American Carbon Registry
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METHODOLOGY FOR THE QUANTIFICATION AND REGISTRATION OF ENVIRONMENTAL IMPACTS OF GREEN FINANCE FOR

GREEN BUILDING PROJECTS: NEW CONSTRUCTION AND MAJOR RENOVATIONS

VERSION 1.0

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ABOUT AMERICAN CARBON REGISTRY® (ACR)

ACR is a scientific standards body for the creation of environmental assets. This includes tradable assets like carbon offset credits issued by ACR Environmental Markets and the quantification of environmental attributes of financial instruments by ACR Capital Markets. We complement decades of expertise in the development of market-making standards and project measurement methodologies with operational expertise in the verification, registration, issuance, retirement, and reporting of environmental claims.

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Rockefeller Brothers Fund
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ACRONYMS

ACEEE	American Council for an Energy-Efficient Economy
ACR	American Carbon Registry
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
CBECS	Commercial Building Energy Consumption Survey
CCF	Hundred cubic feet
CHP	Combined heat and power
CLF	Carbon Leadership Forum
CO_2e	Carbon dioxide equivalent
DHW	Domestic hot water
DOE	United States Department of Energy
EC3	Embodied Carbon in Construction Calculator
eGRID	Emissions & Generation Resource Integrated Database
EIA	United States Energy Information Administration
EPA	United States Environmental Protection Agency
EPD	Environmental Product Declaration
EUI	Energy use intensity
ft^2	Square foot
FTE	Full-time equivalent employee
gal	Gallon
GHG	Greenhouse gas
GHGI	Greenhouse gas intensity

GJ	Gigajoule
gpf	Gallons per flush
gpm	Gallons per minute
GWP	Global warming potential
HERS	Home Energy Rating System
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
ILFI	International Living Future Institute
IPCC	Intergovernmental Panel on Climate Change
K-12	Kindergarten through 12th grade
kBtu	Thousand British thermal units
kgal	Kilogallons (thousand gallons)
KPI	Key performance indicator
kWh	Kilowatt-hour (thousand watt-hours)
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
m^3	Cubic meter
MMBtu	Million British thermal units
MT	Metric ton
N/A	Not applicable
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic
RNG	Renewable natural gas
SDG	United Nations Sustainable Development Goals

SSR	Greenhous gas source, sink, and reservoir
USGBC	United States Green Building Council
zEPI	Zero Energy Performance Index

CONTENTS

FIGURES

TABLES

EQUATIONS

1 METHODOLOGY DESCRIPTION

This Methodology for the Quantification and Registration of Environmental Impacts of Green Finance for Green Building Projects: New Construction and Major Renovations was developed as part of ACR's Green Finance Impact Program.

This Methodology describes the approach and process for quantifying environmental key performance indicators (KPIs) for bond-funded activities related to the new construction or major renovation of green buildings. It calculates a project's Carbon Return and applies a benchmark to assess a project's impact relative to other investments in the same building category. This Methodology documents the approach used to quantify the following environmental benefits:

- Greenhouse gas (GHG) emission reductions;
- On-site renewable energy generation;
- Energy use and savings; and
- Water use and savings.

Residential and commercial buildings represent 32% of U.S. GHG emissions when the impact of electricity generation is distributed by sector.[1] The biggest source of emissions is the energy used in building operations, followed by the emissions from building construction. Over the past 20 years, the energy efficiency and emissions performance of new buildings has increased substantially, thanks to a combination of new technologies (e.g., heat pumps, solar photovoltaics, LED lighting), increasingly stringent energy codes,[2] and reductions in the emissions intensity of purchased electricity.

A 'green' building is a building that, in its design, construction, or operation, reduces or eliminates negative impacts and can create positive impacts on our climate and natural environment.[3] Green buildings typically include many features with GHG reduction benefits, including efficient energy use, renewable energy generation, efficient use of water (which reduces the energy needed to heat water), and low carbon building materials.

This Methodology quantifies the environmental benefits of any new construction or major renovation green building project. The methods for assessing the environmental impacts of a green building project apply both prior to building construction and upon building operation. It calculates expected building performance compared to a baseline using "prototype" values calculated by the U.S. Department of Energy (DOE) and other sources. This Methodology includes predetermined baselines and benchmarks for the following building types: offices,

[1] Sachs, J. et. al (2020), p. 17.

[2] U.S. DOE (2016).

[3] World Green Building Council (2020).

primary and secondary schools, and multifamily residential buildings.[4] It contains methods for assessing the environmental impacts of a green building projects funded with bond proceeds, including:

- Environmental KPIs;
- Carbon Return ($MTCO_2e$ per $1,000 bond financing per year); and
- Project performance relative to energy benchmark, where applicable.

This document provides the project eligibility requirements, quantification approach, and project data requirements. Additional resources and requirements applicable to ACR's Green Finance Impact Program are available at www.winrock.org/ms/acr-capital-markets.

[4] For other building types, custom baselines and appropriate benchmarks can be calculated by applying the principles of this Methodology to project-specific custom energy models, as described in this Methodology.

2 CALCULATOR TOOL

This Methodology details the technical methods used to calculate environmental KPIs for bond-funded projects. To make these methods accessible to issuers, ACR has created an easy-to-use calculator that embeds the methods and equations found in this document. The accompanying Calculator Tool and instructions for use are available to program participants at www.winrock.org/ms/acr-capital-markets.

Consistent with guidance from the International Capital Markets Association,[5,6] the results for each metric derived according to this Methodology are displayed in the Calculator Tool as the:

- Total impact accured over the duration of the project operational life;
- Pro-rated values representing the portion of the impact attributable to the bond financing compared to the total project costs; and
- Annual impact during a representative year when operational at normal capacity.

[5] ICMA (2021a), p. 19.

[6] ICMA (2021b), p. 8.

3 METHOD APPLICABILITY

Bond-funded activities must satisfy the following conditions for this Methodology to apply:

I. Building is or intends to qualify as green under a certification that has minimum requirements for energy efficiency.
II. Building is a new construction or major renovation.
III. Building reduces GHG emissions by reducing or avoiding embedded carbon and/or operational energy consumption through:
    A. Use of efficient design, technologies, and/or operational and maintenance practices to reduce electricity use;
    B. Use of efficient design, technologies, and/or operational and maintenance practices, including electrification, to reduce or avoid on-site fossil fuel combustion;
    C. Generation of on-site renewable electricity to reduce or avoid use of grid electricity;
    D. Use of water-efficient technologies, design, and operational practices that reduce the amount of energy used to heat or cool water; and/or
    E. Use of low-carbon building materials or, in the case of major renovations, the reuse of existing structures to reduce embodied carbon impacts.
IV. Building is located in the United States.
V. Issuer supplies project data per requirements described in Chapter 11.

Project aggregation for the purpose of reporting is permitted for projects that quantify environmental impacts using this Methodology and accompanying calculator tool, provided that aggregated projects all:

I. Are of the same building use type and have the same design attributes as input into the calculator tool;
II. Use the same major types of building materials as input into the Embodied Carbon in Construction Calculator (EC3) embodied carbon tool (applicable when building designs are available);
III. Are located in the same state and have the same energy code baseline; and
IV. Are located in the same electricity grid region.

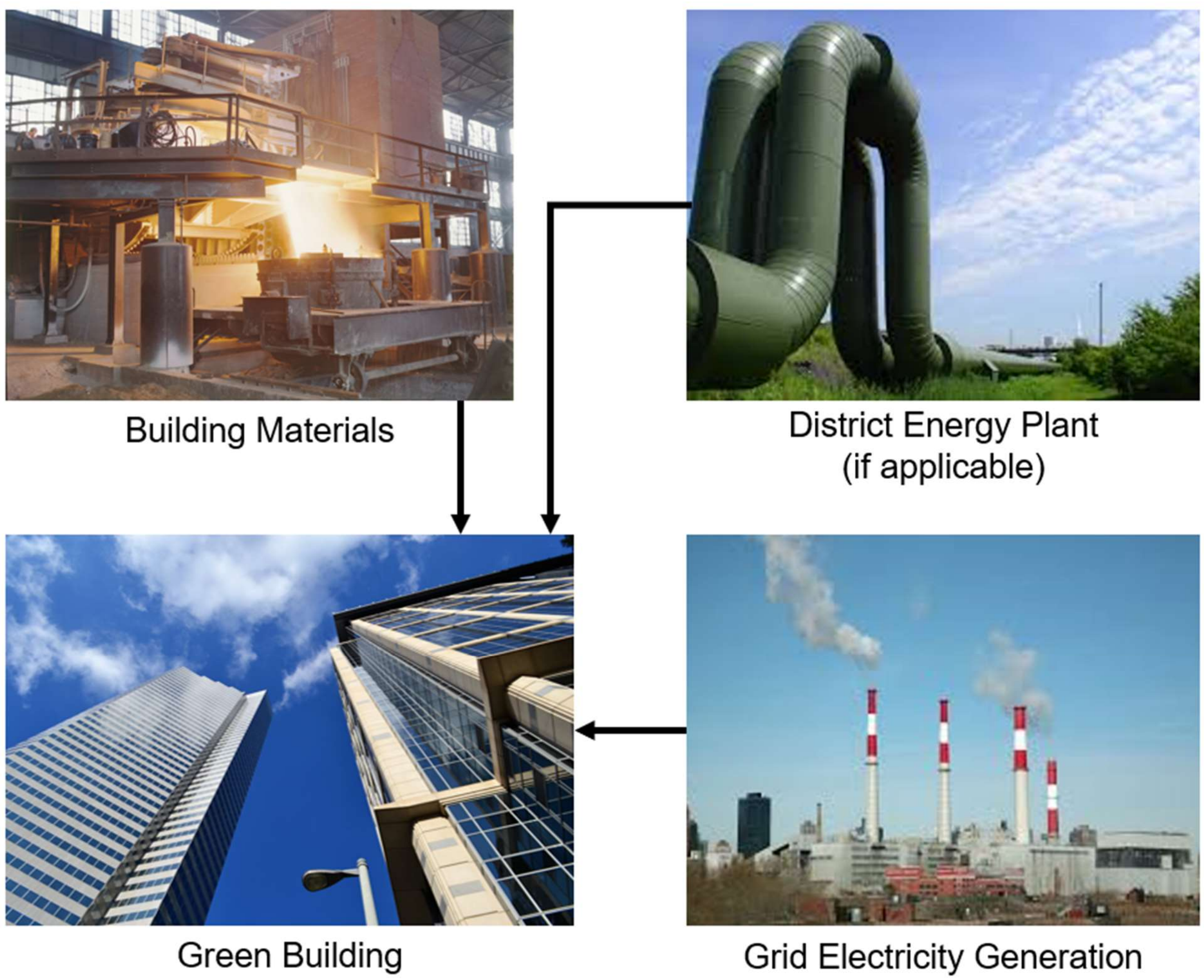
See Chapter 12 for definitions of terms used above and throughout this Methodology.

