BSR/ASHRAE Standard 228P

Public Review Draft

Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance

Third Public Review Draft (August 2022)
Showing Proposed Independent Substantive Changes to Previous Public Review Draft)

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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FOREWORD

ASHRAE Standard 228P can be used to determine whether a site has achieved "Zero Net Energy" or "Zero Net Carbon" on an operational basis, meaning that the source energy or carbon flows coming into a site are less than or equal to those flowing outward during building/site operation and any allowed offsets. The calculations are based on a source energy/captured energy efficiency approach and allowances are made for some off-site credit.

This Third Independent Substantive Change Public Review shows substantive changes in the Normative and Informative portions of the standard approved by the committee for publication/public review. These changes were made in response to input received from the First and Second Public Reviews with some additional modifications proposed by committee members after receiving that public input.

This is a review of Independent Substantive Changes to normative text made since the last public review. Some informative materials have also been significantly modified and are available for comment. Text that was removed from the earlier Public Review Draft is provided for reference but is shown in ~~strikeout~~. Text that has been added is shown <u>underlined</u>.

Only these changes are open to comment at this time. All other material is provided for context only and is not open for Public Review comment except as it relates to the proposed changes.

4. ADMINISTRATION, ENFORCEMENT, AND COMPLIANCE

4.2.5 Zero Net Energy and Zero Net Carbon Portfolio and Community

4.2.5.1 The zero net energy credit, E_{net}, of individual sites making up a zero net energy portfolio or community shall be totaled and the sum shall be less than or equal to zero <u>and shall be reported on Appendix A Form 7</u>.

4.2.5.2 The net greenhouse gas emission, GHG_{net}, of individual sites making up a zero net carbon portfolio or community shall be totaled and the sum shall be less than or equal to zero<u> and shall be reported on Appendix A Form 8</u>.

6. SOURCE ENERGY PERFORMANCE

TABLE 1 Annual Source Energy Conversion Factors for United States and Canada

Form 2 Row	**Energy Form (Footnote 3)**	**Source Energy Conversion Factor (Footnote 1)**
6.a	Imported Fuel Oil	1.19
6.b	Imported Renewable Fuel Oil	Footnote 2
7.a	Imported Propane	1.15
<u>7.b</u>	<u>Imported Renewable Propane</u>	<u>Footnote 2</u>

Footnote 1: For locations outside the United States or Canada, the adopting authority shall fill in Table 1 with source energy conversion factors.

Footnote 2: A qualified person shall provide the source energy conversion factor.

TABLE 4 Hourly Electric Generation Mix and Source Energy Conversion Factors

Generation Type	Hourly Generation Mix (fraction of whole)	Source Energy Conversion Factor
Biomass	Footnote 1	~~1.37~~ Footnote 2

Footnote 1: The qualified person shall provide hourly generation mix and total source energy conversion factor.

Footnote 2: The Authority Having Jurisdiction shall approve the source energy conversion factor for each source of biomass.

Informative Note: ASHRAE Standard 105-2021 Informative Appendix J provides guidance on source energy conversion factors for biomass.

7. Greenhouse Gas Emissions Performance

7.2 Greenhouse Gas Emission Factors. GHG shall be calculated using a consistent time horizon by a qualified person in accordance with Section 7.3 and either Section 7.2.1 or Section 7.2.2.

TABLE 5 Annual Greenhouse Gas Emission Factors for the United States and Canada

Form 2 Row	Energy Form (Footnote 3)	Greenhouse Gas Emission Factor (kg CO_2e/kWh) (Footnote 1)
6.a	Imported Fuel Oil	0.303
6.b	Imported Renewable Fuel Oil	Footnote 2
7.a	Imported Propane	0.261
7.b	Imported Renewable Propane	Footnote 2

Footnote 1: For locations outside the United States or Canada, the adopting authority shall fill in Table 5 with greenhouse gas emission factors.

Footnote 2: A qualified person shall provide the greenhouse gas emission factor.

