ANSI/ASHRAE Standard 105-2014R

Public Review Draft

Standard Methods for Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions

First Public Review (October 2019)
(Complete Draft for Full Review)

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 by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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(This foreword 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.)

FOREWORD

ANSI/ASHRAE Standard 105 was originally published in 1984 and dealt primarily with on-site energy use in buildings. Subsequent editions expanded the scope to more comprehensively address overall building energy performance, in addition to energy use. Recognizing the potential impact of building performance on greenhouse gas emissions, the last edition of ASHRAE Standard 105 published in 2014 extended the evaluations to source energy use and allowed for the evaluation of greenhouse gas emissions associated with the required primary energy generation.

The current edition of ASHRAE Standard 105 is written in code-intended language so that it may be referenced or adopted by enforcement authorities to provide standardized methods for determining, expressing, and comparing the energy performance of buildings for evaluations of building design, retrofit, and operational strategies. It provides consistent methods for reporting building energy use in terms of delivered energy in all its forms and expressions of energy performance, for comparing design options, and for comparing energy performance in terms of energy resources used and greenhouse gas emissions produced, both across buildings and for energy efficiency measures within buildings or at building sites.

The committee discussed and evaluated the impact of developing methods for determining, expressing, and comparing the impact of building performance on water use in buildings. The committee decided that the interactions between building energy performance, building use and occupancy, and source energy generation options were too complex to easily characterize the relationships between building performance and building water use. While the committee agreed that building performance does impact water usage and that alternative approaches to building design, retrofit, and operation can have significant impact on water use, this standard does not currently address this aspect of building performance.

The standard provides flexibility for adopting agencies and authorities to incorporate localized considerations when accounting for greenhouse gas emissions associated with the source energy requirements. The basis for all energy measurements is the annual energy flow across the building and site boundaries. This edition of the standard supplements site energy measurements with methods for determining primary energy and greenhouse gas emissions produced at the option of the adopting authority. Because primary energy and greenhouse gas equivalence conversion factors will vary internationally, regionally, and even locally, they have been left to the discretion of the adopting authority. The standard contains a non-mandatory, informative appendix of source energy factors that may be used by the adopting authority if desired.

This standard is accompanied by supplemental files that include the forms shown in Normative Appendices A, B, C, D, E, and F. These forms can be found online at www.ashrae.org/105-2019forms. **[Note: Link is non-working. Will be updated prior to publication.]**

1. PURPOSE

This standard provides consistent methods for determining and reporting the energy performance of buildings to facilitate a comparison of design and operation strategies in new and existing buildings as well as the development of building energy performance standards and reporting of greenhouse gas emissions associated with building operation. This standard provides consistent methods for determining, expressing, and comparing the energy performance of and the greenhouse gas emissions associated with the design of new buildings and improvements to, or changes in, the operation of existing buildings.

2. SCOPE

2.1 This standard covers

a. new buildings and existing buildings or portions thereof;
b. the determination and expression of building energy performance and the estimate of greenhouse gas emissions associated with that energy use; and
c. techniques for the comparison of the energy performance and associated greenhouse gas emissions between different buildings, alternative design strategies for the same new building, or for improvements to, or changes in, the operation of existing buildings.

2.2 This standard does not

a. establish building energy performance or greenhouse gas emissions goals or limits;
b. present a method for certification of prediction methodology, such as computer programs;
c. address embodied energy of building materials and systems; or
d. incorporate transportation energy or associated greenhouse gas emissions for building functions, including commuting, business travel, and process transportation.

3. DEFINITIONS

adopting authority: the agency or agent that adopts this standard.

avoided energy: energy not consumed based on comparisons between alternative design or operational strategies or energy efficiency measures based on the last units of energy subtracted from a system.

avoided greenhouse gas emissions: greenhouse gas not emitted based on comparisons between alternative design or operational strategies or energy efficiency measures based on the last units of energy subtracted from a system.

building: a structure wholly or partially enclosed within exterior walls, or within exterior and party walls, and a roof, affording shelter to persons, animals, or property.

building energy: energy consumed by a building as measured at the boundaries of the building (E_{bld}).

building energy performance: a measure of how a building performs with respect to energy consumption divided by normalization parameters (e.g., $kBtu/ft^2 \cdot yr$) in terms of delivered energy forms to the building or building site or in terms of the resources consumed to generate, transmit, and deliver those energy forms to the building site.

building site: a building, or group of buildings, and site that utilize a single submittal for a construction permit or that are within the boundary of contiguous properties under single ownership or effective control.

comparison framework: a set of data and a methodology that serve as the bases for comparison of a building, portion of a building, or building site with respect to energy performance or greenhouse gas emissions.

conditioned: provided with a heat supply capable of maintaining an air temperature of 50°F (10°C) or higher inside a building space, or provided with a cooling supply capable of maintaining an air temperature of 86°F (30°C) or lower inside a building space.

energy: the capacity for doing work. Energy comprises forms that may be transformed from one form into another, including thermal (heat), mechanical (work), electrical, or chemical. Customary measurement units are British thermal units (Btu), Joules (J), or kilowatt-hours (kWh).

energy cost: the total cost for energy supplied to a building or building site, including base charges, consumption charges, distribution charges, demand charges, customer charges, power factor charges, and miscellaneous charges, such as sales taxes.

energy form: any thermal, mechanical, electrical, or chemical energy delivered across a building or building site boundary to provide energy services to a building or building site.

energy performance: an expression of energy use relative to specific building characteristics, end uses, or other factors that allows potential comparison with other proposed buildings, new buildings, or existing buildings.

existing building: a building or portion thereof that has been in operation and normal use for at least 12 consecutive months following the date of initial occupancy or the date of the certificate of occupancy, or occupancy class change, whichever is later.

greenhouse gas emissions: A measure used to determine and compare the emissions of various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalent (CO_2e) emissions from carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are included. The CO_2e for a gas is calculated by multiplying the weight of the gas by its associated GWP.

gross floor area: the sum of the floor areas of all the spaces within the building with no deductions for floor penetrations other than atria. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but it excludes covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, roof overhangs, parking garages, surface parking, and similar features.

higher heating value: the amount of heat produced per unit of fuel when complete combustion takes place at constant pressure, the products of combustion are cooled to the initial temperature of the fuel and air, and the vapor formed during combustion is condensed.

new building: a building or portion thereof that has been in operation for less than 12 consecutive months following the date of initial occupancy or the date of the certificate of occupancy, whichever is later.

normalization parameter: a factor or parameter that allows for data pertaining to the energy use of a building or system to be compared to the energy use of alternative buildings or systems.

on-site: located within the building site.

primary energy: site energy plus the estimated energy consumed or lost in the extraction, processing, and transportation of primary energy forms such as coal, oil, natural gas, biomass, and nuclear fuel; energy consumed in conversion to electricity; and energy consumed or lost in transmission and distribution to the building site.

primary energy performance: primary energy divided by a normalization parameter.

proposed building: a building or portion thereof that is in the design or construction phase.

renewable energy: energy forms derived from incoming solar radiation, including energy from photosynthetic processes; energy from wind, waves, and tides, plant material and animal waste; and energy from the internal heat of the earth.

site energy: energy consumed as measured or estimated at the building site boundary (E_{site}).

site energy performance: site energy divided by a normalization parameter.

stored imported energy: energy forms that are stored on the building site for future use by the building or for export.

4. COMPLIANCE

4.1 Compliance Paths. All buildings shall have their energy consumption determined and expressed in accordance with Section 4.2. Where additional expressions of energy performance or greenhouse gas emissions are made, they shall be determined and expressed in accordance with Sections 4.3 through 4.6.

4.2 Building Energy, Site Energy, and Energy Cost. Building energy, site energy, and energy cost shall be measured and determined in accordance with Section 5 and reported on Forms 1 and 2.

4.3 Primary Energy Performance. The energy performance of a building in terms of primary energy shall be estimated and determined in accordance with Section 6 and reported on Form 3.

4.4 Greenhouse Gas Emissions. The greenhouse gas emissions shall be determined in accordance with Section 7 and reported on Form 4.

4.5 Additional Expressions of Building Energy Performance or Greenhouse Gas Emissions. Additional expressions of building energy performance or greenhouse gas emissions shall be determined in accordance with Section 8 and reported on Form 5.

4.6 Comparisons Related to Building Energy Performance or Greenhouse Gas Emissions. The comparison of building energy performance or greenhouse gas emissions to that of other buildings, alternative designs associated with the same building, or established energy use indices, targets, or performance metrics shall be in accordance with Section 9 and reported on Form 6.

5. MEASUREMENT AND EXPRESSION OF BUILDING ENERGY AND SITE ENERGY

5.1 Compliance. Annual building energy, site energy, and energy cost for a building, building site, or portion thereof per unit of gross floor area shall be reported on Forms 1 and 2 in accordance with this section, based on measured energy used or, when applied to the performance of a new building or proposed building, energy expected to be used.

5.2 Basic Building Characteristics. The building characteristics in Sections 5.2.1 through 5.2.7 shall be reported on Forms 1A and 1B.

5.2.1 A building identifier and address, including city, state, country, and zip (mail) code.

5.2.2 The start and end dates of the reporting period.

5.2.3 The gross floor area.

5.2.4 The total number of conditioned floors, with subtotals of above-grade and below-grade floors.

5.2.5 The primary year of construction of the building shall be determined based on the year of construction of 50% or more of the conditioned floor area. Where the building has had additional conditioned floor area added subsequent to that primary year of construction and the aggregate of those additions represents less than 50% of the conditioned floor area, then the floor area associated with those additions shall be reported under a secondary year of construction and the percentage of the gross floor area associated with the primary and secondary year of construction reported with the year.

5.2.6 The building type showing the percentage of the gross floor area allocated to the various space uses in the building. The total of all the percentage values shall be 95% or greater. Common spaces, circulation spaces, and other support spaces shall be allocated proportionally to the space(s) they serve.

5.2.7 The building end use type showing the percentage of the gross floor area allocated to the various end uses in the building. The total of all the percentage values of the gross floor areas allocated to the various end uses based on the building occupancy shall be 95% or greater. End uses serving common spaces, circulation spaces, and other support spaces shall be allocated proportionally to the space(s) they serve.

5.3 Energy Consumption. The building energy, site energy, and energy cost for each energy form used by an existing building or expected to be used by a new building or proposed building over a period of 12 consecutive months (365 days) shall be reported as set forth in Sections 5.3.1 and 5.3.2.

5.3.1 Energy Data Collection. The source of data for each energy form shall be either a utility bill, utility meter, site installed meter, on-site measurement, or estimate. Where estimated, a description of the method used to estimate energy consumption shall be provided. Where energy use is determined from another source, that source shall be described and methodology provided.

5.3.1.1 Where energy consumption is based on interpolation or extrapolation of measured data, it shall be determined in accordance with the following:

a. Extrapolate short-term or spot measurements to cover the full operating schedule.
b. Use deliveries minus energy management system time history of consumption.
c. Use deliveries and read gauge (oil or propane).
d. Use deliveries and stick tank (oil).
e. Use deliveries and subtract carloads (coal, wood, or biomass).
f. Use deliveries and estimate size of pile (coal, wood, or biomass).

5.3.1.2 Energy simulations shall only be used to estimate the energy consumption of new buildings or proposed buildings or to estimate changes in energy consumption resulting from proposed improvements to existing buildings.

5.3.2 Reporting Period. The amount of each energy form used in the 365-day period shall be recorded. Each record of energy used shall be adjusted to the same 365-day period.

5.3.2.1 Non-stored Imported Energy. The amount of each non-stored imported energy form shall be measured or estimated in accordance with Section 5.3.1. Energy loads that are outside the boundary of the building or building site shall be measured by a separate meter or estimated and subtracted from the building energy or site energy use. All energy consumption amounts shall be recorded in the units reported or expected to be reported on the energy bill or measured by the installed meter.

5.3.2.2 Stored Imported Energy. Consumption of imported energy stored on-site shall be measured or estimated in accordance with Section 5.3.1 as the amount of energy imported minus the net change in inventory during a period of 12 consecutive months that matches the measurement period recorded in Form 1. The cost of the stored imported energy used by the building shall be determined using the cost of the oldest fuel in storage rather than its replacement cost.

5.3.2.3 On-Site Dedicated Renewable Energy Production. Buildings utilizing renewable energy captured onsite shall measure the renewable energy delivered to the building through the use of British thermal unit or kilowatt-hour meters.

Exceptions:
a. Energy collected and utilized by passive means such as passive solar thermal or natural ventilation.
b. Energy collected through the use of ground-source or water-source heat pumps.

5.3.2.4 On-Site Energy Production. Buildings utilizing energy produced on-site shall determine the produced energy exported from the building site or delivered to the building by collecting data in accordance with Section 5.3.1.

5.4 Site Energy Conversion Factors. The multiplier to convert the units of site energy for each energy form to kBtu (kWh) shall be reported. All energy forms shall be converted to the same units, either kBtu or kWh, and the converted value recorded.

5.4.1 Fuel Heat Conversion Factors. Conversion factors for fuel heat content shall be obtained from the utility bills or fuel supplier. Where fuel heat content values are not available, the default values in Table 5.4.1 shall be used and the use of such default values noted on Form 2. Where the higher heating value for gases listed in Table 5.4.1 is used in buildings whose elevation is above 2000 ft (610 m), the higher heating value shall be adjusted for elevation. Where liquid fuel providers do not make temperature corrections, that information shall be noted on Form 2. For fuels not listed in Table 5.4.1, fuel higher heating values shall be determined from a source approved by the adopting authority and the value and source noted on Form 2.

5.5 Energy Cost. The energy cost for each energy form used shall be reported on Form 2. The monetary value or compensation for energy exported from the building site shall be recorded as a negative number.

5.6 Building Energy, Site Energy, and Energy Cost Indices. The building energy, site energy, and energy cost indices shall be reported.

