K1.2.4 Source Energy Conversion Factor for Electricity

The source energy conversion factor is calculated as shown below in Equation K1. For the United States national grid in 2017, the numerator is 32.53 quads from the last column of Table K3 and the denominator is last row from Table K4. 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 regions.

Equation K1

$$r_e = \frac{\sum_{f=1}^{n} EG_f \times HR_f \times r_f}{NG}$$

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 K3).
HR_f = Heat rate for the f^{th} energy form, kWh/kWh (from Table K2).
r_f = Source energy conversion factor for the f^{th} energy form, unitless (from Table K1). 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 K4).
f = Index for the energy form.
n = Number of energy forms used to make electricity.

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 K5. 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 (see
Emissions from non-combustible 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 United States. Table K6 and these 20-year weights are used to determine the CO_2e values in Table K5. The total emissions from Table K5 are used for fuels delivered directly to buildings or power plants.

Table K5 – Direct and Indirect Emissions from Fossil Fuels Use
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.. These NREL data in this report were derived from the United States Life Cycle Inventory (LCI) Database, maintained by NREL.

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[2]	738.26	0.0323	0.1033	768
Gasoline	560.88	0.0057	0.0029	562
Biomass[3]	355.04	0.0243	0.0414	368
Indirect Emissions (lb/MWh of input)				
Natural Gas (at the building) [1]	39.19	2.7000	0.0008	266
Natural Gas (at the power plant [1]	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[2]	26.16	1.1649	0.0005	124
Gasoline	95.54	1.0168	0.0018	181
Biomass[3]	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[2]	764.42	1.1972	0.1038	892
Gasoline	656.41	1.0225	0.0047	744
Biomass[3]	371.64	0.0442	0.0414	386

1. 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.
2. The NREL report gives values for various types of coal, but bituminous is used for this analysis since it is most common form in the USA.
3. 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.

Emissions from non-combustible 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 United States.

Table K6 – Global Warming Potential (unitless multipliers)
Source: https://en.wikipedia.org/wiki/Global_warming_potential

	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
Source: IPCC 2013, AR4 without climate carbon feedbacks			

K2.2. Emissions from Electricity Generation
Emissions related to electricity generation are calculated by multiplying the total emissions from Table K5 for each CO_2e emitting fuel times the quantity of that fuel from Table K3 that is used to generate electricity. The sum is then divided by the net electricity generation from Table K4, as shown in Equation K2.

Equation K2

$$CO_2e = \frac{\sum_{f=1}^{n} F_f \times E_f \times C}{NG}$$

Where

CO_2e = Carbon dioxide equivalent emissions, lb/MWh
F_f = The quantity of carbon emitting fuel used at the power plant for the f^{th} energy form, quads (from Table K3)

E_f = The total emissions rate for the f^{th} energy form, kWh/kWh (from Table K5)
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 K4)
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 K7. 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.

Table K7 – Efficiency Assumptions for District Energy Systems

Heating Efficiency	70%	Overall Efficiency
Cooling Efficiency	4.4	Overall COP
Losses CHW	5%	
Losses HW	10%	
Losses Steam	15%	

Source: Defaults from 2.4.1.2.3 of LEED District Energy Guide