4 PROJECT BOUNDARIES

4.1 SPATIAL BOUNDARY

The spatial boundary includes the physical and geographical site where the building will be located,[7] the location of generating plants for purchased off-site (grid) electricity, the location of any district energy systems providing heat and/or cooling, if applicable, and, for the purpose of quantifying embodied carbon in construction materials, the locations where building materials are made, as depicted in Figure 1.

Figure 1: Spatial Boundary



[7] A project's spatial boundary is not limited to the geographic footprint of the building structure as it may encompass surrounding landscaping and supporting infrastructure (e.g., energy or water supply).

A project proponent may or may not have operational control over all components within the spatial boundary. A green building project's benefits can accrue at a site outside of the operational control – but as a direct result – of a project. This Methodology is designed to capture these benefits as long as they occur within the spatial boundary. This Methodology relies on reasonable assumptions, supported by data and literature, when assessing project impacts that occur upstream of a green building project site.

4.2 TEMPORAL BOUNDARY

The temporal boundary is designed to capture impacts associated with the project during its construction and operational life. Figure 2 depicts the project phases, from project identification through the operational life, and how the different phases relate to the quantification of project impacts. GHG emissions associated with embodied carbon in building materials are part of the construction phase.

This Methodology assumes an operational life of 30 years for a new construction or major renovation green building project, starting when the building receives its certificate of occupancy, and uses this time period when assessing a project against the benchmark. While the full lifetime of a building can be very long – sometimes, over 50 or 100 years – during that timeframe, many individual building systems will be replaced.[8,9,10] The 30 year period of time is consistent with when a building generally needs its major mechanical equipment updated and the timeframe during which it will also get other "substantial improvements."[11] Individual project operational lives may vary. To apply a different operational life to the quantification of project benefits, project proponents must substantiate the alternative project duration with documentation (e.g., manufacturer specifications for average lifetime, ASHRAE equipment lifetime tables, cost segregation study). If a project proponent substantiates a different operational life than that used in the benchmarks, that duration will be used when assessing the project against the benchmarks.

When building designs are available, embodied carbon emissions from the raw material supply, transport, and manufacturing of carbon-intensive building materials such as steel and concrete are included in the construction phase of the temporal boundary. However, precisely defining the time period during which the materials used in the buildings were manufactured is not necessary because these emissions are related to physical materials and not activities.

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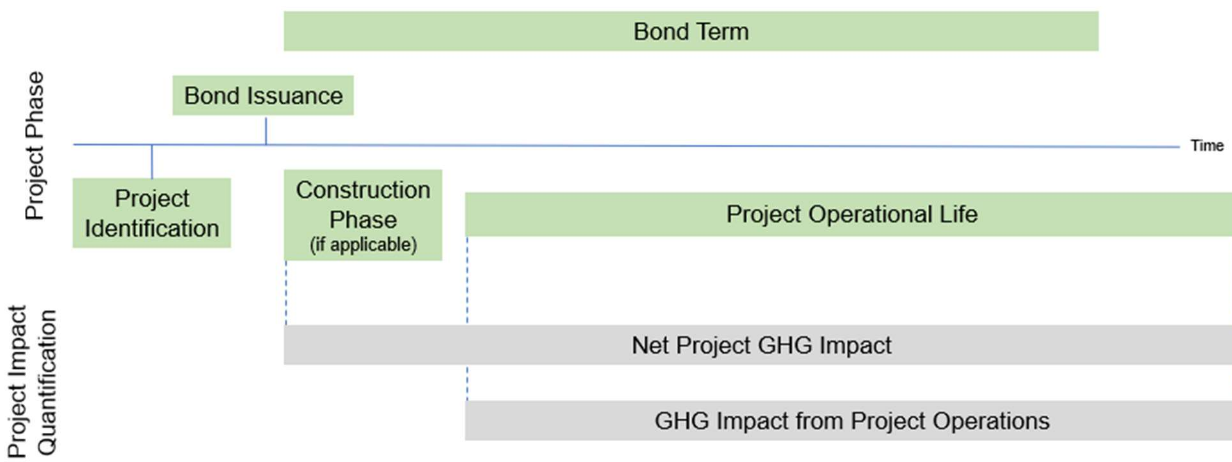
[8] Albrice, D. (2015).

[9] Carbon Leadership Form. (2018).

[10] Fannie Mae. (2019).

[11] A "substantial improvement," which is often, but not necessarily, synonymous with the more colloquial terms "complete renovation" or "gut-rehab," is a renovation that impacts over 50% of the building's value, and thus, is subject to new building code requirements. Because new code requirements will have a different baseline, any GHG saving calculations from the initial construction of the building cease to be valid at this time.

Figure 2: Project Phase Timeline



4.3 GHG ASSESSMENT BOUNDARY

The GHG assessment boundary, depicted by Figure 3 and Table 1 below, delineates the sources, sinks, and reservoirs (SSRs) that are included or excluded in quantifying emissions and emission reductions associated with the green building project. Table 1 also describes the SSRs used for the quantification of the project impact and the GHG benchmark.

Figure 3 illustrates the GHG assessment boundary for new construction or major renovation green building projects.

I. SSRs inside the grey box are included and must be accounted for under this Methodology.
II. SSRs outside the grey box are not included in the assessment boundary.
III. SSRs in green boxes are relevant to the net project GHG impact and the GHG benchmark.
IV. SSRs in blue boxes are relevant only to the net GHG impact.

Figure 3: GHG Assessment Boundary Diagram

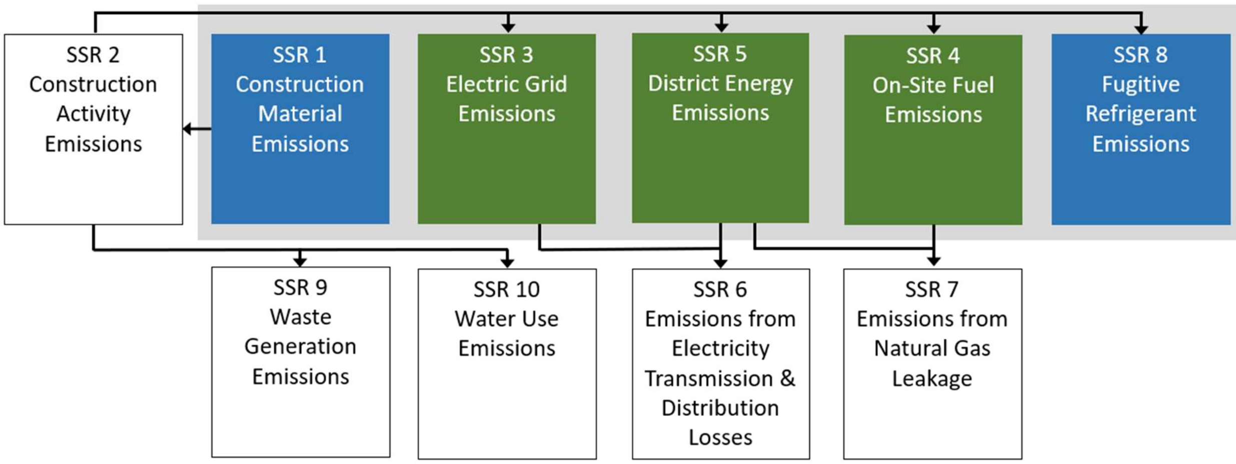


Table 1 lists the SSRs for new construction and major renovation green building projects, indicating which gases are included in, or excluded from, the GHG assessment boundary.

Table 1: GHG Sinks, Sources, and Reservoirs

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
1 Construction Material Emissions	Stationary and mobile combustion emissions from fossil fuel consumed for the raw material supply, transport, and manufacturing of building materials	CO_2	I/E	Included or excluded depending on the availability of building designs
		CH_4	I/E	
		N_2O	I/E	

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
2 Construction Activity Emissions	Stationary and mobile combustion emissions from the construction of the building, including energy and fuel used for on-site construction and transportation of building and waste materials	CO_2	E	Emissions are generally not tracked or quantified, and are assumed to be equivalent to the construction of a typical building
		CH_4	E	
		N_2O	E	
3 Electric Grid Emissions	Stationary emissions from the generation of grid electricity consumed by the project	CO_2	I	Primary activity of the project
		CH_4	I	
		N_2O	I	
4 On-site Fuel Emissions	Stationary emissions for the combustion of natural gas or other fuels on-site	CO_2	I/E	Primary activity of the project Biogenic CO_2 emissions are excluded
		CH_4	I	
		N_2O	I	
5 District Energy Emissions	Stationary emissions from on-site or off-site generation of district steam, hot water, or chilled water, if applicable	CO_2	I	Primary activity of the project
		CH_4	I	
		N_2O	I	
6 Emissions from Electricity Transmission & Distribution	Stationary emissions from the generation of grid electricity lost in transmission and distribution	CO_2	E	Industry practice is to attribute these emissions to the utility, rather than to the building
		CH_4	E	
		N_2O	E	

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
7 Emissions from Natural Gas Leakage	Net fugitive emissions of natural gas from pipelines	CO_2	E	Industry practice is to attribute these emissions to the utility, rather than to the building
		CH_4	E	
		N_2O	E	
8 Fugitive Refrigerant Emissions	Net fugitive emissions from refrigerant leakage	CO_2	I	Primary activity of the project
		HFCs		
9 Waste Generation Emissions	Net fugitive, stationary combustion, and mobile combustion emissions from waste generated by building operation and landfilled or incinerated	CO_2	E	The resulting GHG emissions are assumed to be equivalent with and without the project. While emissions from waste management practices can be estimated using the U.S. EPA's WARM tool, is not appropriate to directly compare the modeled results with GHG emissions from different sectors on an annual basis[12]
		CH_4	E	
		N_2O	E	

[12] EPA (2019), p. 1-21.