TABLE 8 Hourly Generation Mix and Greenhouse Gas Emission Factors

Generation Type	Generation Mix (%)	Greenhouse Gas Emission Factor (kg CO_2e/kWh)
Biomass	Footnote 1	~~0.059~~ Footnote 2
~~Non-replenished Biomass~~	~~Footnote 1~~	~~1.436~~

Footnote 1: The qualified person shall provide hourly generation mix and total greenhouse gas emission factor.

<u>Footnote 2: The Authority Having Jurisdiction shall approve the Greenhouse Gas Emission Factor for each source of biomass.</u>

<u>**Informative Note**: ASHRAE Standard 105-2021 Informative Appendix J provides guidance on greenhouse gas emission factors for biomass.</u>

TABLE 10 Refrigerant <u>Global Warming Potential</u> ~~Greenhouse Gas Emission Factor~~

Refrigerant Type	~~Greenhouse Gas Emission Factor~~ <u>Global Warming Potential</u> (kg CO_2e/kg refrigerant)
HCFC-22	1760
HCFC-123	79

7.4 Annual Site Calculation. Net GHG shall be calculated using greenhouse gas emissions calculated from imported energy plus refrigerant leakage minus exported energy and any qualified off-site renewable energy and carbon offset procurement, in accordance with and discounted as determined in Section 8. The total shall be the net for annual GHG in accordance with Equation 2.

$$GHG_{net} = [\Sigma (E_{imp} \cdot GEF_{imp}) + \Sigma (REF_{leak} \cdot GEF_{ref})] - [\Sigma (E_{exp} \cdot GEF_{exp}) + (E_{rec} \cdot GEF_{rec} \cdot DF_{rec}) + \text{~~}PCO\text{~~}\underline{CCO}] \quad (2)$$

Where

GHG_{net} = net greenhouse gas emissions of the site

E_{imp} = imported energy by energy form crossing the site boundary

GEF_{imp} = greenhouse gas emission factor by energy form for imported energy crossing the site boundary

REF_{leak} = refrigerant mass leakage across the site boundary for each type of refrigerant

GEF_{ref} = greenhouse gas emission factor for each type of refrigerant

E_{exp} = exported energy by energy form crossing the site boundary

GEF_{exp} = greenhouse gas emission factor by energy form for exported energy crossing the site boundary

E_{rec} = qualified off-site renewable energy.

GEF_{rec} = greenhouse gas emission factor by energy form for qualified off-site renewable energy

DF_{rec} = discount factor for off-site renewable energy in accordance with Section 8

~~*PCO*~~*CCO* = ~~procured~~ <u>credited</u> carbon offset ~~credit~~ in accordance with Section 8

8 QUALIFICATIONS FOR OFF-SITE RENEWABLE ENERGY AND CARBON OFFSET PROCUREMENT

8.6 Carbon Offsets Procurement. Projects shall be credited for procured carbon offsets provided the carbon offsets ~~are certified and retired~~ <u>consist of carbon sequestered within 12 calendar months of the emissions the project is offsetting</u>. A qualified person shall document <u>offset permanence, additionality, transparency,</u> an exclusive chain of custody, ~~and~~ <u>sole</u> ownership of the procured carbon offsets, their certification, ~~and~~ their retirement<u>, and verification that environmental justice and social equity considerations exist to prevent transfer of burdens to communities not connected to the building project</u>.

8.7 <u>Credited</u> Carbon Offsets ~~Procurement~~ Limit <u>and Procurement</u>. Annual ~~procured~~ <u>credited</u> carbon offsets~~, after applying a discount factor of 0.20 to procured carbon offsets,~~ shall be less than or equal to the greenhouse gas emissions calculated from refrigerant leakage, plus 20% of the greenhouse gas emissions calculated from imported energy in accordance with Equation 3. <u>A minimum of 5 units of carbon offsets shall be procured for each unit of credited carbon offsets</u>.

$$\cancel{PCO}\ \underline{CCO} <= \Sigma\,(REF_{leak} \cdot GEF_{ref}) + [0.20 \cdot \Sigma\,(E_{imp} \cdot GEF_{imp})] \qquad (3)$$