TABLE 5.4.1 Higher Heating Values

Fuel Oils		
Number 2 Oil	139,000 Btu/U.S. gal	10.8 kWh/L
Number 4 Oil	146,000 Btu/U.S. gal	11.3 kWh/L
Number 6 Oil	154,000 Btu/U.S. gal	11.9kWh/L
Gaseous Fuels		
Natural Gas	100,000 Btu/therm	1,000 kCal/thermie
Propane	91,600 Btu/US gal	7.1 kWh/L

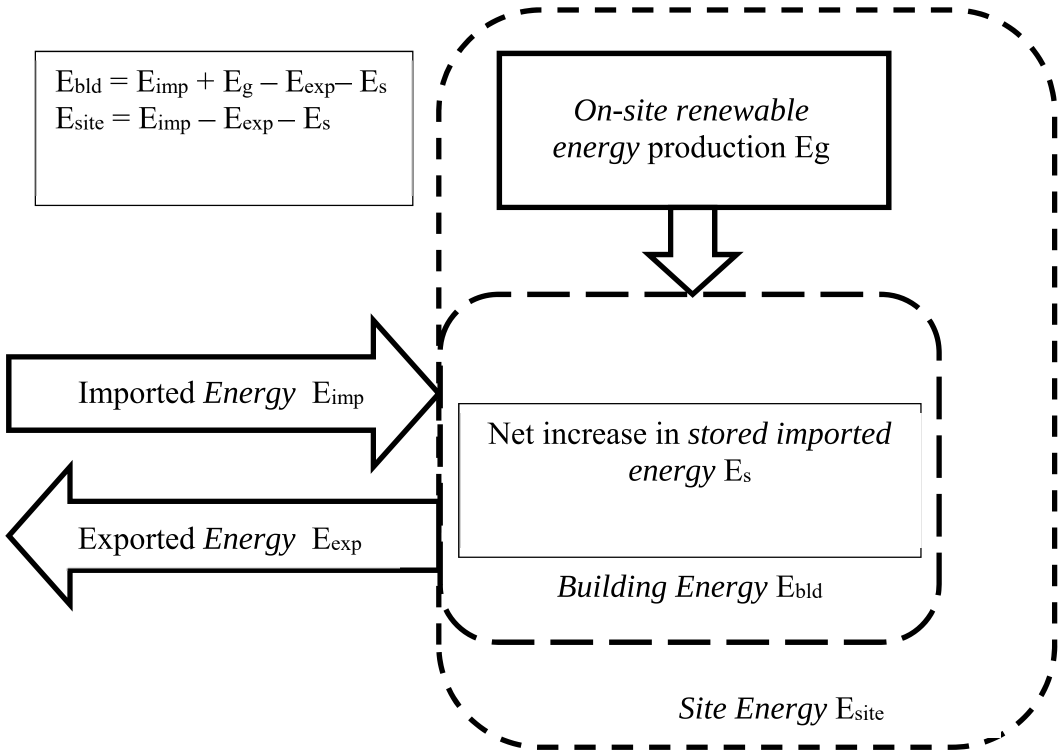

Figure 5.6 Building energy and site energy flows.

5.6.1 The building energy is the sum of all energy used within the building. It is equal to the energy imported to the building site plus on-site produced energy minus energy exported from the building site minus the net change in stored imported energy or on-site renewable energy inventory during the reporting period determined in accordance with Section 5.3.2 (see Figure 5.6).

5.6.2 The site energy is the sum of the imported energy minus exported energy crossing the building site boundary minus the net change in stored imported energy inventory during the reporting period determined in accordance with Section 5.3.2 (see Figure 5.6).

6. DETERMINATION AND EXPRESSION OF PRIMARY ENERGY PERFORMANCE

6.1 Compliance. The annual primary energy use of a building or portion thereof per unit of gross floor area shall be reported on Form 3 in accordance with this section and based on annual site energy determined in accordance with Section 5.

6.2 Reporting Period. The reporting period shall be determined in accordance with Section 5.3.2.

6.3 Units. Primary energy use of the building shall be converted to consistent units by multiplying the energy consumption by energy form reported using Form 2 by the conversion factor given in Table 6.3. Site energy exported by the building shall be converted to primary energy units using the same conversion factor as the imported energy form it displaces.

TABLE 6.3 Primary Energy Conversion Factors

Form 2 Row	**Imported *Energy Form***	***Primary Energy* Conversion Factor (See Note 1)**
1.	Electricity	
2.	Natural Gas	
3.	Steam	
4.	Hot Water	
5.	Chilled Water	
6.	Number 2 Fuel Oil	
7.	Propane	
8.	Coal and Other	
9.	Biofuel Biomass	

Note 1: The adopting authority shall fill in Table 6.3 with primary energy conversion factors.

7. EXPRESSION OF GREENHOUSE GAS EMISSIONS

7.1 Compliance. The annual greenhouse gas emissions of a building or portion thereof per unit of gross floor area shall be reported on Form 4 in accordance with this section and based on annual site energy determined in accordance with Section 5.

7.2 Reporting Period. The reporting period shall be determined in accordance with Section 5.3.2.

7.3 Units. Energy-related greenhouse gas emissions by the building shall be converted to consistent units by multiplying the energy consumption by energy form reported using Form 2 by the conversion factor given in Table 7.3. Site energy exported by the building shall be converted to greenhouse gas emissions units using the same conversion factor as the imported energy form it displaces.

TABLE 7.3 Greenhouse Gas Emissions Factors

Form 2 Row	**Imported *Energy Form***	***Greenhouse Gas Emissions* Factor (kg/kWh) (See Note 1)**
1.	Electricity	
2.	Natural Gas	
3	Steam	
4.	Hot Water	
5.	Chilled Water	
6	Fuel_Oil	
7.	Propane	
8.	Coal and Other	
9.	Biomass	

Note 1: The adopting authority shall provide Table 7.3 with greenhouse gas emissions factors.

8. ADDITIONAL NORMALIZED EXPRESSIONS OF BUILDING ENERGY PERFORMANCE OR GREENHOUSE GAS EMISSIONS

8.1 Compliance. Additional expressions of building energy performance or greenhouse gas emissions associated with a building or portion thereof shall be reported on Form 5 in accordance with this section and based on annual site energy determined in accordance with Section 5.

8.1.1 Where additional expressions of site energy performance are reported, the requirements of Section 5 shall be met.

8.1.2 Where additional expressions of primary energy performance are reported, the requirements of Section 6 shall be met.

8.1.3 Where additional expressions of greenhouse gas emissions are reported, the requirements of Section 7 shall be met.

8.2 Reporting Period. The reporting period shall be determined in accordance with Section 5.3.2.

8.3 Specification of Normalization Parameters. Additional factors for comparing or normalizing site energy performance, primary energy performance, or greenhouse gas emissions shall be specified, either by using factors listed on the applicable form or by naming other factors that are not listed and providing the basis for those factors.

8.3.1 For each normalization parameter to be used, the type of factor and the value of the factor shall be specified on Form 5.

8.3.2 For each factor to be used, the units of the factor shall be specified.

8.4 Additional Normalizing Parameters of Energy Performance. For each additional normalized expression of building energy performance or greenhouse gas emissions, the applicable index or indices, the normalizing factor, the normalized expression of energy performance, and the units of the normalization parameters shall be reported.

9. COMPARISON OF BUILDING ENERGY PERFORMANCE OR GREENHOUSE GAS EMISSIONS

9.1 Compliance. The comparison of a building's site energy performance, primary energy performance, or greenhouse gas emissions to that of a different building, alternative designs for the same proposed building or new building, or improvements in the operation of an existing building using national, regional, or avoided energy methods of comparison shall be reported on Form 6 in accordance with this section, based on site energy determined in accordance with Section 5. Each method of comparing site energy performance or primary energy performance or greenhouse gas emissions shall conform to the requirements of this section.

9.2 Basis of Comparison. The site energy by energy form reported on Form 2 shall be used for all site energy performance or energy cost comparisons and as the basis of input values for primary energy conversion factors on Form 3 or greenhouse gas emission factors on Form 4 for comparison of primary energy performance or greenhouse gas emissions. The relevant index from Form 2, Form 3, or Form 4 shall be used as the basis of input values for corresponding comparisons using additional normalizing expressions on Form 5.

9.3 Reporting Period. The reporting period shall be determined in accordance with Section 5.3.2.

9.4 Building Comparison Identification. The building identification data, including building ID and address, comparison period start and end dates, gross floor area, and indices used for comparison shall be reported on Form 6.

9.5 Applicable Comparisons. Comparisons that are to be applied to the building shall be reported as specified on Form 6. Comparison indices listed on Form 6 that are not applied to the building shall be indicated as "N/A."

9.6 Energy Performance or Greenhouse Gas Emissions Comparison Results. The performance values resulting from each comparison of the building to be compared to a comparison framework shall be reported on Form 6.

9.6.1 For each performance value reported, the type of value, the range of any performance scale, and any units of a performance scale shall be reported on Form 6.

9.7 Comparison Method

9.7.1 Type of Comparison Method. The type of comparison method shall be specified on Form 6 as documented. For a comparison to be of the documented type, a report describing the analytical method used to develop the performance comparison method shall be prepared. The mean, maximum, and minimum values of the data set for any normalization parameters developed; any model coefficients for normalization modes developed; and any data screening limits imposed on the data set used shall be available to the requester and reported on Form 6.

Exception: The type of comparison method shall be permitted to be ad hoc/undocumented and indicated on Form 6 when a performance comparison method cannot report the public availability of the required information.

9.7.2 Comparison Data Set and Filters. All comparison factors used in an energy performance or greenhouse gas emissions comparison method shall be specified by descriptive names on Form 6. Any data filters used to screen or reduce the data set used within the comparison method shall be specified by descriptive names on Form 6, along with the engineering or other units and data filter criteria used for any comparison method data set filters.

9.8 Primary Energy Performance for National Comparisons. The primary energy performance and primary energy index for national comparisons shall be reported on Form 3. Primary energy for imported-minus-exported electricity used by the building shall be converted to consistent units by multiplying the electricity use by the primary energy conversion factor in Table 9.8, as applicable, based on the nation in which the building is located. Imported fossil fuel, district steam, or district hot water delivered from off site and used by the building shall be converted to consistent primary energy units by multiplying the imported-minus-exported fossil fuel, district steam, or district hot-water use by the primary energy conversion factor in Table 9.8, as applicable, based on the nation in which the building is located. Site energy exported by the building shall be converted to primary energy units using the same conversion factor as the imported energy form it displaces.

TABLE 9.8 Primary Energy Conversion Factors for National Comparisons

Form 2 Row	**Imported *Energy Form***	***Primary Energy* Conversion Factor (See Note 1)**
1.	Electricity	
2.	Natural Gas	
3.	Steam	
4.	Hot Water	
5.	Chilled Water	
6.	Fuel Oil	
7.	Propane	
8.	Coal and Other	
9.	Biomass	

Note 1: The adopting authority shall provide Table 9.8 with primary energy conversion factors.

9.9 Greenhouse Gas Emissions for National Comparisons. The greenhouse gas emissions and greenhouse gas emissions index for national comparisons shall be reported on Form 4. Greenhouse gas emissions for imported-minus-exported electricity used by the building shall be converted to consistent units by multiplying the imported-minus-exported electricity use by the greenhouse gas emissions factor in Table 9.9, as determined by the adopting authority, based on the nation in which the building is located. Imported fossil fuels, district steam, or district hot water used by the building shall be converted to consistent greenhouse gas emissions units by multiplying the imported-minus-exported fossil fuel, district steam, or district hot-water use by the greenhouse gas emissions factor in Table 9.9, as determined by the adopting authority, based on the nation in which the building is located. Site energy exported by the building shall be converted to greenhouse gas emissions using the same conversion factor as the imported energy form it displaces.

TABLE 9.9 Greenhouse Gas Emissions Factors for National Comparisons

Form 2 Row	**Imported *Energy Form***	***Greenhouse Gas Emissions* Factor (kg/kWh) (See Note 1)**
1.	Electricity	
2.	Natural Gas	
3.	Steam	
4.	Hot Water	
5.	Chilled Water	
6.	Fuel Oil	
7.	Propane	
8.	Coal and Other	
9.	Biomass	

Note 1: The adopting authority shall provide Table 9.9 with greenhouse gas emissions factors.

9.10 Primary Energy Performance for Regional Comparisons. The primary energy performance and primary energy index for regional comparisons shall be reported on Form 3. For buildings in the United States, primary energy for imported-minus-exported electricity used by the building shall be converted to consistent units by multiplying the imported-minus-exported electricity consumption by the conversion factor in Table 9.10a, as determined by the adopting authority, based on the eGRID subregion in which the building is located, or a regional primary energy conversion factor, as determined by the adopting authority, for locations not included in the eGRID database.

Fossil fuel, district steam, or district hot water used by the building shall be converted to consistent regional primary energy units by multiplying the imported-minus-exported fossil fuel, district steam, or district hot-water use by the primary energy conversion factor in Table 9.10b, as determined by the adopting authority, based on the region in which the building is located. Site energy exported by the building shall be converted to primary energy units using the same conversion factor as the imported energy form it displaces.

TABLE 9.10a **Electricity Primary Energy Conversion Factors for Regional Comparisons**

Region Name	*Primary Energy* Conversion Factor (See Note 1)

Note 1: The adopting authority shall provide Table 9.10a with region names and primary energy conversion factors.

TABLE 9.10b Primary Energy Conversion Factors for Regional Comparisons

Form 2 Row	Imported *Energy Form*	Region Name	*Primary Energy* Conversion Factor (See Note 1)
1.	Electricity		
2.	Natural Gas		
3.	Steam		
4.	Hot Water		
5.	Chilled Water		
6.	Fuel Oil		
7.	Propane		
8.	Coal and Other		
9.	Biomass		

Note 1: The adopting authority shall provide Table 9.10b with regional energy conversion factors.

9.11 Greenhouse Gas Emissions for Regional Comparisons. The greenhouse gas emissions and greenhouse gas emissions index for regional comparisons shall be reported on Form 4. For buildings in the United States, greenhouse gas emissions for imported-minus-exported electricity consumed by the building shall be converted to consistent units by multiplying the imported-minus-exported electricity consumption by the greenhouse gas emissions factor in Table 9.11a, as determined by the adopting authority, based on the eGRID subregion in which the building is located, or a regional greenhouse gas emissions factor, as determined by the adopting authority, for locations not included in the eGRID database.

Fossil fuel, district steam, or district hot water used by the building shall be converted to consistent greenhouse gas emissions units by multiplying the imported-minus-exported fossil fuel, district steam, or district hot-water use by the regional greenhouse gas emissions factors in Table 9.11b, as determined by the adopting authority, based on the nation in which the building is located. Site energy exported by the building shall be converted to greenhouse gas emissions using the same conversion factor as the imported energy form it displaces.

TABLE 9.11a Electricity Greenhouse Gas Emissions Factors for Regional Comparisons

Region Name	*Greenhouse Gas Emissions* Factor lb/kBtu (kg/kWh) (See Note 1)

Note 1: The adopting authority shall provide Table 9.11a with region names and greenhouse gas emissions factors.

TABLE 9.11b Greenhouse Gas Emissions Factors for Regional Comparisons

Form 2 Row	Imported *Energy Form*	Region Name	*Greenhouse Gas Emissions* Factor (kg/kWh) (See Note 1)
1.	Electricity		
2.	Natural Gas		
3.	Steam		
4.	Hot Water		
5.	Chilled Water		
6.	Fuel Oil		
7.	Propane		
8.	Coal and Other		
9.	Biomass		

Note 1: The adopting authority shall provide Table 9.11b with greenhouse gas emissions factors.