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
10 Water Use Emissions	Net fugitive, stationary combustion, and mobile combustion emissions from the water and wastewater system	CO_2	E	Emissions associated with energy used to heat domestic hot water (DHW) used onsite are captured in SSRs 3, 4, or 5, depending on the energy source Emissions from the conveyance and delivery of potable water to the building and the processing of wastewater generated at the building are attributed to the utility and excluded due to the lack of comparable data
		CH_4	E	
		N_2O	E	

5 PERIODIC REVIEWS

ACR may periodically update (or decide to retire) this Methodology. Such updates occur when significant changes to accounting best practices or the legislative and/or regulatory context justify an update; when sufficient new data is available to revise eligibility requirements, benchmarks, or emission factors; when ACR becomes aware of clarifications that should be made; or for other reasons. Before assessing a project's impacts against the benchmarks contained in this document, the project proponent should ensure that they are using the latest version of the Methodology.

6 QUANTIFICATION OF GHG IMPACT

GHG emission reductions from green building projects are quantified using the methods and equations in the following sections. This chapter describes how to establish the Carbon Return of the project and compare performance relative to the GHG benchmark for green building projects.

GHG emissions are converted to carbon dioxide-equivalent (CO_2e) using the 100-year global warming potential (GWP) in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.[13] This Methodology may be adjusted to updated GWPs in the future.

6.1 QUANTIFICATION OF NET PROJECT GHG IMPACT & CARBON RETURN

A green building project's GHG emission reductions are assessed using the methods and equations in Subsections 6.1.1 – 6.1.10 below. Each subsection covers a different SSR and the net project GHG impact is calculated in Subsection 6.1.11.

6.1.1 CONSTRUCTION MATERIAL EMISSIONS

Construction material emissions refer to the stationary and mobile combustion emissions from fossil fuel consumed for the raw material supply, transport, and manufacturing of building materials. The emissions from materials used in construction, also referred to as a building's embodied carbon, are significant and are calculated as part of this Methodology, if building designs are available. Embodied carbon can only be quantified using this Methodology when building designs are available; this Subsection does not apply to projects without building designs.

When applicable, the issuer shall use the Embodied Carbon in Construction Calculator (EC3) tool[14] to calculate the embodied carbon emissions of building materials and the emission reductions from using lower-emission materials. The EC3 tool is a free, open-access tool for estimating the embodied carbon emissions of a building using published Environmental Product Declarations (EPDs). The EC3 tool has over 35,000 EPDs. At this time, emissions are estimated per product for raw material supply, transport, and manufacturing, but not for other stages of the product life cycle.

[13] IPCC (2018), Table 2.14.

[14] Building Transparency (2020). Available at https://buildingtransparency.org/ec3.

While setting an appropriate embodied carbon baseline for a whole building is difficult without detailed knowledge of the planned building and local common building materials, baselines can and have been set per material. The Carbon Leadership Forum (CLF) Embodied Carbon Benchmark Study[15] sets representative, conservative benchmarks for embodied carbon per material and building type and is the basis for the EC3 tool. CLF and the EC3 tool both use the term "conservative benchmark" in a way that is roughly equivalent to how ACR uses the term "baseline", so these terms are treated as synonymous for this section only. Quantifying embedded carbon in construction materials in EC3 involves determining a conservative benchmark for each material and the appropriate substitute materials used that reduce embodied carbon.

For this Methodology, embodied carbon is calculated for the primary framing and facing materials used for the building, including the following, as applicable: concrete, steel, aluminum, wood, glass, and insulation. Avoided embodied carbon emissions are calculated using the outputs of the EC3 tool and Equation 1.

Equation 1: Avoided Embodied Carbon Emissions

$$\mathbf{AEC} = \sum_{i} (\mathbf{CBEC}_i \times \mathbf{QB}_i) - \sum_{i} (\mathbf{ECT}_i \times \mathbf{QP}_i)$$

WHERE	
AEC	Avoided embodied carbon emissions ($MTCO_2e$)
$CBEC_i$	Conservative benchmark embodied carbon from substituted baseline building material *i*, from EC3 Tool ($MTCO_2e$/quantity of baseline building material *i*)
QB_i	Quantity of substituted baseline building material *i* (units vary)
ECT_i	Embodied carbon target from project building material *i*, from EC3 tool or EPD documentation ($MTCO_2e$/quantity of material *i*)
QP_i	Quantity of project building material *i* (units vary)

[15] Carbon Leadership Forum (2017).

6.1.2 CONSTRUCTION ACTIVITY EMISSIONS

Construction activity emissions refers to the stationary and mobile combustion emissions from the construction of the building, including energy and fuel used in on-site construction and transportation of building and waste materials. This emission source is excluded from the GHG assessment boundary on account of it being small relative to the overall emissions of the project and not tracked or reported as standard industry practice. Moreover, it is assumed that the emissions from the activities involved in constructing the green building are roughly equivalent to a typical building, and thus would occur regardless of the green finance.

6.1.3 ELECTRIC GRID EMISSIONS

Electric grid emissions refer to the stationary emissions from the generation of grid electricity consumed by the project. All operational electricity savings and associated emission reductions are derived from the difference in energy use between the "baseline" and "project" scenarios. The difference between the baseline and project emissions represents savings resulting from efficient use of electricity and the generation of on-site renewable electricity. Energy use is calculated using energy use intensities (EUIs). These EUIs will vary based on the building type and location of the building, among other factors. To ensure consistency, the EUIs used in the baseline (BEUI) and project (PEUI) scenarios must assume the same building type(s), climate zone, and GHG emission factors.

Only additional on-site renewable electricity, as defined in Chapter 12, is allowed to be subtracted from electricity use. The direct purchase of off-site renewable electricity is not included in the Methodology. Only renewable energy sources without combustion are included, in line with guidance from U.S. Green Building Council (USGBC) and the International Living Future Institute (ILFI).[16]

Energy used to support transportation loads, such as electric vehicle charging, are generally metered separately and should be treated as a process load (i.e., not included in the construction of EUIs for the purpose of assessing energy use, savings, and emissions).

Baseline Energy Use Intensity

BEUIs for office, multifamily residential, and primary/secondary schools have been derived and published in an accompanying workbook available at www.winrock.org/ms/acr-capital-markets. Individual BEUIs are specific to climate zone and state energy code; the issuer must use the BEUI appropriate for the building location.

For most of the U.S., ACR developed these BEUIs for each of the 16 climate zones by analyzing the prototype building energy model data published by the U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL) for all versions of ANSI/ASHRAE/IES Standard 90.1 currently in use (i.e., 2004, 2007, 2010, 2013, 2016, and 2019), and all versions

[16] International Living Future Institute (2020).

of the International Energy Conservation Code (IECC) currently in use (i.e., 2006, 2012, 2015, and 2018).[17,18] For California, which uses California-specific climate zones in its energy code (Title 24), ACR used reports published by the California Energy Commission comparing prototype commercial building performance under Title 24 to ASHRAE 90.1-2013,[19] and single-family and low-rise multifamily building performance under Title 24 to IECC 2015.[20] Additional information on how the BEUIs were constructed is available within the accompanying workbook.

For other building types where baselines have not been developed, the issuer must use a custom baseline for BEUI. The custom baseline must be derived from an energy model of the project building, calibrated for the requirements of the energy code currently enforced by the state government. A list of state energy codes can be found in Appendix A, Table A-1.[21]

Project Energy Use Intensity

If a building-specific EUI target has been set as part of the building design, use the design features to determine the PEUI in the equations below. If calculating environmental impacts prior to the building design, PEUI is calculated using the prerequisite (minimum) energy savings requirements for the targeted green building certification. See a list of green building certifications with such prerequisites in Appendix A, Table A-2.[22] For green building certifications with a % savings target measured against a certification-specific baseline (such as 90.1-2010 for LEED BD+C v4), multiply the baseline EUI by (1 - % energy savings target) to determine PEUI. For green building certifications with prescriptive design requirements or targets, such as Passive House or ENERGY STAR Homes, the issuer should work with the design team to determine the appropriate PEUI target.

Electricity Energy Use Intensity and Emission Factors

Baseline electricity energy use intensity ($BEUI_E$) is the electricity portion of the overall baseline energy use intensity (BEUI); project electricity energy use intensity ($PEUI_E$) is the electricity portion of the overall project energy use intensity (PEUI). U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID)[23] is used to provide standard electricity grid GHG emission factors for each of the 26 eGRID subregions, as shown in Appendix A, Table A-3.

[17] U.S. DOE (2020a).

[18] U.S. DOE (2020b).

[19] Alatorre, M. & Neumann, I. (2016a).

[20] Alatorre, M. & Neumann, I. (2016b).

[21] U.S. DOE (2020c).

[22] The list of green building certifications is not exhaustive but compiles certifications that are widely used, available for common commercial and multifamily residential buildings, and includes a minimum prerequisite for energy efficiency improvements. The versions listed include those available for use by new projects as of January 2021.

[23] U.S. EPA (2021a).