Where
~~*PCO* = procured carbon offset~~
<u>*CCO* = credited carbon offset</u>
E_{imp} = imported energy by energy form crossing the site boundary
GEF_{imp} = greenhouse gas emission factor by energy form for imported energy crossing the site boundary
REF_{leak} = refrigerant mass leakage across the site boundary for each type of refrigerant
GEF_{ref} = greenhouse gas emission factor for each type of refrigerant

8.8 Carbon Offset~~s~~ Procurement ~~Certification~~ <u>Registration Protocol</u> and Retirement. Procured carbon offsets ~~certification and~~ retirement shall be documented in accordance with one of the carbon offset~~s~~ ~~certification standards~~ <u>registration protocols</u> listed here.
Verified Carbon Standard;
Climate Action Reserve;
Gold Standard; or
American Carbon Registry.

8.9 Carbon Offset Project Restrictions. Carbon offset projects shall be limited to ~~forest carbon offset projects (afforestation or reforestation, avoided conversion, and improved forest management), landfill gas offset projects and agricultural manure management offset projects~~ <u>technologies and strategies that permanently sequester carbon for a minimum of 200 years that are assessed to have a de minimis risk of release of sequestered emissions.</u>

(This appendix is part of this standard. It contains requirements necessary for conformance to the standard.)

NORMATIVE Appendix A –Compliance Forms

FORM 2—ANNUAL SITE ENERGY CONVERSION CALCULATION

Energy Form[2, 4]	Energy Use Numerical Value	Units	Conversion Factor[1] to kWh	Annual Site Energy kWh/yr
6a. Imported Grid Fuel Oil				
6b. Imported Renewable Fuel Oil				
7a. Imported Grid Propane				
7b. Imported Renewable Propane				

FORM 3—ANNUAL NET SOURCE ENERGY CALCULATION

Energy Form[5]	Annual Site Energy (Form 2 Column 5) kWh/yr	Source Energy Conversion Factor[1]	Annual Source Energy kWh/yr
6a. Imported Grid Fuel Oil			
6b. Imported Renewable Fuel Oil			
7a. Imported Grid Propane			
7b. Imported Renewable Propane			

FORM 4—ANNUAL NET GREENHOUSE GAS EMISSIONS CALCULATION

Energy Form[5]	Annual Site Energy (Form 2 Column 5) kWh/yr	Greenhouse Gas Emission Factor[1] kg CO_2e/kWh	Annual Greenhouse Gas Emissions kgCO_2e/yr
6a. Imported Grid Fuel Oil			
6b. Imported Renewable Fuel Oil			
7a. Imported Grid Propane			
7b. Imported Renewable Propane			

FORM 4A —Refrigerant Loss Calculation

Equipment Identification	Equipment Type, See Table 9	Refrigerant Leakage Rate, See Table 9	Refrigerant Charge kg	Annual Refrigerant Loss[1] kg	Refrigerant Type	~~Greenhouse Gas Emission Factor~~ Global Warming Potential, See Table 10 Kg CO_2e/kg refrigerant	Annual Greenhouse Gas Emissions per Year Loss x ~~Factor~~ GWP Kg CO_2e/yr
						Sum, to Form 4:	

1 For Existing Buildings, Annual Refrigerant Loss shall be either actual annualized loss based on service records for the equipment or the Table 9 Leakage Rate times Refrigerant Charge.

FORM 5 — QUALIFIED OFF-SITE RENEWABLE ENERGY PROCUREMENT CALCULATION

Off-Site Renewable Energy Calculation	A. Annual Off-Site Renewable Energy[1] kWh/yr	B. Discount Factor[2]	C. Source Energy Conversion Factor[3]	D. Greenhouse Gas Emission Factor[4] kg CO_2e/kWh	E. Annual Renewable Source Energy Procurement AxBxC kWh/yr	F. Annual Greenhouse Gas Emissions Procurement AxBxD kg CO_2e/yr
1. Electricity						
2. Natural Gas						
3. Fuel Oil						
4. Propane						
5. Biomass						