9.12 Avoided Primary Energy Comparisons. The primary energy performance and primary energy index for avoided primary energy comparisons shall be reported on Form 3. Primary energy for imported-minus-exported electricity used by the building shall be converted to consistent units by multiplying the imported-minus-exported electricity use by the primary energy conversion factor in Table 9.12a, as determined by the adopting authority, based on the avoided electricity generation mix of the national or regional power pool or on-site electric generation serving the building.

Fossil fuels, district steam, or district hot water used by the building shall be converted to consistent primary energy units by multiplying the imported-minus-exported fossil fuel, district steam, or district hot-water use by the primary energy conversion factors in Table 9.12b, as determined by the adopting authority, based on the nation or region or on-site non-electric energy production in which the building is located. Site energy exported by the building shall be converted to primary energy units using the same conversion factor as the imported energy form it displaces.

TABLE 9.12a Electricity Primary Energy Conversion Factors for Avoided Energy Comparisons

Region Name	Avoided *Primary Energy* Conversion Factor (See Note 1)

Note 1: The adopting authority shall provide Table 9.12a with region names and primary energy conversion factors.

TABLE 9.12b Primary Energy Conversion Factors for Avoided Energy Comparisons

Form 2 Row	Imported *Energy Form*	Region Name	Avoided *Primary Energy* Conversion Factor (See Note 1)
1.	Electricity		
2.	Natural Gas		
3.	Steam		
4.	Hot Water		
5.	Chilled Water		
6.	Fuel Oil		
7.	Propane		
8.	Coal and Other		
9.	Biomass		

Note 1: The adopting authority shall provide Table 9.12b with regional energy conversion factors.

9.13 Avoided Greenhouse Gas Emissions Comparisons. The greenhouse gas emissions and greenhouse gas emissions index for avoided greenhouse gas emissions comparisons shall be reported on Form 4. Greenhouse gas emissions for imported-minus-exported electricity used by the building shall be converted to consistent units by multiplying the imported-minus-exported electricity use by the conversion factor in Table 9.13a, as determined by the adopting authority, based on the avoided electricity generation mix of the national or regional power pool or on-site electric generation serving the building.

Fossil fuels, district steam, or district hot water used by the building shall be converted to consistent greenhouse gas emissions units by multiplying the imported-minus-exported fossil fuel, district steam, or district hot-water use by the greenhouse gas emissions factors in Table 9.13b, as determined by the adopting authority, based on the nation or region or on-site non-electric energy generation in which the building is located. Site energy exported by the building shall be converted to greenhouse gas emissions using the same conversion factor as the imported energy form it displaces.

TABLE 9.13a Electricity Greenhouse Gas Emissions Factors for Avoided Greenhouse Gas Emission Comparisons

Region Name	*Avoided Greenhouse Gas Emissions* Factor lb/kBtu (kg/kWh) (See Note 1)

Note 1: The adopting authority shall provide Table 9.13a with region names and greenhouse gas emissions factors.

TABLE 9.13b Greenhouse Gas Emissions Factors for Avoided Greenhouse Gas Emission Comparisons

Form 2 Row	Imported *Energy Form*	Region Name	*Greenhouse Gas Emissions* Factor lb/kBtu (kg/kWh) (See Note 1)
1.	Electricity		
2.	Natural Gas		
3.	Steam		
4.	Hot Water		
5.	Chilled Water		
6.	Fuel Oil		
7.	Propane		
8.	Coal and Other		
9.	Biomass		

Note 1: The adopting authority shall provide Table 9.13b with greenhouse gas emissions factors.

(This is a normative appendix and is part of the standard.)

NORMATIVE APPENDIX A—FORM 1A—BUILDING CHARACTERISTICS

Building ID ______________________ Measurement Start Date ____________

Address ______________________ End Date ____________

City, State, Country, ZIP (mail) Code ______________________

Gross Floor Area[1] ______________________

Number of Conditioned Floors ________ Above Grade ________ Below Grade ________

Primary year of construction[2] ____________ Secondary ____________

Building Type[3] (percent of gross floor area)

Office
- ____ Owner Occupied
- ____ Leased (1-5 Tenants)
- ____ Leased (5+ Tenants)
- ____ Bank / Financial
- ____ Courthouse
- ____ Other - Define

Hotel / Motel
- ____ Motel (No Food)
- ____ Hotel
- ____ Hotel/Convention
- ____ Other - Define

Apartment
- ____ General Occupancy
- ____ Seniors Only
- ____ Dorm / Fraternity / Sorority
- ____ Other - Define

Education
- ____ Primary
- ____ Pre-School / Daycare
- ____ Secondary
- ____ College / University
- ____ Other - Define

Food Services
- ____ Restaurant - Full Service
- ____ Fast Food
- ____ Take Out
- ____ Lounge
- ____ Other - Define

Auto Services
- ____ Service / Repair
- ____ Sales
- ____ Other - Define
- ____ Sales

Public Order
- ____ Jail / Penitentiary
- ____ Fire / Police Station

Health Care
- ____ Nursing Home / Assisted Living / Hospice
- ____ Psychiatric
- ____ Clinic / Outpatient
- ____ Active Treatment Hospital
- ____ Other – Define

Retail
- ____ Dry-cleaning / Laundromat
- ____ Supermarket / Food Market
- ____ General Merchandise
- ____ Shopping Mall without Tenant Loads
- ____ Shopping Mall without Tenant Lighting Loads
- ____ Shopping Mall
- ____ Specialty Shop
- ____ Bakery
- ____ Other – Define

Assembly
- ____ Theatre
- ____ Library
- ____ Convention Center
- ____ Museum/Gallery
- ____ Religious worship
- ____ Arena/Gym
- ____ Arena/Rink
- ____ Nightclub
- ____ Other - Define

Other
- ____ Laboratory
- ____ Warehouse
- ____ Warehouse - Refrigerated
- ____ Recreation/Athletic Facility
- ____ Post Office / Center
- ____ Transport Terminal
- ____ Multi-Use Complex
- ____ Data Center
- ____ Other – Define

---

[1] See Section 3 for definition of *gross floor area*.
[2] The median year for construction of at least 51% of the *conditioned* floor area.
[3] *BUILDING* TYPE: determine *building* type and then enter the percent of *gross floor area* for each sub-area or sub-type, dividing common areas between major sub-areas or sub-types.

FORM 1.B—BUILDING ENERGY CHARACTERISTICS

End Use Type
(percent of gross floor area)

Cooling

_____ Electric Chiller
_____ Absorption Chiller
_____ Gas Engine Chiller
_____ Rooftop A/C
_____ Rooftop Heat Pump
_____ Ground Source Heat Pump
_____ Computer Room A/C
_____ Split System
_____ Air Source Heat Pump
_____ Water Source Heat Pump
_____ Evaporative Cooling
_____ Other (type:_________)

Heating

_____ Steam
_____ Hydronic (fuel type: ______)
_____ Natural Gas Furnace
_____ Propane Furnace
_____ Biomass Furnace
_____ Electric Furnace
_____ Oil Fired Furnace
_____ Forced Air Gas
_____ Forced Air Electric
_____ Natural Gas Infrared
_____ Electric Infrared
_____ Ground Source Heat Pump
_____ Heat Recovery Heat Pump
_____ CHP
_____ Other (type:____________)

Lighting

_____ T-12 Fluorescent Tube
_____ T-8 Fluorescent Tube
_____ T-5 Fluorescent Tube
_____ Compact Fluorescent
_____ LED
_____ Metal Halide
_____ Incandescent
_____ High Pressure Sodium
_____ Other (type:_________)

End Use Type
(equipment input rating in kW or Btu/h)

Cooking

_____ Natural Gas
_____ Electric
_____ Steam
_____ Propane
_____ Other (type:_________)

Specialty Ventilation

_____ Kitchen Hoods
_____ Fume Hoods
_____ Restaurant and Other Exhaust

Plug Loads

_____ Computers
_____ Concession Machines
_____ Other___________________

Process Loads

_____ Clothes Washing
_____ Clothes Drying
_____ Servers
_____ Other

(This is a normative appendix and is part of the standard.)

NORMATIVE APPENDIX B—FORM 2—SITE ENERGY PERFORMANCE SUMMARY

Energy Form	Source of *Energy* Data[4]	*Energy* Use Numerical Value	Units	Conversion Factor[3] to kBtu (kWh)	Annual *Site Energy* kBtu/yr *(kWh/yr)*	*Energy Cost* ($)
1. Imported Electricity						
2. Imported Natural Gas						
3. Imported Steam						
4. Imported Hot Water						
5. Imported Chilled Water						
6. Imported Fuel Oil						
7. Imported Propane						
8. Imported Other[5]						
9. Thermal – *On-Site* Production						
10. Electricity – *On-Site* Production						
11. Renewable Other – On-Site Production[5]						
12. Net Increase in *Stored Imported Energy*						
13. Exported Electricity						
14. Exported Steam						
15. Exported Hot Water						
16. Exported Chilled Water						
17. Exported Other[5]						
Building Energy [1] sum of 1 to 11 minus sum of 12 to 17					**A:**	
Site Energy [2] sum of 1 to 8 minus sum of 12 to 17					**B:**	**C:**
Notes						

[1] *Building Energy* is the sum of all *energy* used in the *building*. When the imported *energy* meter records the purchased *energy* minus the exported *energy* under a net metering agreement, exported *energy* shall not be double counted.

[2] *Site Energy* is the sum of the imported *energy* minus exported *energy*. When the imported *energy* meter records the purchased *energy* minus the exported *energy* under a net metering agreement, exported *energy* shall not be double counted.

[3] Section 5 of Standard 105-2014R.

[4] The source of data for each *energy form* shall be either a utility bill, utility meter, site installed meter, *on-site* measurement, or estimate. Where estimated, a description of the method used to estimate *energy* use shall be provided. Where *energy* use is determined from another source, that source shall be described and methodology provided.

[5] If there is more than one "other" *energy form*, the entry shall be split or additional notations made to so indicate.

Site Energy and Cost Indices

Building Energy Index (A÷*Gross Floor Area*) ______________________ kBtu/ft^2·yr (kWh/m^2·yr)

Site Energy Index (B÷*Gross Floor Area*) ______________________ kBtu/ft^2·yr (kWh/m^2·yr)

Energy Cost Index (C÷*Gross Floor Area*) ______________________ $/ft^2·yr ($/m^2·yr

(This is a normative appendix and is part of the standard.)

NORMATIVE APPENDIX C—FORM 3—PRIMARY ENERGY PERFORMANCE SUMMARY

Site Energy Form	Annual *Site Energy* (Form 2 Column 6) kBtu/yr *(kWh/yr)*	*Primary Energy* Conversion Factor[2]	Annual *Primary Energy* kBtu/yr *(kWh/yr)*
1. Imported Electricity			
2. Imported Natural Gas			
3. Imported Steam			
4. Imported Hot Water			
5. Imported Chilled Water			
6. Imported Fuel Oil			
7. Imported Propane			
8. Imported Other[3]			
9. Net Increase in *Stored Imported Energy*			
10. Exported Electricity			
11. Exported Steam			
12. Exported Hot Water			
13. Exported Chilled Water			
14. Exported Other[3]			
Primary Energy [1] Sum of 1 to 8 minus sum of 9 to 14			**B:**

[1] *Primary Energy* is the sum of the imported *energy* converted to its primary form minus exported *energy* converted to its primary form. When the imported *energy* meter records the purchased *energy* minus the exported *energy* under a net metering agreement, exported *energy* shall not be double counted.

[2] Section 6 or Section 9 of Standard 105-2014R.

[3] If there is more than one "other" *energy form*, the entry shall be split or additional notations made to so indicate.

Primary Energy Index

Primary Energy Index (B÷*Gross Floor Area*) ______________________ kBtu/ft^2·yr (kWh/m^2·yr)

(This is a normative appendix and is part of the standard.)

NORMATIVE APPENDIX D—FORM 4—GREENHOUSE GAS EMISSIONS SUMMARY

Site Energy Form	Annual *Site Energy* (Form 2 Column 6) kBtu/yr *(kWh/yr)*	*Greenhouse Gas Emission* Factor[2] lb/kBtu *(kg/kWh)*	Annual *Greenhouse Gas Emissions* lb/yr *(kg/yr)*
1. Imported Electricity			
2. Imported Natural Gas			
3. Imported Steam			
4. Imported Hot Water			
5. Imported Chilled Water			
6. Imported Fuel Oil			
7. Imported Propane			
8. Imported Other[3]			
9. Net Increase in *Stored Imported Energy*			
10. Exported Electricity			
11. Exported Steam			
12. Exported Hot Water			
13. Exported Chilled Water			
14. Exported Other[3]			
Greenhouse Gas Emissions [1] Sum of 1 to 8 minus sum of 9 to 14	Not Applicable	Not Applicable	**B:**

[1] *Greenhouse gas emissions* associated with imported *energy* converted to its primary form minus *greenhouse gas emissions* associated with exported *energy* converted to its primary form. When the imported *energy* meter records the purchased *energy* minus the exported *energy* under a net metering agreement, exported *energy* shall not be double counted.
[2] Section 7 or Section 9 of Standard 105-2014R.
[3] If there is more than one "other" *energy form,* the entry shall be split or additional notations made to so indicate.

Greenhouse Gas Emissions Index

Greenhouse gas emissions Index (B÷*Gross Floor Area*) ____________________ lb/ft²·yr (kg/m²·yr)

(This is a normative appendix and is part of the standard.)

NORMATIVE APPENDIX E—FORM 5—ADDITIONAL EXPRESSIONS OF ENERGY PERFORMANCE OR GREENHOUSE GAS EMISSIONS

Specification of *Normalization Parameters*			
Additional *Normalization Parameters*	**Type of Factor**	**Value of Factor**	**Units of Factor**
Number of full-time equivalent workers	Occupancy		Workers
Number of full-time equivalent students	Occupancy		Students
Number of licensed hospital beds	Occupancy		Beds
Food service seating capacity	Occupancy		Seats
Food service meals per day	Occupancy		Meals per day
Number of personal computers	Occupancy		Personal Computers
Weekly hours of operation	Occupancy		Hours/week
Annual months of operation	Occupancy		Months/year
Computer center and communication areas	*Building*		Percent of floor area
Annual average power density for computer center and communication areas	*Building*		W/ft^2 (W/m^2)
Percent of *gross floor area* heated	*Building*		Percent heated
Percent of *gross floor area* cooled	*Building*		Percent cooled
Heating degree-days (base 65°F/18°C)	Weather		Degree-days
Cooling degree-days (base 65°F/18°C)	Weather		Degree-days
Parking garage floor area	*Building*		ft^2 (m^2)
Natatorium space floor area	*Building*		ft^2 (m^2)
Natatorium present or not	*Building*		Yes or No, 1 or 0
Annual peak electric demand	*Energy*		kW
Electricity generation capacity	*Energy*		kW
Annual electricity generation	*Energy*		kWh/yr
Electric vehicle charging	*Energy*		kWh/yr.