When calculating $PEUI_E$, users may use utility-specific emission factors, if available and documented.

Baseline electric grid emissions are calculated using Equation 2.

Equation 2: Baseline Electric Grid Emissions

$$\mathbf{BGHG_E} = \left[\sum_t (\mathbf{BEUI}_{Et} \times \mathbf{GFA}_t) - \mathbf{RE_B} \times \mathbf{3.412}\right] \times \mathbf{EGRID} \times \mathbf{YEARS}$$

WHERE	
$BGHG_E$	Baseline electric grid emissions ($MTCO_2e$)
$BEUI_{Et}$	Electricity EUI of baseline building, appropriate for building use type *t*, state energy code, and climate zone (kBtu/ft^2/year) Select property types have $BEUI_E$ values in accompanying workbook
GFA	Gross floor area of project building for building use type *t* (ft^2)
RE_B	Annual baseline output of on-site renewable electricity generation systems (kWh/year) By default, baseline on-site renewable electricity generation is set at 0, unless it is required by state code
3.412	Conversion kBtu per kWh
EGRID	eGRID subregion annual CO_2e output emission factor, from Appendix A, Table A-3 ($MTCO_2e$/kBtu)
YEARS	Operational life (years)

Project electric grid emissions are calculated using Equation 3.

Equation 3: Project Electric Grid Emissions

$$\mathbf{PGHG_E} = \left[\sum_t (\mathbf{PEUI}_{Et} \times \mathbf{GFA}_t) - \mathbf{RE_P} \times 3.412\right] \times \mathbf{EEF} \times \mathbf{YEARS}$$

WHERE	
$PGHG_E$	Project electric grid emissions ($MTCO_2e$)
$PEUI_{Et}$	Electricity EUI of project building, appropriate for building use type *t*, ($kBtu/ft^2/year$)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
RE_P	Annual project output of on-site renewable electricity generation systems (kWh/year)
3.412	Conversion kBtu per kWh
EEF	Electricity emission factor from utility, if available ($MTCO_2e/kBtu$) If utility-specific emission factor is not available, default to eGRID subregion annual CO_2e output emission factor, from Appendix A, Table A-3
YEARS	Operational life (years)

6.1.4 ON-SITE FUEL EMISSIONS

On-site fuel emissions refer to the stationary emissions for the combustion of natural gas or other fuels on-site. All operational fuel savings and associated emission reductions are derived from the difference in energy use between the “baseline” and “project” scenarios.

The difference between the baseline and project emissions represents savings resulting from efficient use of natural gas and other fossil fuels and/or their displacement by electricity or biofuels. Fuel use is calculated using EUIs. These EUIs will vary based on the building type and location of the building, among other factors. To ensure consistency, the EUIs used in the baseline (BEUI) and project (PEUI) scenarios must assume the same climate zone. See subsection 6.1.3 for further discussion of how BEUI and PEUI are derived.

Fuel Energy Use Intensity and Emission Factors

Baseline fuel energy use intensity ($BEUI_F$) is the on-site fossil fuel portion of the overall baseline energy use intensity (BEUI); project fuel energy use intensity ($PEUI_F$) is the on-site fossil fuel and biofuel portion of the overall project energy use intensity (PEUI).

The baselines for this Methodology assume natural gas to be the only fossil fuel burned (combusted) on-site, but a project scenario may include other fuels, including biofuels. If the project building is all-electric or uses a district energy system for all thermal energy demands, the $PEUI_F$ of the project building will be 0, resulting in 100% fuel emissions savings. The U.S. EPA's emission factors for the ENERGY STAR Portfolio Manager[24] and the U.S. EPA's Emission Factors for Greenhouse Gas Inventories[25] are used to provide standard emission factors for natural gas and other fuels, as shown in Appendix A, Table A-4.

For biofuels, the CO_2e emissions are biogenic and therefore excluded from the emission factors, consistent with IPCC guidance,[26] while the CH_4 and N_2O emissions are included. Biogas delivered to site refers to biogas that is piped directly from a generation site, such as a landfill or farm, to the project site. Renewable Natural Gas (RNG) is biogas that is delivered through the regulated utility's natural gas distribution system; in this sense, it is analogous to off-site renewable electricity and is thus assigned the same emission factor as natural gas.

Baseline on-site fuel emissions are calculated using Equation 4.

Equation 4: Baseline On-Site Fuel Emissions

$$\mathbf{BGHG_F = \sum_t (BEIU_{F\mathit{t}} \times GFA_\mathit{t}) \times 0.00005311 \times YEARS}$$

WHERE	
$BGHG_F$	Baseline on-site fuel emissions ($MTCO_2e$)
$BEUI_{Ft}$	EUI for on-site natural gas for baseline building, appropriate for building use type *t*, state energy code, and climate zone (kBtu/ft^2/year) Select property types have $BEUI_F$ values in the accompanying workbook
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
0.00005311	GHG emissions factor for natural gas ($MTCO_2e$/kBtu)
YEARS	Operational life (years)

[24] ENERGY STAR (2020a), Figure 1.
[25] U.S. EPA (2021b).
[26] IPCC (2006), p. 1-6.

Project on-site fuel emissions are calculated using Equation 5.

Equation 5: Project On-Site Fuel Emissions

$$\mathbf{PGHG_F} = \sum_{t,i} \left(\mathbf{PEUI}_{\mathbf{F}t,i} \times \mathbf{GFA}_t \times \mathbf{FUEL}_i \right) \times \mathbf{YEARS}$$

WHERE	
$PGHG_F$	Project on-site fuel emissions ($MTCO_2e$)
$PEUI_{Ft,i}$	EUI of on-site fuel for project building, appropriate for building use type *t* and fuel type *i* (fuel types listed in Appendix A, Table A-4) (kBtu/ft^2/year)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
$FUEL_i$	GHG emission factor of fuel type *i* from Appendix A, Table A-4 ($MTCO_2e$/kBtu)
YEARS	Operational life (years)

6.1.5 DISTRICT ENERGY EMISSIONS

District energy emissions refer to the stationary emissions from on-site or off-site generation of district steam, hot water, or chilled water, if applicable.

All operational energy savings and associated emission reductions are derived from the difference in energy use between the “baseline” and “project” scenarios. The difference between the baseline and project emissions represents the combustion of fossil fuels (usually natural gas) at a central plant to deliver energy to the building via a district energy system in the project scenario. District energy use is calculated using EUIs. See subsection 6.1.3 for further discussion of how BEUI and PEUI are derived.

District Energy Use Intensity and Emission Factors

The baseline assumes no district energy use, so baseline district energy use intensity ($BEUI_D$) is 0. Project district energy use intensities for steam ($PEUI_S$), hot water ($PEUI_{HW}$), and chilled water ($PEUI_{CW}$) make up the district energy portion of the overall project energy use intensity (PEUI).

District energy will not be applicable to most projects and these EUIs will be assumed to be 0. However, for projects connected to a district energy loop, such as those on university campuses or located in municipalities with multi-user district energy systems, there will be emissions associated with production of energy distributed through the district system.

The EPA's Emission Factors for the ENERGY STAR Portfolio Manager[27] are used to provide standard default emission factors for district energy systems, as shown in Appendix A, Table A-5. These factors are generally useful, but because they represent an average of combined heat and power (CHP) and traditional district energy systems, they may not align with the emissions intensity of a particular system. If a building is sourcing district energy from a regional network or utility company, site-specific GHG emission factors for that district energy are unlikely to be known and the default emission factors provided in this Methodology will be used. If the issuer has access to emissions data for the district energy system, the issuer may provide site-specific GHG emission factors for the energy produced from that system in order to capture the full compounded energy savings achieved by combining an efficient building with an efficient district system. These site-specific values would come from district energy system operating records for the fuel and/or electricity consumed at the plant, and the efficiency ratio between the input fuel at the plant and the energy distributed to the district system.[28]

[27] ENERGY STAR (2020a), Figure 1.

[28] Site-specific district energy system emission factors shall follow the methodology used for accounting for district energy system efficiency used by ENERGY STAR available at https://www.energystar.gov/buildings/tools-and-resources/portfolio-manager-technical-reference-source-energy.

Project district energy system emissions are calculated using Equation 6.

Equation 6: Project District Energy System Emissions

$$PGHG_D = \sum_t (PEUI_{St} \times GFA_t \times DS + PEUI_{HWt} \times GFA_t \times DHW + PEUI_{CWt} \times GFA_t \times DCW) \times YEARS$$

WHERE	
$PGHG_D$	Project district energy system emissions ($MTCO_2e$)
$PEUI_{St}$	District steam EUI of project building, appropriate for building use type *t* (kBtu/ft²/year)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
DS	District steam GHG emission factor ($MTCO_2e$/kBtu) If site-specific emission factor is not available, use default value available from Appendix A, Table A-5
$PEUI_{HWt}$	District hot water EUI of project building, appropriate for building use type *t* (kBtu/ft^2/year)
DHW	District hot water GHG emission factor ($MTCO_2e$/kBtu) If site-specific emission factor is not available, use default value available from Appendix A, Table A-5
$PEUI_{CWt}$	District chilled water EUI of project building, appropriate for building use type *t* (kBtu/ft^2/year)
DCW	District chilled water GHG emission factor ($MTCO_2e$/kBtu) If site-specific emission factor is not available, use default value available from Appendix A, Table A-5
YEARS	Operational life (years)

6.1.6 EMISSIONS FROM ELECTRICITY TRANSMISSION & DISTRIBUTION

Emissions from electricity transmission and distribution losses refer to the stationary emissions from the generation of grid electricity lost in transmission and distribution. Between 5.1% and 5.5% of electricity is lost in the transmission and distribution of electricity from power plants to end use customers.[29] This emission source is excluded from the GHG assessment boundary because industry standard practice is to attribute these emissions to the electric utilities, and not to consumers.