5. Sum of Column F Rows 1 to 4
6. Max Annual Off-Site Permitted (from Form 5A and 5B)
The Smaller of Line 5 or 6 (to Form 3 Row 20)
Sum of Column F Rows 1 to 4 (to Form 4, Row 20)

Footnotes:

1. See Section 8 for required qualifications.
2. See Table 15.
3. See Table 1.
4. See Table 5.

FORM 6 —PROCURED CARBON OFFSET CREDIT CALCULATION

Carbon Offset Project Identifier	~~Certification Standard~~ Registration Protocol	Annual ~~Greenhouse Gas Emissions Credit Procurement~~ Credited Carbon Offsets (CCO) (kg/yr)	~~Discounted PCO~~ Minimum Annual Procured Carbon Offsets (5 x CCO) (kg/yr)
		n/a	
		n/a	
		n/a	
		n/a	
		n/a	

	Credited Carbon Offsets from equation 3 (column 3) or, sum of Annual Procured Carbon Offsets (column 4)	~~**Sum of Projects Discounted PCO**~~	
	Is the Sum of Procured Carbon Offsets >= 5 x Credited Carbon Offsets (yes/no)		

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INFORMATIVE APPENDIX C– EMBODIED ENERGY AND CARBON CALCULATIONS

~~Aluminum has been described as "Congealed Electricity." Beyond the operational energy used in a building or on a site, there is energy used and carbon generated in the creation of materials used in the building and the construction of the building itself.~~

~~ASHRAE 228 Zero Net Energy and Zero Net Carbon Guidelines for Buildings are applied to reduce operational energy use. The World Council on Sustainable Business Practices found that embodied energy of manufacturing, transport, and construction accounted for 12% and Maintenance and renovation, 4% of the energy footprint of a Building (The World Council on Sustainable Business Practices, 2007). As operational energy reaches net-zero usage, the non-operational embodied energy becomes a higher percentage of the non-renewable energy footprint of the facility up to 100%. Addressing embodied energy is the next step in energy conservation of facilities. This analysis is similar but not identical to a net-zero carbon analysis.~~

[Graphic Deleted]

~~Embodied energy is defined as the total amount of non-renewable primary energy required for all direct and indirect processes related to the creation of the building, its maintenance, and end-of-life. In this sense, the forms of embodied energy consumption include the energy consumption for the initial stages, the recurrent processes, and the end of life processes of the building. (Institute for Building Environment and Energy Conservation, 2016).~~

~~It is usually expressed in megajoules (MJ) per reference unit per year of the RSP. (Institute for Building Environment and Energy Conservation, 2016) (RSP – Reference Study Period).~~

[Graphic deleted]

~~There are multiple definitions and boundaries of embodied energy. Some definitions only account for cradle (raw material extraction) to gate (produced material) while others take a cradle to grave (end of life disposal) approach. Each stage within the building process uses energy and creates carbon emissions. Standard EN15978:2011 illustrates the lifecycle stages that can be incorporated into the calculations of a building's total impact. Each aspect of the process incorporates energy. Therefore, when possible, a cradle to grave analysis should be pursued as shown in the above definitions to account for life cycle energy usage.~~

~~The analysis usually initiates between an owner, architect, and structural engineer at the commencement of the design initiative. The layout and structural members make up the bulk of the embodied energy framework of a facility. Once a layout is decided upon, a reference "baseline" is modeled to determine how much non-renewable energy a general code compliant structure would require. This "baseline" must be of the same dimensions and usage type as the reduced energy final design. Iterative material analyses are then completed until a maximum reduction that benefits the facility, maintains the operational net zero, and is within the client's budget is found. The same steps may be used throughout the entire process until the completion of building construction. These iterations lead to a reduction of embodied energy.~~

[Graphic deleted]

~~The analyzing process includes employing third party verified datasets of environmental product declarations (EPD's) for each material or assembly used and applying their usage factors to each corresponding component usually within BIM software or applying it by a calculated area of each material. EPD's currently exist for many regions and are provided by manufacturers. ISO 14025 has been instituted Page: 42 to assist in regulating these declarations as ambiguity has persisted within reporting metrics such as how to incorporate travel distance to different construction sites from one manufacturing facility which may be beyond the manufacturer's control.~~