Additional *Normalization Parameters*			
Index from Form 2, Form 3, or Form 4	**Additional Normalizing Factor**	**Value of Normalized Expression**	**Units of Normalized Expression**

Values of additional *normalization parameters* not applicable to additional expressions shall be shown as “N/A.”

(This is a normative appendix and is part of the standard.)

NORMATIVE APPENDIX F—FORM 6—COMPARISON OF ENERGY PERFORMANCE OR GREENHOUSE GAS EMISSIONS

Building ID ______________________ Comparison Start Date ____________

Street Address ______________________ Comparison End Date ____________

City, State, Country, ZIP (mail) Code ______________________

Gross Floor Area from Form 1 ____________ Square feet (square meters)

Site Energy Index from Form 2 ____________ kBtu/ft^2·yr (kWh/m^2·yr)

Energy Cost Index from Form 2 ____________ \$/ft^2·yr (\$/m^2·yr)

Primary Energy Index from Form 3 ____________ kBtu/ft^2·yr (kWh/m^2·yr)

Greenhouse Gas Emissions Index from Form 4 ____________ lb/ft^2·yr (kg/m^2·yr)

Performance Value(s)	**Type of Value** (numeric scale, grade, other)	**Range of performance scale (worst to best)**	**Units of performance scale (or N/A)**

TYPE of COMPARISON METHOD: _____ Documented _____ Ad hoc / Undocumented
TIME PERIOD: _____ Annual _____ Other, specify ____________________________
NAME of COMPARISON METHOD: ____

Documented Comparison Access Information		
	Access point of report describing analytical methods	URL or other:
	Access point of comparison data base used for analytical method	URL or other:

Data Filters Used for Analysis, provide for ALL METHODS

Comparison Factor Name/Description	**Units**	**Filter Criteria**

For additional factors, attach additional sheet(s)

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INFORMATIVE APPENDIX G—FUEL HEAT CONTENT CONVERSION VALUES—OTHER FUELS

TABLE G1 Higher Heating Values

Coals	**Btu/lb**		**kWh/kg**	
Anthracite	12,700		8.2	
Semianthracite	13,600		8.8	
Low-Volatile Bituminous	14,350		9.3	
Medium-Volatile Bituminous	14,000		9.0	
High-Volatile Bituminous A	13,800		8.9	
High-Volatile Bituminous B	12,500		8.1	
High-Volatile Bituminous C	11,000		7.1	
Subbituminous B	9,000		5.8	
Subbituminous C	8,500		5.5	
Fuel Oils	**Btu/U.S. gal**		**kWh/L**	
#1	135,000		10.5	
#2	See Table 5.1		See Table 5.1	
#4	See Table 5.1		See Table 5.1	
#5L	148,000		11.5	
#5H	150,000		11.6	
#6	See Table 5.1		See Table 5.1	
Gas				
Natural Gas	See Table 5.1		See Table 5.1	
Propane	See Table 5.1		See Table 5.1	
Bagassee (Moisture Free)	8900 Btu/lb		5.8 kWh/kg	
Sawdust, Peat, Bark	9000 Btu/lb		5.8 kWh/kg	
Woods	**Mass lb/cord[a] (kg/m^3)**		**Million Btu/Cord[a] (kWh/m^3)**	
Species	**Green[c]**	**Air-Dry[b]**	**Green[c]**	**Air-Dry[b]**
Ash	3840 (480)	3440 (430)	16.5 (1300)	20.0 (1600)
Aspen	3440 (430)	2160 (270)	10.3 (800)	12.5 (1000)
Beech, American	4320 (540)	3760 (470)	17.3 (1400)	21.8 (1800)
Birch, yellow	4500 (560)	3680 (460)	17.3 (1400)	21.3 (1700)
Douglas fir	3200 (400)	2400 (300)	13.0 (1100)	18.0 (1500)
Elm, American	4320 (540)	2900 (360)	14.3 (1200)	17.2 (1400)
Hickory, shagbark	5040 (630)	4240 (530)	20.7 (1700)	24.6 (2000)
Maple, red	4000 (500)	3200 (400)	15.0 (1200)	18.6 (1500)
Maple, sugar	4480 (560)	3680 (460)	18.4 (1500)	21.3 (1700)
Oak, red	5120 (640)	3680 (460)	17.9 (1400)	21.3 (1700)
Oak, white	5040 (630)	3920 (490)	19.2 (1600)	22.7 (1800)
Pine, eastern white	2880 (360)	2080 (260)	12.1 (1000)	13.3 (1100)
Pine, eastern yellow	4000 (500)	2600 (330)	14.2 (1100)	20.5 (1700)

a Based on 80 ft^3 of solid wood stacked in a 128 ft^3 cord, for a void fraction of 37.5%. Cubic meters apply to the gross volume of a stacked pile of wood with this void fraction.
b 20% moisture
c 40% to 60% moisture

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INFORMATIVE APPENDIX H—MEASURING ENERGY USE

The purpose of this appendix is to provide a description and outline for measurement of site energy forms used in an existing building, as required in Section 5.

H1. ELECTRICITY

Electricity consumption is measured in kilowatt-hours and appears on the bill supplied by the utility. The measurement of consumption may be carried out by using the same meter readings as those taken by the utility or by taking regular independent meter readings. For sites with net metering of purchased and renewable site-generated electricity, imported energy should reflect the total electricity use of the building (imported and site generated) when the exported energy is also reported.

Where electricity is not purchased from a utility but is generated on-site or delivered free, the measurement should be made using a commercially acceptable kilowatt-hour meter.

H2. NATURAL GAS

Natural gas consumption is measured in cubic feet and appears on the bill supplied by the utility as cubic feet or therms. Reporting of natural gas consumption is typically in therms. The measurement of consumption may be carried out by using the utility's meter readings or by taking regular independent meter readings.

Where natural gas is not purchased from a utility but is found on-site or delivered free, the measurement should be made using a commercially acceptable gas meter.

Conversion of cubic feet to therms should include correction for altitude.

H3. FUEL OIL

Oil is supplied to customers in a number of different grades, varying from kerosene to heavy fuel oil, and is delivered and charged for in gallons. The cost per unit will vary with the supplier, the grade of oil, and the size of the load delivered at any one time. The heavier fuel oils require heating for ease of pumping and especially for ensuring that they have the correct viscosity at the burner. In the main storage tanks, the oil is heated to a temperature that will ensure adequate flow to the pumps and service tanks.

Before reaching the burner nozzles, the oil is raised to a higher temperature to acquire a sufficiently low viscosity to ensure good atomization by the burner. The oil can be heated using electricity or steam. It is important to account for the energy used for the preheating of the oil.

Measurement of oil consumption may be carried out using one or more of the following methods:

a. Using the supplier’s delivery notes or metered delivery tickets.
b. Installing an integrating meter between the tanks and the delivery point.
c. Installing an integrating meter between the tanks and the fuel-burning equipment to check consumption rates.
d. Installing an integrating meter before each fuel burner.
e. Using the storage tank gauges (i.e., at the start of the monitoring period, note the amount of oil in the tanks, add to this any deliveries made within the period, then subtract the amount of oil remaining at the end of the period).
f. Using a daily service tank.
g. Using a calibrated dipstick.

Whichever method is selected, contents of the storage tanks should be noted just before a delivery is made and after the new supply has settled down, thus enabling a further check on supplies to be carried out.

For a delivery vehicle with a metering device:

1. Examine the delivery ticket to ensure the correct quantity and type of fuel is being discharged.
2. Ensure that the meter reads zero before any discharging is commenced.
3. After discharge is completed, examine the meter and check that it reads the quantity for which you are going to sign.

Gauges on the oil storage tank, even ones in good order, are not acceptable as proof of delivery but can nevertheless provide a good cross check.

H4. COAL

Solid fuels are generally delivered in bulk with a delivery ticket. This ticket will show the following:

- Gross weight (mass).
- Tare weight (mass).
- Net weight (mass).

Providing the documents are correct, the net weight (mass) only is signed for.

Once the fuel is in stock, accurate measurement of consumption can be difficult unless there is a recording meter on the grate, screw feed, or boiler.

However, storage bays provide a suitable means of estimating stores of coal serving day-to-day consumption, especially if the coal is delivered in bulk.

Operations staff are skilled in estimating what stocks are left based on levels in storage bays over a period of time. Therefore, the amount used can be calculated by estimating the amount of coal in stock at the beginning of the period, adding any deliveries made within the period, and then subtracting the amount of coal remaining at the end.

H5. LIQUIFIED PETROLEUM GAS (LPG)

The two main grades of liquified petroleum gas (LPG) used in heating installations are commercial propane and butane. Both are stored as a liquid under pressure and become gas when the pressure is released. LPG is delivered to customers in liquid form by a tanker and measured by a recording meter equipped with a ticket printout device. Storage tanks are fitted with liquid level gauges that can be used for checking-and-measuring purposes, but gas drawn from the storage tanks is usually fed to the plant through a gas meter. This enables a check to be made on supplies and consumption rates and is an ideal measuring device.

H6. HEATING/COOLING SUPPLIED

Some companies have considered it more economical to purchase heating or cooling than to run their own heating or cooling plants. Others have entered into agreements with specialist organizations to manage the heating or cooling plants on the owners’ behalf. In these cases, it is usual for a formal contract to exist between the parties concerned stating the terms and conditions under which the energy is supplied, whether it be in the form of hot water, chilled water, hot air, cold air, or steam. Such contracts state precisely the method of charging for the heating or cooling supplied based on readings taken from equipment such as Btu meters, steam meters, storage tank gauges, electric meters, gas meters, oil delivery notes, etc., with adjustments to the figures for plant efficiencies and the energy content of the fuel. Based on readings taken from this equipment, the customer is charged accordingly.

To account for faults or errors that occur in the agreed-upon measuring equipment, an alternative method of calculating or estimating the consumption is usually written into the contract.

It is usual for the consumer to have some means of crosschecking the consumption, even if this is the same metering equipment used by the heat supplier, thus enabling the customer to monitor and control consumption.

H7. ON-SITE RENEWABLE ENERGY

On-site renewable energy includes any renewable energy source harnessed at a site, such as solar, wind, biogas, biomass, or geothermal, that is converted to electric or thermal energy. Site-harvested renewable energy displaces purchased energy and should be measured and reported in the same fashion as the energy form it displaces.

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INFORMATIVE APPENDIX I—ADJUSTING ENERGY USE TO A 365-DAY YEAR

The purpose of this appendix is to provide a method of adjusting the utility bill data to a period of 365 days and of adjusting nonsynchronous billing periods. If a building receives more than one utility bill, it is likely that they are not on the same billing period. For the purpose of this standard, all energy measurements should be adjusted to cover the same consecutive 365 days.

To achieve this result, first select the analysis period corresponding to the energy form with the largest total. This will minimize the errors from adjustments. Adjust the other energy form start and stop times to match the analysis period by adding or subtracting the appropriate average daily energy use values from the beginning and ending of the measured energy period. Use the monthly daily average energy use for the first month to adjust the beginning of the measurement period, and use the monthly daily average energy use for the last month to adjust the ending of the measurement period. When finished, the total number of days covered by the energy use data should be 365.

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INFORMATIVE APPENDIX J—BOUNDARY SPECIFICATIONS AND CONVERSION FACTOR OPTIONS

The purpose of this appendix is to provide information on boundary specifications and conversion factor options that may be helpful to adopting authorities for use in comparisons of building energy performance and associated greenhouse gas emissions.

J1. BOUNDARY SPECIFICATIONS

Boundary specifications are where the measurements are made and are a critical element of any building energy performance comparison. Boundary specifications can be thought of as a “black box” where what goes in and out across the boundary can be measured. Establishing rational and defensible boundary specifications will help users provide meaningful and equitable comparisons and help the adopting authority achieve its energy and environmental performance objectives. Boundary specifications for the energy sector that are typically used include point-of-use energy, building energy, site energy, energy cost, and primary energy.

J1.1. Measurement Locations. “Point-of-use energy” is energy consumed to operate an appliance or other device. For example, the boundary specification for DOE appliance rulemaking is legislatively mandated at the appliance point of use, which is defined by DOE as the energy consumed to operate the appliance determined in accordance with prescribed test procedures. DOE energy factors such as the water heater uniform energy factor (UEF) and furnace annual fuel utilization efficiency (AFUE) are based on “point-of-use energy.”

The “building energy” boundary includes energy consumed by a building, including on-site renewable energy production used by the building, as measured at the boundaries of the building. Building energy is the summation across the building of “point-of-use energy” by energy or fuel type during a given time period. Establishing a building energy boundary specification can be challenging when determining how to address energy use associated with support structures or services such as parking garages or storage sheds that are not conditioned but consume energy for lighting and other energy services. Such energy use may be excluded from the “building energy” consumption when determining building energy performance but can be a significant additional demand for energy in some situations. The “site energy” boundary specification includes such energy consumption in the metered energy but may also have challenges when allocating support structure energy use across several buildings on campuses or multi-building sites.

The “site energy” boundary, typically but not always drawn at the property line, includes energy crossing the boundary for use by a building and other energy-consuming services located on the building site as well as any exported energy. This definition excludes on-site renewable energy production generated and used within the site. The “site energy” boundary specification aligns closely with utility metered energy. It would likely be less than "building energy" whenever on-site renewable energy is produced to meet the "building energy" use requirements.

J1.2. Energy Boundaries. "Energy cost" is the total cost for energy and fuel supplied to a building or building site, including such charges as base charges, demand charges, customer charges, power factor charges, and miscellaneous charges such as sales taxes. This total represents the net cost to supply an energy form to a building site after deducting payments for exported energy.

"Primary Energy" currently has different boundary specifications as implemented in the U.S. by the Department of Energy (DOE) and the Environmental Protection Agency (EPA). Three alternative boundary specifications for primary energy have been defined by DOE and EPA as follows:

"Primary Energy" (DOE): Energy consumed on-site, plus energy losses that occur in the generation, transmission, and distribution of electricity. As can be seen in Figure J1, this definition does not include fuel and energy that is used to extract or deliver fuel to an electric generating or district heating / cooling plant.