6.1.7 EMISSIONS FROM NATURAL GAS LEAKAGE

Emissions from natural gas leakage refers to the net fugitive emissions of natural gas from pipelines. Some natural gas is lost in the process of extraction, transmission, and distribution. This emission source is excluded from the GHG assessment boundary because industry standard practice is to attribute these emissions to the natural gas producers and natural gas utilities, and not to consumers.

6.1.8 FUGITIVE REFRIGERANT EMISSIONS

Fugitive refrigerant emissions refer to the net fugitive emissions from refrigerant leakage. Refrigerants from air conditioners, heat pumps, and refrigeration equipment generally have high emissions intensities, but emissions can be reduced by using refrigerants with lower GWPs. Refrigerant emissions depend on the system charge, leakage rate, and refrigerant type. This methodology provides an approach to calculate the system charge and leakage rate and holds these values constant in the baseline and project scenario. The avoided climate impact, as calculated below, is based on the selection of lower-GWP refrigerants for the project building.

The system charge (lbs of refrigerant) depends on the cooling load (tons), building type, and system type. Many factors contribute to the cooling load, including building location, orientation, size, enclosure, and internal loads. Users may supply a building-specific cooling load or, if unavailable, use the simplified lookup approach provided in Table A-6 (Btu/ft^2) depending on climate zone and recommendations from HVAC industry experts. Once the cooling load is determined, a volume of refrigerant (lb) per ton of cooling is applied to determine the system load. Users can supply a system-specific volume rate from the manufacturer, use median values for multifamily, office, and K-12 school building types and a variety of heat pump system types sourced from a report for the City of Seattle[30] and listed in Table A-7, or use a default

[29] U.S. EPA (2021c). p. 35.

[30] PAE Engineers (2020), pp. 21-23.

value of 3 lbs/ton. The default value is an average based on a commonly used estimate of 2-4 lbs of refrigerant is per ton of cooling.[31,32,33] System charge is calculated using Equation 7.

Equation 7: Refrigerant System Charge

$$RSC = \frac{CL}{12,000} \times \sum_{t} (RCVR_t \times GFA_t)$$

WHERE	
RSC	Refrigerant system charge (lbs)
CL	Cooling load (Btu/ft^2) If building-specific value is not available, use default value available from Appendix A, Table A-6
12,000	Conversion Btu per ton of capacity
RCVR	Refrigerant charge volume rate (lb refrigerant/ton of capacity) If building-specific value is not available, use default value available from Appendix A, Table A-7 for select building and cooling system types or 3 lbs/ton for all others
GFA_t	Gross floor area of project building for building use type *t* (ft^2)

[31] Fixd repair (2019).
[32] Charlotte HVAC Guide (2021).
[33] NWA Cooling and Heating (2019).

This Methodology uses the leakage rate default assumptions from LEED[34] and Equation 8 to determine the refrigerant leakage over the project life.

Equation 8: Refrigerant Leakage

$$\mathbf{RL} = \mathbf{RSC} \times 2\% \times \mathbf{YEARS} + \mathbf{RSC} \times 10\% \times \left\lceil \frac{\mathbf{YEARS}}{\mathbf{15}} \right\rceil$$

WHERE	
RL	Refrigerant leakage (lbs)
RSC	Refrigerant system charge from Equation 7 (lbs)
2%	Assumed annual leakage rate (%)
YEARS	Operational life (years)
10%	Assumed reclamation leakage rate (%)
15	Refrigerant reclamation period (years)

Due to the range of refrigerant GWPs, the selection of refrigerant is most consequential to the greenhouse gas impact of fugitive refrigerant emissions. This Methodology assumes the use of R-410-A for the baseline building. While expected to be phased down in the coming years, it remains the most common refrigerant in new systems. [35,36,37,38] The avoided climate impact from the selection of low-GWP refrigerants is calculated using Equation 9 and the refrigerant and refrigerant blend GWPs sourced from the U.S. EPA based on 100-year GWPs from the IPCC[39,40] found in Table A-8.

[34] USGBC (2021).
[35] Turpin, J. (2021).
[36] Hess, B. (2021).
[37] Bon, M. (2020).
[38] Strongin, S. & McConahey, E. (2021).
[39] U.S. EPA (2014a), pp. 3-4.
[40] U.S. EPA (2010), pp. 2.

Equation 9: Avoided Fugitive Refrigerant Emissions

$$AFR = \frac{RL}{2,204.62} \times (2,088 - GWP_R)$$

WHERE	
AFR	Avoided fugitive refrigerant emissions ($MTCO_2e$)
RL	Refrigerant leakage from Equation 8 (lbs)
2,204.62	Conversion lb per MT
2,088	GWP of R-410A
GWP_R	GWP of refrigerant used in project building, from Appendix A, Table A-8

6.1.9 WASTE GENERATION EMISSIONS

Waste generation emissions refer to the net fugitive, stationary combustion, and mobile combustion emissions from waste generated by building operation and landfilled or incinerated. The waste generated is mostly a function of management decisions and occupant behavior rather than building design and, as a result, this emission source is assumed to be equivalent with and without the project and is therefore excluded from the GHG assessment boundary.

6.1.10 WATER USE EMISSIONS

Water use emissions refer to the net fugitive, stationary combustion, and mobile combustion emissions from the water and wastewater system. For simplicity, domestic hot water (DHW) energy loads are not broken out separately from other energy loads. Emissions associated with the energy needed to heat DHW for use on-site are included within the GHG assessment boundary and captured within the Baseline and Project EUIs for electricity, on-site fuel use, and/or district energy system use, depending on the energy source for water heating. See subsections 6.1.3, 6.1.4, and 6.1.5 for the Methodology for calculating these emissions.

Emissions associated with the conveyance and delivery of potable water to the project and the processing of wastewater generated by the project, either for use in the building or for associated landscaping, are excluded from the GHG assessment boundary because these emissions are attributed to the water and wastewater utilities, and not to consumers, where a lack of data hinders accounting at this level.

6.1.11 NET PROJECT GHG IMPACT & CARBON RETURN

The following subsection describes how to establish the net GHG impact of the project, which includes operational GHG emission reductions and embodied carbon emission reductions, and how to calculate the Carbon Return, cost-effectiveness, and the social cost of carbon for the bond issuance.

The GHG emission reductions result from reduced energy use in project operations and are calculated using Equation 10.

Equation 10: GHG Emission Reductions from Project Energy Use

$$\mathbf{GHG_P = (BGHG_E - PGHG_E) + (BGHG_F - PGHG_F) + PGHG_D}$$

WHERE	
GHG_P	GHG emission reductions from project energy use ($MTCO_2e$)
$BGHG_E$	Baseline electric grid emissions from Equation 2 ($MTCO_2e$)
$PGHG_E$	Project electric grid emissions from Equation 3 ($MTCO_2e$)
$BGHG_F$	Baseline on-site fuel emissions from Equation 4 ($MTCO_2e$)
$PGHG_F$	Project on-site fuel emissions from Equation 5 ($MTCO_2e$)
$PGHG_D$	Project district energy system emissions, if applicable, from Equation 6 ($MTCO_2e$)

The percent reduction in GHG emissions from project energy use compared to the baseline is calculated using Equation 11

Equation 11: Percent Reduction in GHG Emissions from Project Energy Use

$$GHG_{P\%} = 1 - \frac{(PGHG_E + PGHG_{F+}PGHG_D)}{(BGHG_E + BGHG_F)}$$

WHERE	
$GHG_{P\%}$	Percent reduction in GHG emissions from project energy use (%)
$PGHG_E$	Project electric grid emissions from Equation 3 ($MTCO_2e$)
$PGHG_F$	Project on-site fuel emissions from Equation 5 ($MTCO_2e$)
$PGHG_D$	Project district energy system emissions, if applicable, from Equation 6 ($MTCO_2e$)
$BGHG_E$	Baseline electric grid emissions from Equation 2 ($MTCO_2e$)
$BGHG_F$	Baseline on-site fuel emissions from Equation 4 ($MTCO_2e$)

The building energy carbon performance, or energy greenhouse gas intensity (GHGI), is the annual GHG emissions from project energy use, normalized on the basis of building area. The project energy GHGI is calculated using Equation 12.

Equation 12: Project Energy GHG Intensity

$$GHGI_P = \frac{(PGHG_E + PGHG_F + PGHG_D) \times 1,000}{GFA \times YEARS}$$

WHERE	
$GHGI_P$	Project energy GHG intensity (kg $CO_2e/ft^2/year$)
$PGHG_E$	Project electric grid emissions from Equation 3 ($MTCO_2e$)
$PGHG_F$	Project on-site fuel emissions from Equation 5 ($MTCO_2e$)
$PGHG_D$	Project district energy system emissions, if applicable, from Equation 6 ($MTCO_2e$)
1,000	Conversion kg per MT
GFA	Total gross floor area of project building (ft^2)
YEARS	Operational life (years)

The net project GHG impact is based on the GHG emission reductions from a green building project energy use and the embodied carbon emission reductions from construction phase. The net GHG emission reductions from the project are calculated using Equation 13.

Equation 13: Net GHG Emission Reductions from Project

$$GHG_N = GHG_P + AEC + AFR$$

WHERE	
GHG_N	Net GHG emission reductions from project construction and operations ($MTCO_2e$)
GHG_P	GHG emission reductions from project energy use from Equation 10 ($MTCO_2e$)
AEC	Avoided embodied carbon emissions from EC3 as represented in Equation 1 ($MTCO_2e$)
AFR	Avoided fugitive refrigerant emissions from Equation 9 ($MTCO_2e$)

The Carbon Return of building a green building project is the GHG benefit per thousand dollars of bond financing per year of project operation. The Carbon Return is calculated using Equation 14.