~~Due to its complexities, different software packages and add-ons have been developed, such as Athena Impact Estimator, GaBi, and SimaPro, for the process of life cycle analysis to determine the embodied energy of a structure. A life cycle analysis shall be performed in accordance with ASTM E2921 and ISO Standard 14044.~~

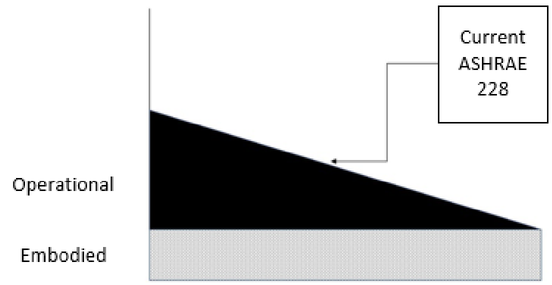
~~Additional information may be found through International Energy Agency Energy in Building and Communities Programme Annex 57 released in 2016, the AIA Guide to Building Life Cycle Assessment in Practice released in 2010, Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method, EN 15978:2011 and LEED v.4. These documents explain useable data sets, specific software, benefits, short-comings, and processes to complete an embodied energy assessment.~~

[Graphic deleted]

~~Achieving net-zero embodied energy as well as operational energy requires that the facility utilize renewable energy to such an extent that it offsets both embodied and operational energy. Embodied energy can also be reduced or zeroed out by selecting suppliers that have reduced or zeroed out their own energy and emissions impacts. Operational energy may be reviewed as required within ASHARE 228 on yearly terms. Achieving net-zero embodied energy may be recovered over a referenced study period of 20-50 years (75 years in ASHRAE 189.1) (adjustable to local code requirement thresholds). In short, nonrenewable energy related to all operational energy plus all embodied energy shall be compensated for with renewable energy generation. This moves the facility from a zero net operational and reduced embodied energy identification to a zero net operational and embodied energy classification. A life cycle analysis shall be performed in accordance with ASTM E2921 and ISO Standard 14044.~~

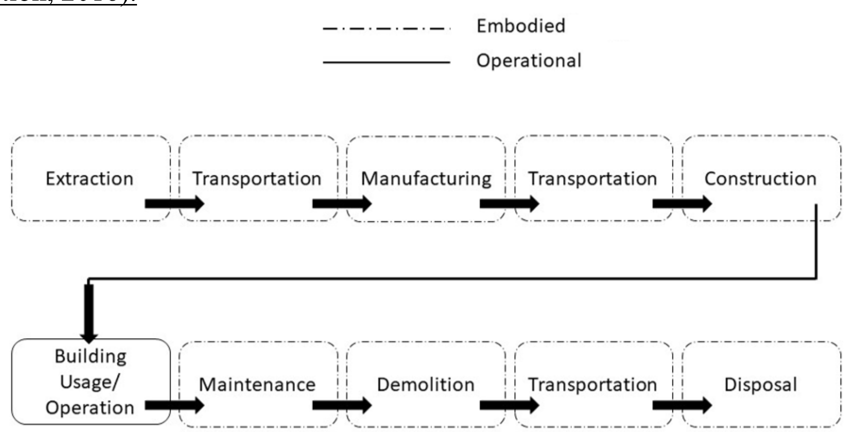
~~If an embodied energy analysis is completed as part of the scope of a project, it is recommended to include a record of the results as a procedural practice. This record may be required to justify achievement of a net-zero facility in the future or to fulfill specific conservation requirements.~~

ASHRAE standards can be applied to reduce operational energy and carbon use. Beyond the operational energy used in a building or on a site, there is energy used and carbon generated in the creation of materials used in the building and the construction of the building itself. The World Business Council for Sustainable Development found that embodied energy of manufacturing, transport, and construction accounted for 12% and maintenance and renovation, 4% of the energy footprint of a Building (World Business Council for Sustainable Development, 2007). As operational energy reaches zero net usage, the non-operational embodied energy becomes a higher percentage of the non-renewable energy footprint of the facility up to 100%. Addressing embodied energy is the next step in energy conservation of facilities. This analysis is similar but not identical to a zero net carbon analysis.