"Full-Fuel-Cycle Energy" (DOE): The energy consumed by a building as measured at the building site plus the energy consumed in the extraction, processing, and transport of primary fuels such as coal, oil, and natural gas; energy losses in thermal combustion in power-generation plants; and energy losses in transmission and distribution to homes and commercial buildings.

"Source Energy" (EPA): The total primary fuel needed to deliver heat and electricity to the building site. Generally, this means the methodology should perform the following adjustments for energy consumed on site:

- Primary Energy (e.g., natural gas, fuel oil)—Account for losses that occur in the distribution, storage, and dispensing of the primary fuel.
- Secondary Energy (e.g., electricity, district steam)— Account for conversion losses at the plant in addition to losses incurred during transmission and distribution of secondary energy to the building.

Primary Energy (Standard 105): The energy consumed as measured at the building site boundary plus the energy consumed in the extraction, processing, and transportation of primary energy forms such as coal, oil, natural gas, biomass, and nuclear fuel; energy consumed in conversion to electricity; and energy consumed in transmission and distribution to the building site.

Figure J1 illustrates 2017 energy flows in the U.S., including DOE boundary specifications for site energy, primary energy, and full-fuel-cycle energy. Source energy as defined by EPA and primary energy as defined by DOE account for primary energy associated with electricity generation but do not provide consistent boundary specifications for electricity and other primary energy sources used in buildings.

The DOE "Full-Fuel-Cycle Energy" option is the basis of the definition of "Primary Energy" used in this standard and in the conversion factor values listed in this appendix. Taking all energy forms to the point of extraction (i.e., wellhead or mine, whether domestic or international) provides a consistent boundary specification for the energy sector when considering primary resource and environmental impacts of building energy use. A key difference between the DOE definition and the Standard 105 definition is the treatment of chemical, mechanical, and thermal energy conversion options that do not involve combustion, including nuclear, hydro, wind, solar, and geothermal energy conversion.

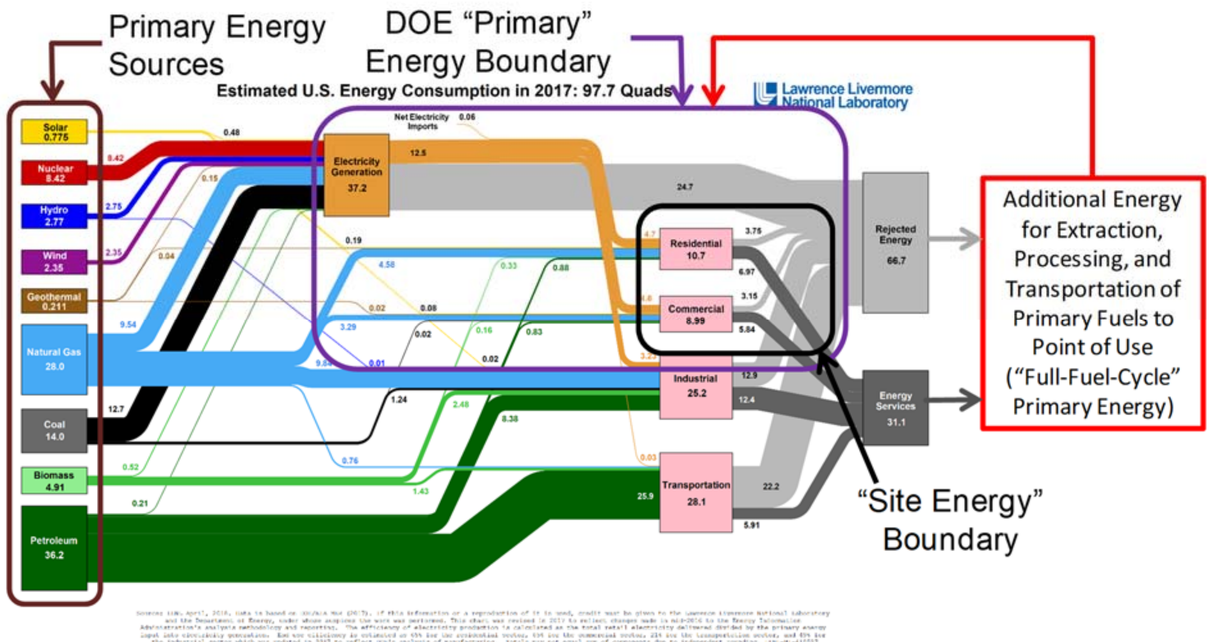

Figure J1 U.S. 2017 Energy Use Profile with Different Boundary Specifications. (Source: Lawrence Livermore National Laboratory [https://flowcharts.llnl.gov/])

J2. CONVERSION FACTORS FOR COMPARISONS

This standard provides several alternative methods of determining, expressing, and comparing building energy performance. Ultimately, the decision on which conversion factors are most appropriate for use by the adopting authority depends on the objective. Site energy conversion factors for each energy form depend only on the energy crossing the site boundary and are insensitive to national average, regional average, or avoided primary energy comparison frameworks. For example, measuring electric energy at the site boundary would not include the conversion losses that may have been incurred in generating that energy. The information developed using Form 2 will always be sufficient for use in site energy comparisons. However, primary energy performance and greenhouse gas emissions comparisons require additional information that may use different comparison frameworks, depending on the specific objective.

For primary energy and greenhouse gas emissions accounting and inventory purposes that take a snapshot of the building's performance during an interval of time (e.g., characterizing the performance of the building as currently designed, constructed, or operated), average factors, either national, regional, or even hourly values may be used to provide the most informative data.

For incremental energy investment decisions that change the building's performance compared to an alternative choice (e.g., energy efficiency design standards or retrofit programs), avoided primary energy and greenhouse gas emission factors may provide better information than energy cost.

J2.1 Non-Combustible Renewable Power Generation Primary Energy Factor Options. Unlike other power generation fuels, non-combustible energy sources for renewable power generation, including hydro, wind, solar, and geothermal heat, do not "consume" fuel in the conventional sense. This fundamental difference creates a significant challenge when trying to determine a reasonable way to account for the primary energy attributable to non-combustible energy forms. Each of these resources is generally considered to have zero fuel cost, zero depletable energy consumption, and zero greenhouse gas emissions. Accordingly, annual primary energy use as the metric for comparison with other forms of energy may be inadequate for these resources. Other metrics and boundary specifications may be needed for comparative analyses and inventory calculations. For instance, "embedded" energy associated with manufacturing and shipping wind, hydro, geothermal, and photovoltaic components and materials of construction may be considered in the calculation, but embedded energy is also difficult to determine and value fairly. Other potential externality impacts of non-combustible energy forms include fish kills, incremental water consumption, bird strikes, or loss of habitat in deserts. Some have argued that the levelized cost of electricity for renewable power over its life cycle may be a reasonable proxy for primary energy that includes embedded energy, but that cost metric proxy could be debated as based on one's time horizon, tax subsidies, and other factors and metrics; including consideration of alternatives to electricity.

Four approaches to determining renewable power primary energy factors are available, including:

1. Incident Energy Efficiency.
2. Fossil Fuel Equivalency.
3. Captured Energy Efficiency.
4. Infinite Energy Efficiency (Zero Energy Use).

Each of the four approaches yields significantly different factors, and each will result in a different valuation of direct use of different energy forms in buildings compared to electric options. They will also impact the valuation of comparisons of renewable electric power compared to other power generation options such as natural gas or nuclear power generation.

J2.1.1 Incident Energy Efficiency (thermodynamic efficiency) is the fraction of input (or incident) energy converted to electricity. The Incident Energy Efficiency approach provides a common metric for primary energy efficiency comparisons across all generation types, including among renewable options because it considers all primary energy to be equivalent. Hydropower is by far the highest primary energy efficiency power source at ~90% efficiency, so it would be strongly incentivized compared to any other option, including other renewable power, conventional power, or direct use of other energy forms in buildings. Based on Incident Energy Efficiency, increased penetration of solar (~14% efficiency) and wind (~25% efficiency) would make the average electric grid primary energy conversion factor worse, not better, thereby dis-incentivizing those forms of renewable power compared to hydropower generation, non-renewable electricity generation, and compared to direct use of other energy forms in buildings. For this reason, the Incident Energy Efficiency approach for determining primary energy use may create inconsistent policy signals as the amount of wind and solar electricity generation grows.

J2.1.2 Fossil Fuel Equivalency (partial substitution method) treats non-combustible renewable power generation as if it is displacing fossil fuel power generation. This is the approach used by EIA in its national annual primary energy use and losses calculations, as described in AER 2011 Appendix F (https://www.eia.gov/totalenergy/data/annual/pdf/sec17_3.pdf), and highlighted in Figure J1 as the factors for "Primary Energy Sources. Fossil Fuel Equivalency is intended to value the primary energy benefit of renewable generation compared to annual average fossil fuel generation it displaces. However, it significantly overstates the contribution of hydropower energy to primary energy use in EIA national annual primary energy use calculations compared to the Incident Energy Efficiency methodology. Like the Incident Energy Efficiency approach, the Fossil Fuel Equivalency approach for determining primary energy use may create inconsistent policy signals as the amount of wind and solar electricity generation grows.

J2.1.3 Captured Energy Efficiency (physical energy content method) treats non-combustible renewable power generation as if it is 100% efficient, irrespective of its Incident Energy Efficiency, or whether it displaces other electricity generation, or is displaced by direct use of other energy forms in buildings. Captured energy values renewable power over direct use of other energy forms in buildings because its energy efficiency is deemed to be 100%, but it does not differentiate among renewable energy generation options. It is effectively a point of use energy metric valuation of renewable power generation and incentivizes all types of non-combustible renewable power compared to other options.

J2.1.4 Infinite Energy Efficiency (zero energy use) assigns no primary energy use to non-combustible renewable power generation, essentially considering it to be infinitely efficient. Some have argued that renewable power production takes advantage of an infinitely available resource (i.e., non-depletable) and therefore should be considered free energy for primary energy efficiency calculations. This approach provides the most incentive for renewable electricity compared to other forms of electricity or direct use of other energy forms in buildings but does not distinguish among renewable electricity generation sources.

J2.1.5 Discussion of Options – United States. US and international governments and representative agencies have chosen the captured energy efficiency methodology for non-combustible renewable power generation. In the US, a 2016 DOE report, "Accounting Methodology for Source Energy of Non-Combustible Renewable Electricity Generation," discusses the impact of Fossil Fuel Equivalency, and Captured Energy Efficiency options for non-combustible renewable power generation https://www.energy.gov/sites/prod/files/2016/10/f33/Source%20Energy%20Report%20-%20Final%20-%2010.21.16.pdf. The DOE report provides guidance on applications for which it considers the Captured Energy Efficiency approach to be more useful than the Fossil Fuel Equivalency approach it had been using for calculations. As noted in the DOE report:

> "neither option is considered more technically "correct" or more "accurate" than the other, as each option needs to be considered along with its intended use to determine which is appropriate. As discussed by EIA, for their purposes, fossil fuel equivalency may be more appropriate when renewable generation always displaces

> fossil fuel generation, and captured energy may be more appropriate when renewable generation never displaces fossil fuels. There are also additional confounding factors such as Renewable Portfolio Standards and priority dispatch of renewables that would make it extremely challenging to calculate a more representative conversion factor that accurately assesses what fuel source renewable generation is displacing."

J2.1.6 Discussion of Options – International. In Canada, IEA, and European Union policy initiatives, the terms used are "partial substitution method" (fossil fuel equivalent in DOE terminology) and "physical energy content method" (captured energy efficiency in DOE terminology). As noted in the Canadian Energy Fact Book (https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/EnergyFactBook_2016_17_En.pdf):

> "The primary energy equivalent of hydroelectricity is calculated using the physical energy content method, as applied by the International Energy Agency and Statistics Canada, in which hydroelectricity is defined as a primary energy form. This differs from the partial substitution method applied by the Energy Information Administration (U.S.), where the primary energy equivalent of hydroelectricity is calculated as the amount of fossil fuel required to generate the same volume of electricity in a thermal power station."

In its FAQ guidance to the public, IEA provides nearly identical information on these two options and its statement about the physical energy content method as the preferred choice:
https://www.iea.org/statistics/resources/questionnaires/faq/
"The partial substitution method:

> In this method, the primary energy equivalent of the above sources of electricity generation represents the amount of energy that would be necessary to generate an identical amount of electricity in conventional thermal power plants. The primary energy equivalent is calculated using an average generating efficiency of these plants. This method has several shortcomings, including the difficulty of choosing an appropriate generating efficiency and the fact that it is not relevant for countries with a high share of hydroelectricity. For these reasons, the IEA, as most of the international organizations, has now stopped using this method and adopted the physical energy content method.

The physical energy content method:

> This method uses the physical energy content of the primary energy source as its primary energy equivalent. As a consequence, there is an obvious link between the principles adopted in defining the primary energy forms of energy sources and the primary energy equivalent of these sources. For instance, in the case of nuclear electricity production, as heat is the primary energy form selected by the IEA, the primary energy equivalent is the quantity of heat generated in the reactors. However, as the amount of heat produced is not always known, the IEA estimates the primary energy equivalent from the electricity generation by assuming an efficiency of 33%, which is the average of nuclear power plants in Europe. In the case of hydro, as electricity is the primary energy form selected, the primary energy

> equivalent is the physical energy content of the electricity generated in the plant, which amounts to assuming an efficiency of 100%."

Directive 2009/28/EC on the promotion of the use of energy from renewable sources established specific calculation criteria for the share of energy from renewable sources. European Union (EU) calculation methods (https://ec.europa.eu/eurostat/statistics-explained/index.php/Calculation_methodologies_for_the_share_of_renewables_in_energy_consumption) also use the Captured Energy Efficiency (physical energy content) method. The EU describes their logic for their inventory (energy statistics and energy balances) purposes as follows:

> "The choice for Eurostat's energy statistics and energy balances is to use the physical energy content method. The general principle of this method is that the primary energy form is taken as the first flow in the production process that has a practical energy use. This leads to different situations depending on the energy product:
>
> - For directly combustible energy products (for example, coal, natural gas, oil, biogas, bioliquids, solid biomass, and combustible municipal/industrial waste), the primary energy is defined as the heat generated during combustion.
> - For products that are not directly combustible, the application of this principle leads to:
>   - the choice of heat as the primary energy form for nuclear, geothermal and solar thermal; and
>   - the choice of electricity as the primary energy form for solar photovoltaic, wind, hydro, tide, wave, ocean.
>
> In cases when the amount of heat produced in the nuclear reactor is not known, the primary energy equivalent is calculated from the electricity generation by assuming an efficiency of 33 %."

Tables in Appendix K include both the Captured Energy Efficiency and Infinite Energy Efficiency approaches to determining the primary conversion efficiency of non-combustible renewable power generation to and from the electric grid.