Equation 14: Carbon Return of Project

$$CR = GHG_N \ / \ \$ \ / \ YEARS$$

WHERE	
CR	Carbon Return of the project ($MTCO_2e$/$1,000/year)
GHG_N	Net GHG emission reductions from project construction and operations from Equation 13 ($MTCO_2e$)
$	Total bond financing for the green building project (dollars, in thousands)
YEARS	Operational life (years)

The overall cost effectiveness of GHG emission reductions for a green building project is the GHG benefit per thousand dollars of bond financing. GHG cost effectiveness is calculated using Equation 15.

Equation 15: GHG Cost Effectiveness of Project

$$\mathbf{GHG_{\$}} = \frac{\mathbf{GHG_N}}{\mathbf{\$}}$$

WHERE	
$GHG_{\$}$	GHG cost effectiveness of the project ($MTCO_2e$/$1,000)
GHG_N	Net GHG emission reductions from project construction and operations from Equation 13 ($MTCO_2e$)
$\$$	Total bond financing for the green building project (dollars, in thousands)

The social cost of carbon benefit of a project is calculated using the current social cost of carbon rate and Equation 16.

Equation 16: Social Cost of Carbon Benefit

$$\mathbf{SCC} = \mathbf{GHG_N} \times \frac{\mathbf{51}}{\mathbf{1,000}}$$

WHERE	
SCC	Social cost of carbon benefit ($, in thousands)
GHG_N	Net GHG emission reductions from project construction and operations from Equation 13 ($MTCO_2e$)
51	Social cost of carbon ($ per $MTCO_2e$)[41,42]
$1,000$	Conversion $ per $1,000

[41] Chemnick (2021).

[42] Whitehouse.gov (2021).

6.2 QUANTIFICATION OF GHG BENCHMARK

A benchmark is a representative standard of performance that facilitates measurement and comparison of impacts across investments in the same category. The analysis contained in this Methodology results in a benchmark based on the typical energy performance of green building projects.

The most common certification for new construction of green buildings is the Leadership in Energy and Environmental Design for Building Design and Construction (LEED BD+C), offered by the USGBC. Analysis by the USGBC shows that the average LEED certified project achieves a 26% reduction in energy use relative to the energy code baseline.[43] However, this analysis contains many projects that are older and measured against an earlier baseline. The latest version of this certification, LEED BD+C v4.1, sets a minimum energy prerequisite of meeting the energy performance of ASHRAE 90.1-2016 and then provides points for achieving energy savings beyond that. In contrast the projects in the USGBC Green Building Information Gateway database are mostly LEED v4 projects, which are compared against a ASHRAE 90.1-2010 baseline or LEED v3 projects, which were compared against a ASHRAE 90.1-2007 baseline. There are an insufficient number of new projects using LEED v4.1 to assess modern performance and, because of the increasing stringency of energy codes across the country, it is quite possible that this 26% energy reduction would not hold for LEED buildings built today.

Other green building certifications that do not use a point-based system have set various standards for green building energy performance. The ENERGY STAR New Construction program for multifamily buildings and the Enterprise Green Communities Criteria from Enterprise Community Partners both require buildings to be 15% more energy efficient than ASHRAE 90.1-2013 (or the local code, if more recent). This level of efficiency equates to a 10-15% energy savings compared to ASHRAE 90.1-2016, depending on the building type and climate zone.

There is also a persistent difference between modeled and real-world energy performance to be considered. There are many reasons for this difference, including but not limited to: the fact that new trophy buildings are often used more intensively than energy models assume, poor operations and maintenance, differences from planned systems to those installed, increasing IT plug loads, and, unfortunately, gaming of energy modeling. Therefore, ACR partnered with USGBC to perform further analysis of real world energy performance data in the USGBC Arc Skoru platform.[44,45] The analysis found the average EUI of LEED office buildings[46] across the United States to be 49.9 kBtu/ft^2 and the median EUI to be 40.5 kBtu/ft^2. This represents a 10% and 26% improvement, respectively, over the unweighted US median for a prototype office

[43] Green Building Information Gateway. (2021).

[44] Arc is a platform that is used to gather real world performance of LEED certified buildings and report that performance online. Arc can also be used to re-certify existing buildings under LEED O+M using performance data.

[45] Palanki, G. (2019).

[46] The Arc dataset used was not sufficiently robust for similar analysis of other building use types.

building built to ASHRAE 90.1-2016 of 54.7 kBtu/ft^2.[47] Analysis of Zero Energy Performance Index (zEPI) scores[48] for a range of buildings in ARC shows that average reported performance is between 0% and 16% better than the zEPI score for a prototype building built to ASHRAE 90.1-2016 in the same climate zone. Notably, many green buildings incorporate renewable energy, which can reduce emissions for the average green building by 2% to 20%--depending on the amount of available rooftop or other on-site space for renewable energy, the level of renewable energy incentives available, building orientation, and building location. This renewable energy potential is not factored into the EUI and zEPI figures above but can be expected to contribute to reducing the building's projected emissions.

Based on green building certification minimum energy prerequisites, typical real-world energy performance improvements of green buildings, consideration of the role of on-site energy generation, and consultations with experts,[49,50] this Methodology sets energy GHGI benchmarks at 15% lower than what would result from a building of the same size, type, and climate zone meeting the ASHRAE 90.1-2016 standard. The benchmarks are only intended for use in comparing the building energy use and associated emissions. While this Methodology also enables the quantification of GHG emission reductions from the use of less carbon intensive construction materials and refrigerants, current datasets are not sufficiently robust to set a clear benchmark for these sources, so no benchmark is set for building materials or refrigerants at this time. This Methodology and the approach to benchmarking may be updated pending further research and analysis.

ACR has generated numerical energy GHGI benchmarks (kg CO_2e/ft^2/year) specific to the building type, climate zone, and regional eGRID GHG emission factor for office buildings, multifamily buildings, and K-12 schools. The energy benchmarks have been derived and published in an accompanying workbook available at www.winrock.org/ms/acr-capital-markets. These benchmarks represent a 15% improvement on the electricity and natural gas BEUIs[51] built to the ASHRAE 90.1-2016 standard. Additional information on how the BEUIs were constructed is available in Section 6.1.3 and within the accompanying BEUI workbook.

For other building types for which energy GHGI benchmarks have not been provided, custom benchmarks are to be derived as 15% lower than the GHGI of a building of that type and in that location built to ASHRAE 90.1-2016. For consistency with the provided benchmarks derived from the U.S. DOE Prototype Building Models, custom benchmarks must assume the use of natural gas or electricity as the source of heating energy, not district energy. This approach will use EUIs from a calibrated energy model meeting ASHRAE 90.1-2016 specifications and then calculate emissions and apply the benchmark reduction using Equations 17 and 18.

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[47] C. Pyke (personal communication, December 1, 2020).

[48] New Buildings Institute (2021).

[49] C. Pyke (personal communication, December 1, 2020).

[50] C. Baker (personal communication, December 4, 2020).

[51] The benchmarks assume no use of district energy since it is not applicable to most buildings and is not included in the DOE prototype energy models. DOE (2020a).

Equation 17: Custom Energy GHGI for ASHRAE 90.1-2016 Standard

$$\mathbf{GHGI_{CE,\mathit{t}} = BEUI_{E2016,\mathit{t}} \times EEF \times 1,000 + BEIU_{F2016,\mathit{t}} \times 0.05311}$$

WHERE	
$GHGI_{CE,t}$	Custom energy GHGI of the building, appropriate for building use type *t,* as if built to the ASHRAE 90.1-2016 standard (kg CO_2e/ft^2/year)
$BEUI_{E2016}$	Electricity EUI of the building, appropriate for building use type *t,* as if built to the ASHRAE 90.1-2016 energy code at project location (kBtu/ft^2/year)
EEF	Electricity emission factor from utility, if available ($MTCO_2e$/kBtu) If utility-specific emission factor is not available, default to eGRID subregion annual CO_2e output emission factor, from Appendix A, Table A-3
1,000	Conversion kg per MT
$BEUI_{F2016}$	Natural Gas EUI of the building, appropriate for building use type *t,* as if built to the ASHRAE 90.1-2016 energy code at project location (kBtu/ft^2/year)
0.05311	GHG emissions factor for natural gas (kg CO_2e/kBtu)

Equation 18: Custom Energy GHGI Benchmark

$$\mathbf{GHGI_{CB,\mathit{t}} = GHGI_{CE,\mathit{t}} \times (1 - 0.15)}$$

WHERE	
$GHGI_{CB,t}$	Custom energy GHGI benchmark of the building, appropriate for building use type *t,* with energy performance improvement of 15% (kg CO_2e/ft^2/year)
$GHGI_{CE,t}$	Custom energy GHGI of the building, appropriate for building use type *t*, as if built to the ASHRAE 90.1-2016 standard, from Equation 17 (kg CO_2e/ft^2/year)
15%	Benchmarked percentage reduction in energy intensity and associated emissions

A project's energy GHGI, quantified per Section 6.1, will be assessed against the energy GHGI benchmark using the methods in Section 6.3. To do this, the project and energy GHGIs must first be converted from kg CO_2e/ft^2/year to total $MTCO_2e$ emission reductions using the ASHRAE 90.1-2016 baseline and Equations 19 and 20.