Embodied attributes become a larger portion of the building emissions as operational energy and carbon are reduced

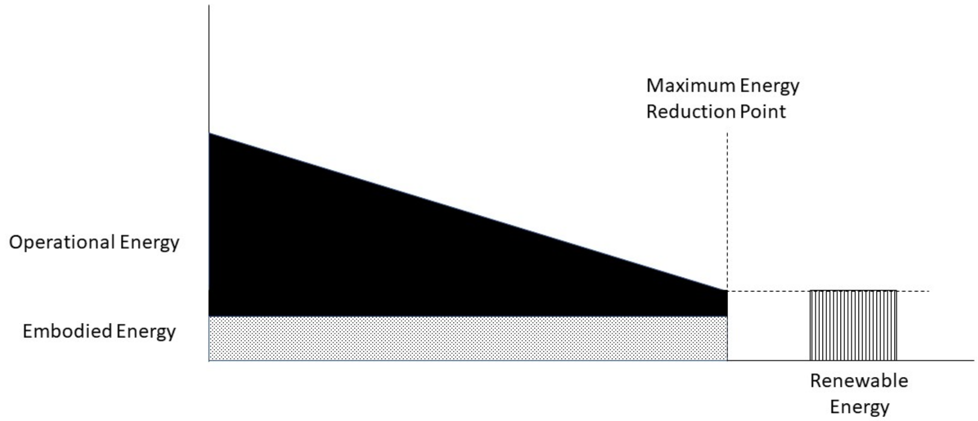
Embodied energy is defined as the total amount of non-renewable primary energy required for all direct and indirect processes related to the creation of the building, its maintenance, and end-of-life. In this sense, the forms of embodied energy consumption include the energy consumption for the initial stages, the recurrent processes, and the end-of-life processes of the building. (Institute for Building Environment and Energy Conservation, 2016).



Traditional Building Life Cycle

It is usually expressed in *megajoules (MJ) per reference unit per year of the RSP.* (Institute for Building Environment and Energy Conservation, 2016) *(RSP – Reference Study Period).*

There are multiple definitions and boundaries of embodied energy. Some definitions only account for cradle (raw material extraction) to gate (produced material) while others take a cradle to grave (end-of-life disposal) approach. Each stage within the building process uses energy and creates carbon emissions. Standard EN15978:2011 illustrates the lifecycle stages that can be incorporated into the calculations of a building's total impact. This has been commonly broken into segments A, B, C, and D. The "A" stage identifies raw materials through construction, "B" the use, remodel, and repair stage, "C" the end-of-life stage. Stage "D" usually encompasses items not specifically addressed under the other stages and can be seen as "benefits beyond the system boundary." Therefore, when possible, a cradle to grave analysis should be pursued as shown in the above definitions to account for life cycle energy usage.



Renewable Energy offsets remaining
Embodied and Operational Energy after efficiencies have been maximized

Achieving Zero Net Energy – Operational and Embodied

As this industry matures, it has become apparent that not just energy should be considered, but also the embodied carbon of a facility. Embodied carbon is defined as carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure (World Green Building Council, 2019). It is usually expressed as CO_2e/GWP.

The analysis usually initiates between an owner, architect, and structural engineer at the commencement of the design initiative. The layout and structural members make up the bulk of the embodied framework of a facility. Once a layout is decided upon, a reference "baseline" is modeled to determine how much non-renewable energy as well as associated carbon emissions a general code compliant structure would require. This "baseline" must be of the same dimensions and usage type as the reduced energy and carbon final design. Iterative material analyses are then completed until a maximum reduction that benefits the facility, maintains the operational zero net, and is within the client's budget is found. The same steps may be used throughout the entire process until the completion of building construction. These iterations lead to a reduction of embodied energy and carbon.