J2.2 Global Warming Potential. Water vapor is by far the dominant and most important Green House Gas (GHG). However, human activity that results in additional water vapor in the atmosphere does not significantly impact the climate because water vapor emitted near ground level does not accumulate in the atmosphere - the amount of water vapor is dependent on local temperature conditions, and in general, increased water vapor emitted just means more precipitation in some form within a few days. Other GHGs are of concern in part because they are influenced by human activity and because they can create feedback loops with water vapor. Of these GHGs, CO_2 is of great interest because its concentration is increasing and because higher concentrations of CO_2 will last in the atmosphere for a very long time. CO_2 is one of the numerous GHGs, each of which has a different impact on global warming. CO_2e (CO_2equivalent) emission factors and calculations provide a potentially useful way to compare different GHGs (other than water vapor) relative to the impact of CO_2. Section 5.3.2 of the

Intergovernmental Panel on Climate Change (IPCC) report "Climate Change 1994" (http://www.ipcc.ch/pdf/special-reports/cc1994/climate_change_1994.pdf) discusses the choice of metric and time horizon for determining CO_2e emissions at that time for use in their comparisons and reporting. Section 8.7 of the IPCC fifth assessment report (AR5) "Climate Change 2013 The Physical Science Basis" http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf provides an extensive discussion of the decisions made and limitations of different options. In AR5, IPCC notes that "Choices of time frames and climate impact are policy-related and cannot be based on science alone, but scientific studies can be used to analyze different approaches and policy choices."

The IPCC CO_2e emissions metric and time horizon were based on consideration of simplicity, precision, accuracy, and relevance to their policy goals. Based on IPCC judgments about these policy factors, Global Warming Potential (GWP) was selected as the default metric for reporting emissions of different gases on a common scale that accounts for varying levels of radiative forcing of each GHG relative to CO_2. Since the IPCC was most interested in minimizing the magnitude of long-term impacts, they adopted the 100-year integration period (GWP_{100}) as the time horizon to implement the multi-gas approach in the 1997 Kyoto Protocol and subsequent agreements.

Choice of time horizon has a strong effect on GWP values and thus on the calculated contributions of CO_2e emissions by component, sector, or nation. Discussion in the AR5 report suggests that a shorter (e.g., 20 year) time horizon may be useful if the speed of potential climate change is of greater interest than the eventual magnitude of the change. Since the IPCC was most interested in minimizing the magnitude of long-term impacts, they adopted the 100-year integration period (GWP_{100}) as the metric to implement the multi-gas approach in the 1997 Kyoto Protocol and subsequent agreements, including U.S. inventory and progress reporting.

Methane (CH_4) is a potent GHG in the short term compared to CO_2. With a lifetime of ~12.4 years, nearly all of methane's absolute global warming potential (AGWP) occurs during the first few decades after emissions. Because of the integrative nature of the GWP concept, the AGWP for CH_4 reaches a constant level after about five decades. In contrast, the AGWP for long-life CO_2 continues to increase for centuries. Thus, the ratio of AGWP for CH_4 and AGWP for CO_2, which defines the GWP for CH_4, falls quickly with increasing time horizon of interest.

Because of this near-term impact, some stakeholders have expressed interest in reducing the GWP time horizon used for analysis, comparisons, and implementation in standards, codes, and regulations. Some organizations, such as the California Air Resources Board and ASHRAE's SSPC 189.1, "Standard for the Design of High Performance Green Buildings Except Low-Rise Residential Buildings," have begun considering shorter-term impacts and have provided comparisons based on the 20-year integration period (GWP_{20}). Tables in Appendix K provide both the GWP_{100} and GWP_{20} time horizons for determining CO_2e emission factors.

J2.3 Nuclear Power Generation. Nuclear power plants use enriched uranium fuel to produce electricity through fission in a nuclear reactor. The heat of nuclear fission boils water to make steam used in turbines to produce electricity. Except for the reactor itself, nuclear power generation uses the same steam turbine generation approach as most coal-fired power plants. The

United States is the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation of electricity.

Nuclear power generation conversion efficiency can be estimated using a national average heat rate for the steam turbine and ancillary equipment based on DOE EIA data (https://www.eia.gov/electricity/annual/html/epa_08_01.html). It represents the weighted national average tested heat rate for nuclear generators as reported on EIA Form EIA-860. It does not include the remaining energy content of spent nuclear fuel. Primary energy factors for nuclear fuel mining, enrichment, and transportation can be estimated based on information from the world nuclear organization based on natural uranium (0.7% U235) mining, 5% U235 enrichment processes (http://www.world-nuclear.org/information-library/nuclear-fuelcycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx), and rail transportation of 5% U235 enriched fuel.

J2.4 Renewable fuels. The production of renewable fuels is an emerging carbon emission reduction strategy to turn organic waste or other biomass feedstock into a low carbon fuel for direct-use applications. Renewable fuels include biogas, such as biomethane or biopropane; bioliquids, such as bioethanol or biodiesel; various forms of solid biomass such as crops, waste wood, or trees; and hydrogen, methane, or other fuel derived from renewable processes, such as wind power to gas.

The Greenhouse Gas reduction potential of biofuel is due primarily to a comparison of its beneficial use versus release of methane or CO_2 to the atmosphere due to natural decomposition processes. The multiple pathways for biofuel production each have different input energy requirements and offsets depending on the alternative uses and emissions of the feedstock. For instance, RNG from agricultural waste digesters contains high levels of CO_2, moisture, and sulfur species, which take energy to remove prior to obtaining pipeline-quality RNG. If such waste were otherwise vented to the atmosphere, RNG derived from such sources would receive a significant methane credit by capturing and using the methane instead of venting it. RNG from landfill gas is processed in a similar fashion as agricultural waste but requires additional energy (typically electric energy) to remove siloxanes.

Determining reasonable primary energy and emission factors for biofuels is complicated. Primary energy factors for biofuels vary significantly depending on the source, processing needed, and underlying assumptions. The US EPA has a Renewable Fuel Standard Program with qualification criteria and pathways for compliance (https://www.epa.gov/renewable-fuel-standard-program). The European Commission has established similar provisions in its biofuels sustainability qualification criteria (https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels).

J2.5 International Energy Considerations. International use of Standard 105 will be straightforward for those countries or regions that have developed their own set of factors for comparisons. Such factors would apply to energy forms in Form 2 and used in Forms 3 and 4. For instance, primary energy and GHG emission factors for building ratings and inventory calculations are available throughout the European Union, https://www.epbd-ca.eu/wp-content/uploads/2018/04/05-CCT1-Factsheet-PEF.pdf and https://cidportal.jrc.ec.europa.eu/ftp/jrc-opendata/COM-EF/dataset/comw/JRC-CoM-EF-CoMW-EF-2017.pdf. European users of Standard 105 would be able to use those resources to inform their choice(s) of conversion factors for their specific purposes.

For international energy markets, primary energy and greenhouse gas emission factors will be impacted by the amount of energy imported from other countries. Compared to domestic production, international shipments can be expected to consume additional transportation energy and sometimes additional processing energy. Imports and exports of oil, natural gas, propane, and coal have changed dramatically in the US over the past 15 years. The US imported much more crude oil (over 12 million barrels per day) in the mid-2000's. Since then, oil imports have dropped significantly with the widespread adoption of advanced hydraulic fracturing and horizontal drilling extraction techniques for both natural gas and oil. The US is now exporting a significant amount of oil products (https://www.eia.gov/todayinenergy/detail.php?id=38672), and oil prices have dropped during the same period.

For similar reasons, natural gas has become a more abundant and affordable energy form since 2005. One consequence of this shift in production techniques is the improved economic attractiveness of liquified natural gas (LNG) for international shipments. LNG is natural gas that has been cooled to –260°F (–162°C), changing it from a gas into a liquid that is 1/600th of its original volume. It requires specially designed liquefaction and export terminals, oceangoing vessels, and import and regasification terminals. It takes additional energy compared to conventional natural gas for liquefaction, shipping, and regasification to produce, transport, and inject it into pipelines in the importing country.

LNG is transported internationally from producers such as Australia, Qatar, and Malaysia to consumers such as Japan, China, South Korea, and other Asian countries. Due to increased shale gas production since 2005, the US has also become an LNG exporter (https://www.eia.gov/todayinenergy/detail.php?id=36452). US LNG exports have increased from nearly none several years ago to over 120 billion cubic feet per month (over 3 billion cubic feet per day) in 2018. The top countries for US LNG exports in 2018 were South Korea, Mexico, Japan, China, and India.

For countries that import primary energy, any estimate of upstream energy losses and greenhouse gas emissions must account for energy production in the country as well as energy imported into the country. Imported energy must account for energy used to convert natural gas to LNG, separate NGLs into LPG, or produce refined oil products; energy used to transport energy via pipeline or ship; energy used to convert the LNG to natural gas or further refinement of oil products; and the energy used to transport the energy within the country that imported the energy.

J2.6 National Primary Energy and Greenhouse Gas Emissions Comparisons. For the purposes of national programs, national average primary energy and greenhouse gas emissions conversion factors may be appropriate. The consistency provided by use of national average factors sends a strong signal regarding energy efficiency and its impact on primary energy and greenhouse gas emissions. While the amount of energy used by identical buildings would vary by climate, this approach does not reward or penalize a building's primary energy or greenhouse gas emissions performance based on its location.

J2.7 Regional Primary Energy and Greenhouse Gas Emissions Comparisons. National average data provides a simple singular primary energy and greenhouse gas emissions conversion factor. However, a national average can distort the primary energy and greenhouse gas emissions impact of the building's site energy in different regions, especially for electricity. Use of regional values has the potential to reflect more accurately the actual primary energy and greenhouse gas emissions associated with the building's site energy. For example, lighting may result in more primary energy consumption and higher greenhouse gas emissions in a region dominated by coal-based electricity (e.g., the RFCW eGRID sub-region) than in a region that includes more hydroelectric power (e.g., the NWPP eGRID sub-region).

Regional factors for energy forms other than electricity may become available in the future and may be useful for the adopting authority to consider should it have access to such information.

If a choice is made to use regional average factors for comparisons in the U.S., eGRID sub-region level data provides a reasonable level of granularity for primary energy and greenhouse gas emissions calculations for electricity. Power is frequently wheeled within these sub-regions and much less frequently wheeled across sub-regions. EPA uses eGRID sub-regions shown in Figure J2 in its greenhouse gas inventory and tracking emissions calculation methodology. The 2015 International Green Construction Code also uses eGRID sub-regions for primary energy and greenhouse gas emission conversion factors for electricity.

J2.8 Avoided Primary Energy and Greenhouse Gas Emissions Comparisons. Average primary energy and greenhouse gas emissions calculations may be useful for inventory purposes, but they may provide misleading information when deciding what energy efficiency or conservation measures to include in new building designs or to implement in retrofit programs. For instance, according to the eGRID2016 database, the average 2016 generation mix in the RFCE sub-region (serving Pennsylvania and nearby states) was 18% coal, 38% natural gas, and 40% nuclear. Using averages, the impact of a reduction in electricity consumption would seem to be shared by coal, natural gas, and nuclear. However, economic dispatch of electricity by the ISO typically brings on plants through the PJM interconnect in the following order: renewable first, then nuclear, followed by natural gas and coal plants. In this case, the electricity saved would likely be from either a gas or coal plant. Using the economic dispatch model, it is unlikely that either renewable or nuclear plants would be affected by the power reduction associated with an energy efficiency or conservation measure. Avoided generation represents the next generation plant used, built, or avoided with that particular fuel type and heat rate and may be location specific. Avoided generation may be a more suitable basis to determine the impact of energy investment decisions on displaced power generation. Avoided generation has the potential to vary over intervals of less than one hour. Addressing avoided power generation on an annualized basis necessarily requires assumed operating characteristics and fractional periods to determine the overall annualized avoided power generation and its impact on primary energy and greenhouse gas emissions calculations.

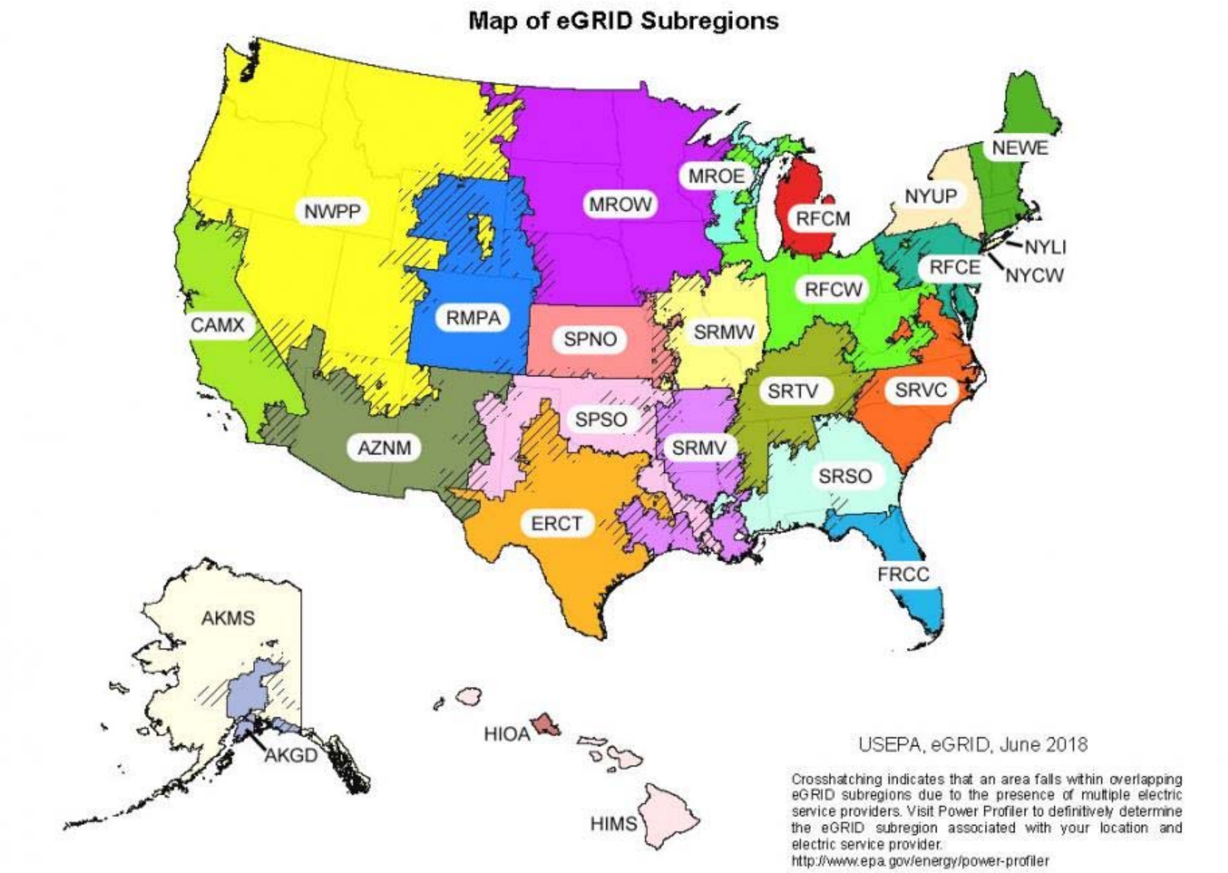

Figure J2 US EPA eGRID sub-region map. (Note: This is a representational map; many of the boundaries shown on this map are approximate because they are based on companies, not on strictly geographical boundaries. EPA's Power Profiler website offers an online calculator that can be used to determine the building's eGRID sub-region based on the local zip code.)