Equation 19: Benchmark Energy GHG Emission Reductions

$$\mathbf{GHG_B} = \frac{\sum_t [(\mathbf{GHGI}_{A,t} - \mathbf{GHGI}_{B,t}) \times \mathbf{GFA}_t]}{1,000} \times \mathbf{YEARS}$$

WHERE	
GHG_B	Benchmark energy GHG emission reductions ($MTCO_2e$)
$GHGI_{A,t}$	GHGI of the building, appropriate for building use type *t,* as if built to the ASHRAE 90.1-2016 energy code, from accompanying workbook or custom from Equation 17 (kg CO_2e/ft^2/year)
$GHGI_{B,t}$	GHGI benchmark of the building, appropriate for building use type *t,* with energy performance improvement of 15%, from accompanying workbook or custom from Equation 18 (kg CO_2e/ft^2/year)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
1,000	Conversion kg per MT
YEARS	Operational life (years)

Equation 20: Project Energy GHG Emission Reductions Compared to ASHRAE 90.1-2016

$$GHG_{PA} = \frac{\left[\sum_t \left(GHGI_{A,t} \times GFA_t / GFA \right) - GHGI_P \right] \times GFA \times YEARS}{1,000}$$

WHERE	
GHG_{PA}	Project energy GHG emission reductions compared to ASHRAE 90.1-2016 reference standard ($MTCO_2e$)
$GHGI_{A,t}$	GHGI of the building, appropriate for building use type *t,* as if built to the ASHRAE 90.1-2016 energy code, from accompanying workbook or custom from Equation 17 (kg CO_2e/ft^2/year)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
GFA	Total gross floor area of project building (ft^2)
$GHGI_P$	Project energy GHG intensity from Equation 12 (kg CO_2e/ft^2/year)
YEARS	Operational life (years)
1,000	Conversion kg per MT

6.3 COMPARISON OF PROJECT GHG IMPACT TO BENCHMARK

This Section describes how project performance is assessed relative to the GHG benchmark. After determining the project and benchmark GHGIs and emission reductions compared to ASHRAE 90.1-2016 standard, the GHG emission reductions associated with a project's energy performance is compared to the energy GHG benchmark in terms of $MTCO_2e$ using Equation 21.

Equation 21: Comparison of Project Energy GHG Emission Reductions to Benchmark

$$GHG_C = GHG_{PA} - GHG_B$$

WHERE	
GHG_C	Project energy emission reductions compared to benchmark ($MTCO_2e$)
GHG_{PA}	Project energy GHG emission reductions compared to ASHRAE 90.1-2016 reference standard from Equation 20 ($MTCO_2e$)
GHG_B	Benchmark energy GHG emission reductions from Equation 19 ($MTCO_2e$)

The project's emission reductions are also compared to the GHG benchmark on a percentage basis (e.g., project energy performance emission reductions are X% relative to benchmark) using Equation 22.

Equation 22: Percentage Comparison of Project Energy GHG Emission Reductions to Benchmark

$$GHG_{B\%} = \frac{GHG_{PA}}{GHG_B}$$

WHERE	
$GHG_{B\%}$	Project energy emission reductions compared to benchmark (%)
GHG_{PA}	Project energy GHG emission reductions compared to ASHRAE 90.1-2016 reference standard from Equation 20 ($MTCO_2e$)
GHG_B	Benchmark energy GHG emission reductions from Equation 19 ($MTCO_2e$)

The project's energy GHGI is compared to the energy GHGI benchmark on a percentage basis (e.g., project energy GHGI is X% of energy GHGI benchmark) using Equation 23.

Equation 23: Percentage Comparison of Project Energy GHGI to Energy GHGI Benchmark

$$GHGI_{B\%} = \frac{GHGI_P}{\sum_t (GHGI_{B,t} \times GFA_t) / GFA}$$

WHERE	
$GHGI_{B\%}$	Project energy GHG intensity compared to energy GHG intensity benchmark (%)
$GHGI_P$	Project energy GHG intensity from Equation 12 (kg $CO_2e/ft^2/year$)
$GHGI_{B,t}$	GHGI benchmark of the building, appropriate for building use type *t,* with energy performance improvement of 15%, from accompanying workbook or custom from Equation 18 (kg $CO_2e/ft^2/year$)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
GFA	Total gross floor area of project building (ft^2)

7 QUANTIFICATION OF ON-SITE RENEWABLE ELECTRICITY GENERATION

In addition to GHG emission reductions, green building projects often generate renewable electricity on-site. The quantity of on-site renewable electricity generated is calculated using Equation 24.

Equation 24: On-site Renewable Electricity Generated

$$REL = RE_P \times YEARS$$

WHERE	
REL	On-site renewable electricity generated over project lifetime (kWh)
RE_P	Annual project output of on-site renewable electricity generation systems (kWh/year)
$YEARS$	Operational life (years)

8 QUANTIFICATION OF ENERGY USE AND SAVINGS

Green building projects reduce energy use through efficiency measures and electrification. This chapter evaluates energy performance, energy savings, and the resulting cost savings. The Energy Use Intensities used in the equations below will be the same Baseline and Project EUIs used in Chapter 6.

8.1 ENERGY PERFORMANCE

Site energy use, also known as final energy use, is the downstream energy consumed by the building during project operations. Site energy use per year, normalized on the basis of building area, is calculated using Equation 25.

Equation 25: Site Energy Use

$$\mathbf{SITE} = \frac{\sum_{t,i}\left[\left(\mathbf{PEUI}_{\mathbf{E}t} + \mathbf{PEUI}_{\mathbf{F}t,i} + \mathbf{PEUI}_{\mathbf{S}t} + \mathbf{PEUI}_{\mathbf{HW}t} + \mathbf{PEUI}_{\mathbf{CW}t}\right) \times \mathbf{GFA}_{t}\right]}{\sum_{t}(\mathbf{GFA}_{t})}$$

WHERE	
SITE	Site energy use (kBtu/ft²/year)
$\mathrm{PEUI}_{\mathrm{E}t}$	Electricity EUI of project building, appropriate for building use type *t* (kBtu/ft²/year)
GFA_t	Gross floor area of project building for building use type *t* (ft²)
$\mathrm{PEUI}_{\mathrm{F}t,i}$	EUI of on-site fuel for project building, appropriate for building use type *t* and fuel type *i* (fuel types listed in Appendix A, Table A-4) (kBtu/ft²/year)
$\mathrm{PEUI}_{\mathrm{S}t}$	District steam EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft²/year)
$\mathrm{PEUI}_{\mathrm{HW}t}$	District hot water EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft²/year)
$\mathrm{PEUI}_{\mathrm{CW}t}$	District chilled water EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft²/year)

Source energy use, also known as total primary energy use, is the upstream energy consumed by the building during project operations, including energy losses in generation, transmission, and distribution. Source energy use per year, normalized on the basis of building area, is calculated using Equation 26. Source-to-site ratios from ENERGY STAR are used.[52]

Equation 26: Source Energy Use

$$\mathbf{SOURCE} = \frac{\sum_{t,i}\left[\begin{array}{c}(\mathbf{PEUI_{Et}} \times \mathbf{GFA}_t) \times \mathbf{SSR}_i + \left(\mathbf{PEUI_{F}}_{t,i} \times \mathbf{GFA}_t\right) \times \mathbf{SSR}_i \\ +\left((\mathbf{PEUI_{St}} + \mathbf{EUI_{HWt}}) \times \mathbf{GFA}_t\right) \times \mathbf{SSR}_i + (\mathbf{PEUI_{CWt}} \times \mathbf{GFA}_t) \times \mathbf{SSR}_i\end{array}\right]}{\sum_t(\mathbf{GFA}_t)}$$

WHERE	
SOURCE	Source energy use (kBtu/ft²/year)
$PEUI_{Et}$	Electricity EUI of project building, appropriate for building use type *t* (kBtu/ft²/year)
GFA_t	Gross floor area of project building for building use type *t* (ft²)
SSR_i	Source-to-site ratio for energy source from Appendix A, Table A-9
$PEUI_{Ft,i}$	EUI of on-site fuel for project building, appropriate for building use type *t* and fuel type *i* (fuel types listed in Appendix A, Table A-4) (kBtu/ft²/year)
$PEUI_{St}$	District steam EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft²/year)
$PEUI_{HWt}$	District hot water EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft²/year)
$PEUI_{CWt}$	District chilled water EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft²/year)

[52] ENERGY STAR (2020b), p. 1.

8.2 ENERGY SAVINGS

Electricity savings from efficiency measures is calculated using Equation 27.

Equation 27: Electricity Savings from Efficiency Measures

$$\mathbf{ES} = \sum_{t} [(\mathbf{BEUI}_{Et} - \mathbf{PEUI}_{Et}) \times \mathbf{GFA}_{t}] \times \mathbf{YEARS}$$

WHERE	
ES	Electricity savings from efficiency measures (kBtu)
$BEUI_{Et}$	Electricity EUI of baseline building, appropriate for building use type *t*, state energy code, and climate zone ($kBtu/ft^2/year$) Select property types have $BEUI_E$ values in accompanying workbook
$PEUI_{Et}$	Electricity EUI of project building, appropriate for building use type *t* ($kBtu/ft^2/year$)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
YEARS	Operational life (years)

Fuel savings from efficiency measures or electrification is calculated using Equation 28. District energy use generally replaces on-site combustion of fossil fuels, either in part or whole, so project district energy use is grouped with on-site fuel consumption to calculate the total fuel savings.

Equation 28: Fuel Savings from Efficiency Measures or Electrification

$$\mathbf{FS} = \sum_{t}\left[\left(\mathbf{BEUI}_{\mathbf{F}t} - \sum_{i}\left(\mathbf{PEUI}_{\mathbf{F}t,i} + \mathbf{PEUI}_{\mathbf{S}t} + \mathbf{PEUI}_{\mathbf{HW}t} + \mathbf{PEUI}_{\mathbf{CW}t}\right)\right) \times \mathbf{GFA}_{t}\right] \times \mathbf{YEARS}$$

WHERE	
FS	Fuel savings from efficiency measures or electrification (kBtu)
$BEUI_{Ft}$	EUI for on-site natural gas for baseline building, appropriate for building use type *t*, state energy code, and climate zone (kBtu/ft^2/year) Select property types have $BEUI_F$ values in the accompanying workbook
$PEUI_{Ft,i}$	EUI of on-site fuel for project building, appropriate for building use type *t* and fuel type *i* (fuel types listed in Appendix A, Table A-4) (kBtu/ft^2/year)
$PEUI_{St}$	District steam EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft^2/year)
$PEUI_{HWt}$	District hot water EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft^2/year)
$PEUI_{CWt}$	District chilled water EUI of project building, appropriate for building use type *t*, if applicable (kBtu/ft^2/year)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
$YEARS$	Operational life (years)

Total energy savings are best quantified looking at source energy, which accounts for energy losses in generation, transmission, and distribution.[53] Source energy is calculated using source-to-site ratios from ENERGY STAR[54] and Equation 29.