The analyzing process includes employing third party verified datasets of environmental product declarations (EPDs) for each material or assembly used and applying their usage factors to each corresponding component usually within BIM software and confirmed by a design professional. EPDs currently exist for many regions and are provided by manufacturers. ISO 14025 and ISO 21930 have been instituted to assist in regulating these declarations as ambiguity has persisted within reporting metrics such as how to incorporate travel distance to different construction sites from one manufacturing facility which may be beyond the manufacturer's control. EPDs provide both energy information to evaluate zero net energy and CO_2e/GWP information to evaluate zero net carbon.

Due to the complexity of developing a life cycle assessment (LCA) from EPDs, different software packages and add-ons have been developed for the process of life cycle analysis to determine the embodied energy and embodied carbon of a structure. A life cycle analysis should be performed in accordance with ASTM E2921 and ISO Standard 14044.

Additional information may be found through *International Energy Agency Energy in Building and Communities Programme Annex 57* released in 2016, the *AIA Guide to Building Life Cycle Assessment in Practice* released in 2010, *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method, EN 15978:2011* and *LEED v.4*. These documents explain useable data sets, specific software, benefits, short-comings, and processes to complete an embodied assessment.

Achieving zero net embodied as well as operational energy and carbon requires that the facility utilize renewable energy to such an extent that it offsets both embodied and operational energy. Embodied attributes can also be reduced or zeroed out by selecting material and product suppliers that have reduced or zeroed out their own energy and emissions impacts during extraction and production. Operational energy and carbon may be reviewed as specified within ASHRAE Standard 228-202x on yearly terms. Achieving net-zero embodied energy and carbon may be recovered over a referenced study period of 20-50 years (75 years in ASHRAE 189.1) (adjustable to local code requirement thresholds). In short, non-renewable energy related to all operational energy plus all embodied energy should be balanced against renewable energy generation. Embodied carbon can also be balanced against carbon sequestered within long-lived building materials. This moves the facility from a *zero net operational and reduced embodied energy* identification to a *zero net operational and embodied energy* classification.

If an embodied energy and carbon analysis is completed as part of the scope of a project, it is recommended to include a record of the results as a procedural practice. This record may be required to justify achievement of a zero net facility in the future or to fulfill specific conservation requirements.

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INFORMATIVE APPENDIX E– GREENHOUSE GAS EMISSION FACTORS FOR THE UNITED STATES USING 20 YEAR GWP TIME HORIZON

Various greenhouse gases (GHGs) have the potential for significantly different global warming impacts depending on the amount of emissions and the warming contribution of each molecule of the gas. A combined emission metric aggregates the impact of these gases and can be used in calculating overall GHG emissions. Global warming potential (GWP) is an index for estimating the relative global warming contribution of atmospheric emissions of a particular greenhouse gas compared to emissions of an equal mass of carbon dioxide (CO_2).

Carbon dioxide equivalent (CO_2e) emissions of each greenhouse gas are its mass emissions multiplied by its time-integrated GWP. Choice of time horizon has a strong effect on GWP values and thus on the calculated CO_2e emissions of each GHG. Two GWP time-horizons are commonly used: 100 years and 20 years (GWP_{100} and GWP_{20}). Tables in this standard are based on GWP_{100} values. While GWP_{100} is more common, GWP_{20} has been adopted for specific applications and by certain jurisdictions. The following tables provide GHG emission factors for the United States using a 20-year GWP time horizon.

Annual GHG Emission Factors for the United States (20-Year GWP Time Horizon)