These two calculation methods (average and avoided) energy and greenhouse gas calculations each have advantages and disadvantages.

Historical average generation numbers may tend to overstate fossil fuel use because in most regions, the percentage of generation from fossil fuel sources (particularly coal) is declining, while renewables are rising. This would tend to overstate greenhouse gas emissions compared to actual current consumption.

Avoided generation, based on economic dispatch, will almost never include zero carbon emission sources such as renewables and nuclear because due to policy and economic factors, they are rarely dispatched. This overstates greenhouse gas emissions. Even if all future generation units in a region were planned to be renewable, and 50% of total generation were nuclear and renewable generation, the emissions numbers based on avoided generation would likely be similar to a location with zero percent renewables and nuclear because the zero carbon resources are not dispatched. In both regions, fossil fuel units will generally be the marginal resource.

A public domain avoided electricity generation emissions analysis methodology is available from EPA to quantify the emission reduction due to energy efficiency measures or clean energy policies (https://www.epa.gov/energy/egrid-technical-support-document). EPA's interest in this methodology arose from its understanding that clean energy policies and energy efficiency improvements reduce emissions at the marginal or non-baseload electric generating units. Analysts and EPA staff have noted that non-baseload emission factors may be better for estimating emission reductions rather than average emission factors (Jacobson and High 2010; DeYoung 2012). Average electricity generation emission factors can be used appropriately to determine carbon footprint or GHG inventory. However, average emission rates typically underpredict the emission reduction when used for energy savings through efficiency improvements because these averages include baseload generation such as nuclear or hydro power, which would not be affected by the efficiency improvement (Jacobson 2009).

EPA recognizes several valid and established approaches to quantify emission reductions using the non-baseload electricity mix (DeYoung 2012). Non-baseload CO_2e emission factors are published by the EPA to facilitate the calculation of emissions reduction due to energy efficiency improvements. The use of eGRID sub-region non-baseload emission factors is recommended by the EPA as a simple, low-cost method to estimate emission reduction potential, to explain emission benefits to the general public, or to determine annual emission reductions or regional/national estimates (DeYoung 2011). EPA's non-baseload emission rates and methodology are currently used in several tools, including EPA's Greenhouse Gas Equivalencies Calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator)

EPA's non-baseload emission rate methodology also provides a convenient way to determine the primary energy factor associated with marginal non-baseload power plants for each eGRID sub-region. The emission factors can be correlated with the associated generation mix of oil, natural gas, and coal. Knowing this mix, the aggregate primary energy conversion factor can be calculated based on marginal power plant efficiency levels for each energy form. In the absence of marginal power plant efficiency level information, average power plant efficiency levels can provide an acceptable substitute.

Keith and Biewald developed a methodology implemented by the EPA for calculating marginal (or non-baseload) power plant emission rates based on the capacity factor of each plant. The capacity factor methodology allows the user to determine marginal energy consumption and GHG emissions at any level of desired aggregation using historical or projected power plant values for any time period. It provides a simplified and reasonably accurate methodology compared to marginal dispatch models or hourly generation databases. The EPA implemented this methodology in the eGRID database to list the emissions of "non-baseload" power plants for application in marginal generation scenarios and analyses. Using this approach, all plants with generation capacity factors less than 0.2 are considered non-baseload generation in the eGRID non-baseload generation database, and those with capacity factors greater than 0.8 are considered baseload generation as shown in Figure J3.

A shortcoming of the marginal economic dispatch approach is that zero emission sources are rarely considered marginal, even if they are the majority of the generation, and in some circumstances are the marginal resource. As such, economic dispatch models and simplified approaches such as the Keith-Biewald methodology described below may overstate the impact of fossil fuel generation on the marginal electricity resource mix.

An example of this issue is the impact of high penetration of renewable generation on the grid. While the above dispatch model may be a reasonable model for most conditions, areas with high photovoltaic (PV) penetration have sometimes run into the "duck curve." This occurs during days of high PV generation and low system loads where the hourly marginal generation may drop so low as to be the renewable energy and in the evening rise to be natural gas or other fuel. In these situations, and where hourly information is available, the adopting authority may want to consider an hourly calculation of marginal energy for primary energy and greenhouse gas calculations.

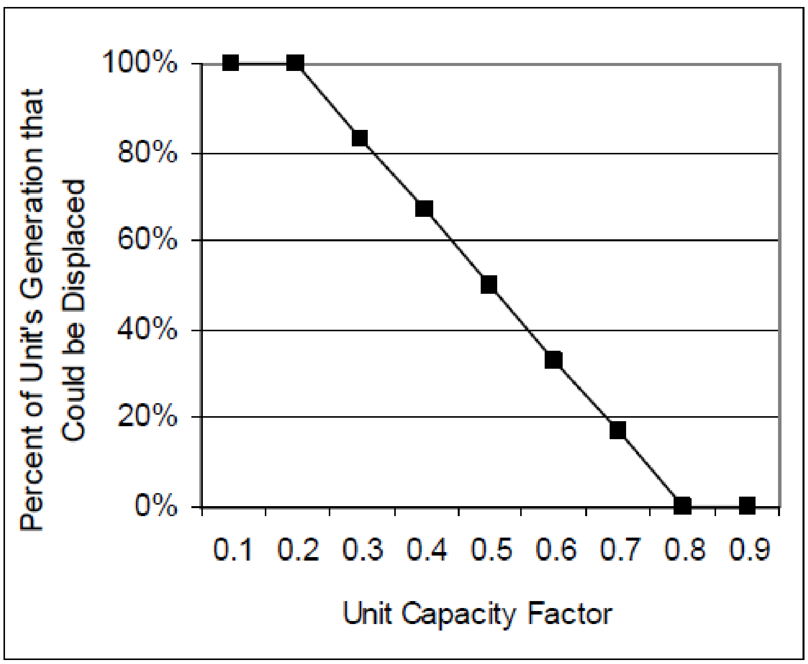

Figure J3 Keith and Biewald Capacity Factor Displacement Methodology
Source: https://www.epa.gov/sites/production/files/2018-07/documents/mbg_2-3_electricitysystembenefits.pdf

J2.9 Other Primary Energy and Greenhouse Gas Emissions Comparisons. Depending on the information required by the adopting authority and the data available, it is possible to consider other comparison formats. An example might be where hourly information is available on electric generation mix that would allow differences in avoided greenhouse gases to be calculated between exported renewable solar energy during the day and imported energy during other hours.

Another example might be the use of projected vs. historical information to derive the factors for comparisons. The electricity grid is undergoing a long-term shift away from coal power generation toward natural gas and renewable power generation. Building energy performance analysis based on historical power generation mix such as the eGRID2016 average mix can provide a potentially misleading result if the shift continues or accelerates. The marginal generation mix methodology avoids this issue for the most part, but still includes some coal power plants as marginal generation in some eGRID sub-regions. It may be instructive to understand the impact of alternative analytical assumptions about the makeup of the electric grid. As shown in Figure J4, the EIA AEO 2018 reference case projection shows a modest decline in total coal and nuclear power generation compared to 2016, with a significant increase in total natural gas and renewable power generation. AEO 2018 also includes several other cases to allow consideration of alternative future scenarios, such as a “Clean Power Plan” scenario.

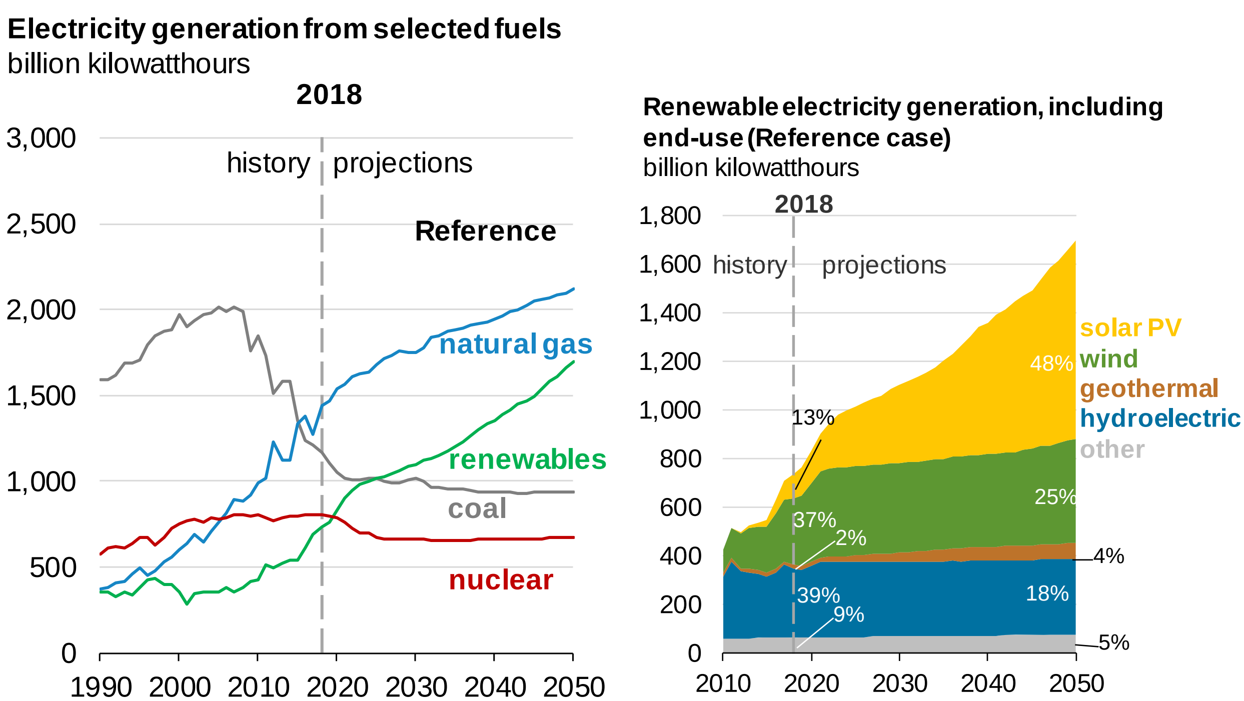

Figure J4 U.S. Power Generation Fuel Mix Trends and Projections through 2050.
Source: EIA Annual Energy Outlook 2019

J2.10 District cooling and Heating. District level cooling and heating provides a unique challenge for national, regional, and marginal conversion calculations. A central chilled-water plant serving the building may use electricity, steam, or fossil fuel as its energy source. If the chiller is powered by electricity, an estimated national conversion factor for district cooling would be approximately 0.23 times the value for electricity if the assumed overall delivered coefficient of performance of the chiller is 4.4. For plants powered by steam or fossil fuel, a more detailed calculation would be required using national average conversion factors for the primary energy source ultimately used to chill the water (e.g., through a combined heat and power plant). Tables in Appendix K include only electric district cooling conversion factors.

Two options for alternative primary energy and emission factors are derived for use in the primary energy and CO_2e emission factor tables in Appendix K that could also be applied to other building energy performance analysis scenarios:

- EIA projection generation mix at current generation efficiencies by fuel type; and
- 85% natural gas at 50% power plant net efficiency coupled with 15% renewable power.

(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—EXAMPLE CONVERSION FACTORS FOR COMPARISONS

K1. INTRODUCTION

The purpose of this appendix is to provide informative examples of conversion factors that may be helpful to adopting authorities for use in comparisons of building energy performance and associated greenhouse gas emissions. The following tables provide examples of factors that may be used in calculating primary energy performance in Normative Appendix C Form 3 and greenhouse gas emissions in Normative Appendix D Form 4.

The conversion factors in Tables K2-A through K3-B for electricity, natural gas, fuel oil, propane, and coal are calculated using the methodology described in Leslie et al. (2010) cited in Appendix L using eGRID2016 data for primary energy and CO_2e greenhouse gas emission factors for electricity as described in Section J.5. The conversion factors for imported steam and hot water assume a net delivered efficiency of 55% for steam and 58% for hot water, with natural gas assumed as the energy form for the district energy plant.

The conversion factors in Tables K4-A and K4-B use the EPA non-baseload emission rate methodology further described in Appendix J Section J.2.8.

K1.1 Example Calculation for Electric Power Generation Primary Energy Factor. The primary energy factor for electric power generation is given by:

$$s_t = \begin{bmatrix} m_1 \\ m_2 \\ \dots \\ m_n \end{bmatrix} \cdot \begin{bmatrix} s_1 \\ s_2 \\ \dots \\ s_n \end{bmatrix} \qquad (1)$$

where, m_i is the fraction of the power generation from each type of fuel and s_i is the primary energy factor of each type of fuel. The subscripts 1 through n for both the generation mix and the primary energy factors specifically represent:

1	Coal
2	Oil
3	Natural Gas
4	Nuclear
5	Hydro
6	Biomass
7	Wind

8 Solar
9 Geothermal
10 Other.

The mix fractions m_i are determined by analysis of the eGRID2016 database. In the case of coal-based generation, the fraction of lignite, bituminous, and sub-bituminous coals used are given by NREL/TP-550-38617.

For example, in the SPSO sub-region, the aggregate average primary energy factor is given by:

$$s_t = \begin{bmatrix} 0.3333 \\ 0.0000 \\ 0.4290 \\ 0.0000 \\ 0.0380 \\ 0.0210 \\ 0.1780 \\ 0.0100 \\ 0.0000 \\ 0.0000 \end{bmatrix} \cdot \begin{bmatrix} 3.52 \\ 4.33 \\ 2.74 \\ 3.38 \\ 1.05 \\ 1.89 \\ 1.05 \\ 1.05 \\ 1.05 \\ 5.15 \end{bmatrix} = 2.61 \qquad (2)$$

The primary energy factors s_i are calculated according to:

$$s_i = \frac{1}{e_1 \cdot e_2 \cdot \ldots \cdot e_n} \qquad (3)$$

where, e_n is the efficiency of each of the processes contributing to power generation. The subscripts 1 through n specifically represent:

1 Extraction
2 Processing
3 Transportation
4 Conversion
5 Distribution.

In the SPSO sub-region for coal-based generation, this yields:

$$s_{coal} = \frac{1}{0.988 \cdot 0.996 \cdot 0.968 \cdot 0.313 \cdot 0.954} = 3.52 \qquad (4)$$

which is the first primary energy value used in Equation 2.

Using this procedure for each type of generation fuel gives the values shown in Table K1 based on the captured energy efficiency methodology.

TABLE K1 Primary Energy Factors for SPSO Sub-region, All Plants

Fuel Type	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	Generation Mix (%)	Primary Energy Factor
Coal	98.8	99.6	96.8	31.3	95.4	28.4	33.3	3.52
Oil	96.3	93.8	98.8	27.1	95.4	23.1	0	4.33
Natural Gas	96.2	97	99.3	41.3	95.4	36.5	42.9	2.74
Nuclear	99	96.2	99.9	32.6	95.4	29.6	0	3.38
Hydro	100	100	100	100	95.4	95.4	3.8	1.05
Biomass	99.4	95	97.5	60.3	95.4	53.0	2.1	1.89
Wind	100	100	100	100	95.4	95.4	17.8	1.05
Solar	100	100	100	100	95.4	95.4	0.1	1.05
Geothermal	100	100	100	100	95.4	95.4	0	1.05
Other	100	100	100	20.3	95.4	19.4	0	5.15
Total	97.9	98.5	98.6	42.5	95.4	38.5	100	2.61

K2 NATIONAL ANNUAL AVERAGE CALCULATIONS

Tables K2-A and K2-B provide aggregated annual average conversion factors for electricity and other energy forms. These national annual average values may be suitable for national program evaluation. Primary energy and greenhouse gas emissions of the building can be converted to consistent units by multiplying the site energy in column 6 of Form 2 by the conversion factors in Tables K2-A and K2-B.

K3 REGIONAL ANNUAL CALCULATIONS

For more granular calculations, eGRID regional based primary energy conversion factors may be used. Tables K3-A and K3-B provide aggregated annual average conversion factors for electricity for each eGRID sub-region. Primary energy and greenhouse gas emissions for imported-minus-exported electricity used by the building can be converted to consistent units by multiplying the imported minus- exported electricity use in column 6 of Form 2 by the conversion factors in Tables K3-A and K3-B based on the eGRID sub-region in which the building is located.

K4 AVOIDED ENERGY CALCULATIONS

Tables K4 A and K4 B provide avoided electricity primary energy and greenhouse gas emissions conversion factors for each eGRID sub-region, including the annualized transmission and distribution losses (EPA 2018). Non-combustible renewable power is not included in the avoided primary energy conversion factors using this approach, so the factors do not change under either the captured energy or infinite energy efficiency approaches.

TABLE K2-A Primary Annual Energy Conversion Factors for National Comparisons

	Energy Form (Form 2)	**Primary Energy Conversion Factor – Captured Energy Efficiency Approach (Form 3)**	**Primary Energy Conversion Factor – Infinite Energy Efficiency Approach (Form 3)**
1.	Imported Electricity	2.79	2.58
2.	Imported Natural gas	1.09	1.09
3.	Imported Steam	1.83	1.83
4.	Imported Hot Water	1.73	1.73
5.	Imported Chilled Water	0.67 (for electric only)	0.62 (for electric only)
6.	Imported Fuel Oil	1.19	1.19
7.	Imported Propane	1.15	1.15
8.	Imported Coal and Other	1.05	1.05
9.	Renewable Thermal – On-Site Production	1.00	1.00
10.	Renewable Electricity – On-Site Production	1.00	1.00
11.	Exported Electricity	2.79	2.58
12.	Exported Steam	1.83	1.83
13.	Exported Hot Water	1.73	1.73
14.	Exported Chilled Water	0.67 (for electric only)	0.62 (for electric only)

TABLE K2-B Greenhouse Gas Emissions Conversion Factors for National Comparisons Using Either a 100 or 20 Year Timeframe

	Energy Form (Form 2)	**Greenhouse Gas Emissions Factor (GWP_{100}) kg/kWh (Form 4)**	**Greenhouse Gas Emissions Factor (GWP_{20}) kg/kWh (Form 4)**
1.	Imported Electricity	0.534	0.597
2.	Imported Natural gas	0.228	0.281
3.	Imported Steam	0.383	0.472
4.	Imported Hot Water	0.362	0.446
5.	Imported Chilled Water	0.128	0.143
6.	Imported Fuel Oil	0.303	0.310
7.	Imported Propane	0.261	0.268
8.	Imported Coal and Other	0.374	0.405
9.	Renewable Thermal – On-Site Production	0.0	0.0
10.	Renewable Electricity – On-Site Production	0.0	0.0
11.	Exported Electricity	0.534	0.597
12.	Exported Steam	0.383	0.472
13.	Exported Hot Water	0.362	0.446
14.	Exported Chilled Water	0.128	0.143

Note: If using I-P calculations, multiply the Appendix K kg/kWh emissions factors by 0.64611 to convert to lb/kBtu.

TABLE K3-A Electricity Primary Energy Conversion Factors for Regional Comparisons

eGRID 2010 Sub-region Acronym	eGRID 2016 Sub-region Name	Primary Energy Conversion Factor – Captured Energy Efficiency Approach (Form 3)	Primary Energy Conversion Factor – Infinite Energy Efficiency Approach (Form 3)
AKGD	ASCC Alaska Grid	2.79	2.59
AKMS	ASCC Miscellaneous	1.93	1.23
ERCT	ERCOT All	2.59	2.43
FRCC	FRCC All	2.85	2.71
HIMS	HICC Miscellaneous	2.81	2.37
HIOA	HICC Oahu	3.48	3.07
MROE	MRO East	3.05	2.85
MROW	MRO West	2.72	2.40
NYLI	NPCC Long Island	3.35	2.84
NEWE	NPCC New England	2.83	2.33
NYCW	NPCC NYC/Westchester	2.93	2.88
NYUP	NPCC Upstate NY	2.27	1.79
RFCE	RFC East	3.04	2.91
RFCM	RFC Michigan	3.02	2.87
RFCW	RFC West	3.11	3.05
SRMW	SERC Midwest	3.16	3.10
SRMV	SERC Mississippi Valley	2.79	2.72
SRSO	SERC South	2.90	2.78
SRTV	SERC Tennessee Valley	3.00	2.92
SRVC	SERC Virginia/Carolina	3.04	2.90
SPNO	SPP North	2.91	2.70
SPSO	SPP South	2.61	2.35
CAMX	WECC California	2.12	1.64
NWPP	WECC Northwest	1.92	1.28
RMPA	WECC Rockies	2.63	2.32
AZNM	WECC Southwest	2.84	2.71

TABLE K3-B Electricity Greenhouse Gas Emissions Factors for Regional Comparisons

eGRID 2016 Sub-region Acronym	eGRID 2016 Sub-region Name	Greenhouse Gas Emissions Factor (GWP_{100}) kg/kWh (Form 4)	Greenhouse Gas Emissions Factor (GWP_{20}) kg/kWh (Form 4)
AKGD	ASCC Alaska Grid	0.599	0.690
AKMS	ASCC Miscellaneous	0.297	0.328
ERCT	ERCOT All	0.549	0.629
FRCC	FRCC All	0.534	0.607
HIMS	HICC Miscellaneous	0.634	0.679
HIOA	HICC Oahu	0.916	0.976
MROE	MRO East	0.876	0.954
MROW	MRO West	0.642	0.706
NYLI	NPCC Long Island	0.671	0.774
NEWE	NPCC New England	0.332	0.377
NYCW	NPCC NYC/Westchester	0.378	0.446
NYUP	NPCC Upstate NY	0.178	0.205
RFCE	RFC East	0.423	0.473
RFCM	RFC Michigan	0.663	0.730
RFCW	RFC West	0.647	0.702
SRMW	SERC Midwest	0.831	0.901
SRMV	SERC Mississippi Valley	0.471	0.544
SRSO	SERC South	0.585	0.654
SRTV	SERC Tennessee Valley	0.614	0.669
SRVC	SERC Virginia/Carolina	0.435	0.480
SPNO	SPP North	0.725	0.792
SPSO	SPP South	0.640	0.722
CAMX	WECC California	0.293	0.342
NWPP	WECC Northwest	0.338	0.371
RMPA	WECC Rockies	0.699	0.769
AZNM	WECC Southwest	0.556	0.620

Note: If using I-P calculations, multiply the Appendix K kg/kWh emissions factors by 0.64611 to convert to lb/kBtu.

TABLE K4-A Electricity Primary Energy Conversion Factors for Avoided Primary Energy Comparisons

eGRID 2016 Sub-region Acronym	eGRID 2016 Sub-region Name	Non-Baseload Primary Energy Conversion Factor (Form 3)
AKGD	ASCC Alaska Grid	3.45
AKMS	ASCC Miscellaneous	3.50
ERCT	ERCOT All	2.83
FRCC	FRCC All	2.80
HIMS	HICC Miscellaneous	4.10
HIOA	HICC Oahu	3.69
MROE	MRO East	3.11
MROW	MRO West	3.25
NYLI	NPCC Long Island	3.64
NEWE	NPCC New England	2.82
NYCW	NPCC NYC/Westchester	2.99
NYUP	NPCC Upstate NY	2.75
RFCE	RFC East	3.10
RFCM	RFC Michigan	3.34
RFCW	RFC West	3.27
SRMW	SERC Midwest	3.20
SRMV	SERC Mississippi Valley	2.73
SRSO	SERC South	2.93
SRTV	SERC Tennessee Valley	3.15
SRVC	SERC Virginia/Carolina	2.92
SPNO	SPP North	3.49
SPSO	SPP South	3.32
CAMX	WECC California	2.68
NWPP	WECC Northwest	3.04
RMPA	WECC Rockies	3.21
AZNM	WECC Southwest	2.93

TABLE K4-B Electricity Greenhouse Gas Emissions Factors for Avoided Greenhouse Gas Emissions Comparisons

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	Greenhouse Gas Emissions Factor (GWP_{100}) kg/kWh (Form 4)	Greenhouse Gas Emissions Factor (GWP_{20}) kg/kWh (Form 4)
AKGD	ASCC Alaska Grid	0.745	0.871
AKMS	ASCC Miscellaneous	0.892	0.970
ERCT	ERCOT All	0.737	0.843
FRCC	FRCC All	0.658	0.749
HIMS	HICC Miscellaneous	1.076	1.140
HIOA	HICC Oahu	0.887	0.935
MROE	MRO East	0.839	0.933
MROW	MRO West	0.956	1.059
NYLI	NPCC Long Island	0.761	0.896
NEWE	NPCC New England	0.604	0.688
NYCW	NPCC NYC/Westchester	0.613	0.729
NYUP	NPCC Upstate NY	0.597	0.690
RFCE	RFC East	0.768	0.860
RFCM	RFC Michigan	0.951	1.046
RFCW	RFC West	0.970	1.055
SRMW	SERC Midwest	0.987	1.076
SRMV	SERC Mississippi Valley	0.634	0.733
SRSO	SERC South	0.756	0.848
SRTV	SERC Tennessee Valley	0.906	0.988
SRVC	SERC Virginia/Carolina	0.753	0.835
SPNO	SPP North	1.062	1.167
SPSO	SPP South	0.875	0.991
CAMX	WECC California	0.560	0.656
NWPP	WECC Northwest	0.816	0.904
RMPA	WECC Rockies	0.910	1.010
AZNM	WECC Southwest	0.764	0.860

Note: If using I-P calculations, multiply the Appendix K kg/kWh emissions factors by 0.64611 to convert to lb/kBtu.

K5 PROJECTED GENERATION MIX ENERGY CALCULATIONS

Table K5 lists the 2016 and the projected generation mix for coal, natural gas, nuclear, and renewable sources generation mix for the EIA AEO 2018 reference case and the clean power plan case, along with the resulting primary energy and CO_2e emission factors for each scenario. Table values assume a captured energy efficiency approach and a GWP_{100} factor.

Table K5 Primary Energy Factors – AEO 2018 Projections Through 2050

Year	**AEO 2018 Reference Case**					
	Generation Mix (%)				**Primary Energy Factor**	
	Coal	**Natural Gas**	**Nuclear**	**Renewable Sources**	**Primary Energy (Captured Energy Efficiency)**	**Greenhouse Gas Emissions GWP_{100} (kg/kWh)**
2016	30.8	33.4	20.2	15.4	2.79	0.534
2020	30.4	28.9	20.0	21.0	2.68	0.502
2030	29.0	30.9	17.3	23.1	2.62	0.495
2040	26.7	31.7	15.6	26.2	2.53	0.473
2050	25.1	33.3	14.0	26.0	2.48	0.463
	AEO 2018 Clean Power Plan Scenario					
2020	30.4	28.9	20.0	21.1	2.68	0.502
2030	23.9	33.5	18.0	24.8	2.55	0.452
2040	22.0	33.7	16.3	28.1	2.47	0.431
2050	19.8	36.0	14.7	27.9	2.41	0.419

K6 NATURAL GAS COMBINED CYCLE + RENEWABLE POWER GENERATION ENERGY CALCULATIONS

The AEO 2018 projection includes a substantial fraction of coal power generation, even in the clean power plan case. As shown in Table K5, the 2016 natural gas generation fraction already exceeds the 2050 AEO reference case projection. Future non-baseload (marginal) power plants may be predominantly natural gas or renewable (wind or solar). To examine the impact of a scenario in which combinations of natural gas and renewable power generation on marginal or future primary energy and CO_2e emission factors, a state-of-the-art combined cycle power plant at a net generation annual efficiency of 50% is paired with different fractions of renewable power using the captured energy efficiency approach (100% generation efficiency) and GWP_{100} emission factors. Table K6 shows the assumed generation mix and resulting primary energy and CO_2e emission factors for each scenario.

Table K6 Natural Gas/Renewable Power Generation Primary Energy Factors

Generation Mix (%)		Primary Energy Factor	
Natural Gas Combined Cycle	**Non-Combustible Renewable Sources**	**Primary Energy (Captured Energy Efficiency) (Form 3)**	**Greenhouse Gas Emissions GWP_{100} (kg/kWh) (Form 4)**
100	0	2.26	0.466
85	15	2.08	0.396
70	30	1.90	0.327
55	45	1.71	0.257
40	60	1.53	0.186
25	75	1.35	0.117
10	90	1.17	0.046
0	100	1.05	0.000

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