Form 2 Row	Energy Form	Greenhouse Gas Emission Factor GWP_{20} (kg CO_2e/kWh)
1.a	Imported Grid Electricity	Table 6 or Table 7
1.b	Imported Specific Electricity	Footnotes 2 and 3
2.a	Imported Grid Natural Gas	0.281
2.b	Imported Renewable Natural Gas	Footnote 2
3.	Imported Steam	0.472 or Footnote 2
4.	Imported Hot Water	0.446 or Footnote 2
5.	Imported Chilled Water	0.143 or Footnote 2
6.a	Imported Fuel Oil	0.310
6.b	Imported Renewable Fuel Oil	Footnote 2
7.a	Imported Propane	0.268
7.b	Imported Renewable Propane	Footnote 2
8.	Imported Coal or Other	0.405 or Footnote 2
9.	Imported Biomass	Footnote 2
10.	On-Site Non-Renewable Energy	Footnote 2
11.a	Imported Transportation Vehicle Energy	Footnote 2
11.b	Imported Landscaping Energy	Footnote 2
12.	Exported Non-Renewable Electricity	Footnote 2
13.	Exported Renewable Electricity	Table 6 or Table 7
14.	Exported Steam	0.472 or Footnote 2
15.	Exported Hot Water	0.446 or Footnote 2
16.	Exported Chilled Water	0.143 or Footnote 2
17.	Exported other	0.405 or Footnote 2
18.	Exported Transportation Vehicle Energy	Footnote 2

Footnote 2: A qualified person provides the greenhouse gas emission factor.

Footnote 3: Grid energy forms are from the electric grid or fuel utility or distribution system. Specific renewable energy forms are from a specific provider meeting the requirements of the adopting authority.

Regional Electricity GHG Emission Factors for United States (20-Year GWP Time Horizon)

eGRID 2018 Sub-region Acronym	eGRID 2018 Sub-region Name	Greenhouse Gas Emission Factor GWP_{20} (kg CO_2e/kWh)
AKGD	ASCC Alaska Grid	0.662
AKMS	ASCC Miscellaneous	0.328
ERCT	ERCOT All	0.581
FRCC	FRCC All	0.574
HIMS	HICC Miscellaneous	0.719
HIOA	HICC Oahu	0.981
MROE	MRO East	0.953
MROW	MRO West	0.708
NYLI	NPCC Long Island	0.784
NEWE	NPCC New England	0.363
NYCW	NPCC NYC/Westchester	0.422
NYUP	NPCC Upstate NY	0.183
RFCE	RFC East	0.450
RFCM	RFC Michigan	0.752
RFCW	RFC West	0.665
SRMW	SERC Midwest	0.896
SRMV	SERC Mississippi Valley	0.555
SRSO	SERC South	0.625
SRTV	SERC Tennessee Valley	0.596
SRVC	SERC Virginia/Carolina	0.456
SPNO	SPP North	0.658
SPSO	SPP South	0.699
CAMX	WECC California	0.323
NWPP	WECC Northwest	0.367
RMPA	WECC Rockies	0.724
AZNM	WECC Southwest	0.616

Hourly Generation Mix and GHG Emission Factors (20-Year GWP Time Horizon)

Generation Type	Generation Mix (%)	Greenhouse Gas Emission Factor GWP_{20} (kg CO_2e/kWh)
Coal	Footnote 1	1.207
Oil	Footnote 1	0.916
Natural Gas	Footnote 1	0.594
Nuclear	Footnote 1	0.047
Hydro	Footnote 1	0
Biomass	Footnote 1	Footnote 2
Wind	Footnote 1	0
Solar	Footnote 1	0
Geothermal	Footnote 1	0
Other	Footnote 1	0.958
Total	100	Footnote 1

Footnote 1: The qualified person provides hourly generation mix and total greenhouse gas emission factor.

Footnote 2: The authority having jurisdiction approves the greenhouse gas emission factor for each source of biomass.

Refrigerant Global Warming Potential (20-Year GWP Time Horizon)

Refrigerant Type	Global Warming Potential GWP_{20} (kg CO_2e/kg refrigerant)
HCFC-22	5690
HCFC-123	325
HFC-134a	4140
HC-290 (Propane)	.072
R-404A	Footnote 1
R-407C	Footnote 1
R-408A	Footnote 1
R-410A	Footnote 1
R-438A	Footnote 1
R-504	Footnote 1
R-717 (Ammonia)	0
R-744 (CO_2)	1
Other	Footnote 1

Footnote 1: GWP values in table sourced from IPCC AR6 WGI at Chapter 7, Table 7.SM.7, "Tables of greenhouse gas lifetimes, 1 radiative efficiencies and metrics". These tables can be used to derive GWP values for other refrigerants and refrigerant blends.