Equation 29: Source Energy Savings from Efficiency Measures or Electrification

$$\mathbf{SES = ES \times 2.8 + FS \times 1.05}$$

WHERE	
SES	Source energy savings (kBtu)
ES	Electricity savings from efficiency measures from Equation 27 (kBtu)
2.8	Source-to-site ratio for electricity
FS	Fuel savings from fuel efficiency measures, district energy, or electrification from Equation 28 (kBtu)
1.05	Source-to-site ratio for natural gas

[53] ENERGY STAR (2020c).
[54] ENERGY STAR (2020b).

The percent reduction in energy use from project building operation compared to the baseline is calculated using Equation 30.

Equation 30: Percent Reduction in Energy Use from Project Building Operation

$$\mathbf{E_{\%} = 1 - \left[\frac{SITE \times \sum_t (GFA_t)}{\sum_t (BEUI_{Et} \times GFA_t + BEUI_{Ft} \times GFA_t)}\right]}$$

WHERE	
$E_{\%}$	Percent reduction in energy use from project building operation (%)
SITE	Site energy use from Equation 25 (kBtu/ft^2/year)
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
$BEUI_{Et}$	Electricity EUI of baseline building, appropriate for building use type *t*, state energy code, and climate zone (kBtu/ft^2/year) Select property types have $BEUI_E$ values in accompanying workbook
$BEUI_{Ft}$	EUI for on-site natural gas for baseline building, appropriate for building use type *t*, state energy code, and climate zone (kBtu/ft^2/year) Select property types have $BEUI_F$ values in the accompanying workbook

8.3 ENERGY COST SAVINGS

The nominal energy cost savings is calculated using the energy conversion rates from Table A-11 (as needed), utility rates, and Equation 31.

Equation 31: Nominal Energy Cost Savings

$$\mathbf{ECS} = \left(\frac{\mathbf{ES}}{3.412} + \mathbf{REL}\right) \times \mathbf{EC} + \sum_t \Big[(\mathbf{BEUI}_{\mathbf{F}t} \times \mathbf{GFA}_t) \times \mathbf{FC}_i - \Big(\sum_i (\mathbf{PEUI}_{\mathbf{F}t,i} \times \mathbf{GFA}_t \times \mathbf{FC}_i) + (\mathbf{PEUI}_{\mathbf{S}t} + \mathbf{PEUI}_{\mathbf{HW}t}) \times \mathbf{GFA}_t \times \mathbf{SHWC} + \mathbf{PEUI}_{\mathbf{CW}t} \times \mathbf{GFA}_t \times \mathbf{CWC}\Big)\Big] \times \mathbf{YEARS}$$

WHERE	
ECS	Energy cost savings ($)
ES	Electricity savings from efficiency measures from Equation 27 (kBtu)
3.412	Conversion kBtu per kWh
REL	On-site renewable electricity generated over project lifetime from Equation 24 (kWh)
EC	Electricity rate for local utility ($/kWh) If local utility rate is not available, use default value available from Appendix A, Table A-10, weighted by building use type
$BEUI_{Ft}$	EUI for on-site natural gas for baseline building, appropriate for building use type *t*, state energy code, and climate zone (kBtu/ft^2/year) Select property types have $BEUI_F$ values in the accompanying workbook
GFA_t	Gross floor area of project building for building use type *t* (ft^2)
FC_i	Fuel cost for fuel type *i* ($/kBtu) For natural gas, if local utility rate is not available, use default value available from Appendix A, Table A-10, weighted by building use type
$PEUI_{Ft,i}$	EUI of on-site fuel for project building appropriate to building use type *t* and fuel type *i* (fuel types listed in Appendix A, Table A-4) (kBtu/ft^2/year)
$PEUI_{St}$	District steam EUI of project building appropriate to building use type *t*, if applicable (kBtu/ft^2/year)

$PEUI_{HWt}$	District hot water EUI of project building appropriate to building use type *t*, if applicable (kBtu/ft^2/year)
SHWC	District steam or hot water cost, if applicable ($/kBtu)
$PEUI_{CWt}$	District chilled water EUI of project building appropriate to building use type *t*, if applicable (kBtu/ft^2/year)
CWC	District chilled water cost, if applicable ($/kBtu)
YEARS	Operational life (years)

9 QUANTIFICATION OF WATER SAVINGS

In addition to reducing energy use, many green building projects also reduce water use. Potable water savings are of great importance in some locales where water is scarce, or where water utility costs are very high; in other locations, they may be a more minor consideration. This Chapter evaluates the water savings (kgal) across the site.[55] Like embodied carbon, water savings can only be quantified using this Methodology when building designs are available; this Chapter does not apply to projects without building designs.

9.1 INDOOR WATER USE

Quantifying potable indoor water savings is a standard part of designing a green building project. Potable indoor water savings comes from the use of efficient water fixtures as well as rainwater collection and greywater recycling systems. This Methodology follows the approach used in the LEED Water Tool[56] for calculating building water use and savings from the water fixtures installed and the use of rainwater capture and water recycling systems. This section calculates the potable indoor water use, use intensity, and savings.

[55] As discussed previously, GHG emission reductions associated with the energy savings from reduced demand for DHW are captured in Subsections 6.1.3, 6.1.4, and 6.1.5.

[56] U.S. Green Building Council (2019). Available at https://www.usgbc.org/resources/leed-v4-indoor-water-use-reduction-calculator.

Annual baseline water fixture use is calculated using flow and flush rates of standard fixtures and Equation 32. All baseline water fixture use is assumed to be potable water.

Equation 32: Annual Baseline Water Fixture Use

$$\mathbf{BWFU} = \frac{\sum_i \left[\mathbf{BFR}_i \times \frac{\mathbf{TIME}_i}{\mathbf{60}} \times \sum_{ui}(\mathbf{USES}_{ui} \times \mathbf{USERS}_u)\right] \times \mathbf{DAYS}}{\mathbf{1,000}}$$

WHERE	
BWFU	Annual baseline water fixture use (kgal potable/year)
BFR_i	Baseline flush/flow rate for fixture type *i* from Appendix A, Table A-12 (gal per flush (gpf) or gal per minute (gpm))
TIME	Duration for fixture type *i* from Appendix A, Table A-12 (seconds) Note: Toilets and urinals use gal per flush and this is not applicable. Enter 60 to cancel out.
60	Conversion seconds per minute
$USES_{ui}$	Uses per day for fixture type *i*, per user class *u* from Appendix A, Table A-13 (uses/day) Note: Toilet and urinal uses per day assumptions are different for males and females of each user class
$USERS_u$	Number of users for user class *u* (users) Note: Toilet and urinal uses per day assumptions are different for males and females of each user class so the number of users for these fixtures must be separated by male and female users
DAYS	Number of days the project is accessible to most users (days/year) Note: Default values are as follows, depending on the building type: 365 for multifamily residential, 260 for offices,[57] and 180 for schools[58]
1,000	Conversion gal per kgal

[57] Mozingo, L. & Arens, E. (2014). p. 20.
[58] Education Commission of the States (2020).

Annual project water fixture use is calculated in the same fashion as the baseline but with different flow/flush rates for the fixtures using Equation 33. If all fixture types in the building will be WaterSense fixtures, project water fixture use is assumed to be 20% less than the baseline[59] and annual project water fixture use will instead be calculated using Equation 34.

Equation 33: Annual Project Water Fixture Use

$$\mathbf{PWFU} = \frac{\sum_i \left[\mathbf{PFR}_i \times \frac{\mathbf{TIME}_i}{\mathbf{60}} \times \sum_{ui}(\mathbf{USES}_{ui} \times \mathbf{USERS}_u)\right] \times \mathbf{DAYS}}{\mathbf{1,000}}$$

WHERE	
PWFU	Annual project water fixture use (kgal/year)
PFR_i	Project flush/flow rate for fixture type *i* (gal per flush (gpf) or gal per minute (gpm))
TIME	Duration for fixture type *i* from Appendix A, Table A-12 (seconds) Note: Toilets and urinals use gal per flush and this is not applicable. Enter 60 to cancel out.
60	Conversion seconds per minute
$USES_{ui}$	Uses per day for fixture type *i*, per user class *u* from Appendix A, Table A-13 (uses/day) Note: Toilet and urinal uses per day assumptions are different for males and females of each user class
$USERS_u$	Number of users for user class *u* (users) Note: Toilet and urinal uses per day assumptions are different for males and females of each user class so the number of users for these fixtures must be separated by male and female users
DAYS	Number of days the building is accessible to most users (days/year) Note: Default values are as follows, depending on the building type: 365 for multifamily residential, 260 for offices,[60] and 180 for schools[61]
1,000	Conversion gal per kgal

[59] U.S. EPA (2020a).
[60] Mozingo, L. & Arens, E. (2014). p. 20.
[61] Education Commission of the States (2020).

Equation 34: Annual Project Water Fixture Use (for WaterSense fixtures)

$$\mathbf{PWFU = BWFU \times 0.80}$$

WHERE	
PWFU	Annual project water fixture use (kgal/year)
BWFU	Annual baseline water fixture use from Equation 32 (kgal/year)
80%	Percent of baseline water fixture use with WaterSense fixtures

Rainwater collection and greywater recycling systems can also reduce the demand for potable water. While not part of the LEED Water Tool, these are important elements to quantify the total potable indoor water savings possible from the project and are incorporated using Equation 35.

Equation 35: Annual Project Potable Indoor Water Use

$$\mathbf{PPIWU = PWFU - RAIN_I - GREY_I}$$

WHERE	
PPIWU	Project potable indoor water use (kgal potable/year)
PWFU	Project water fixture use from Equation 33 or Equation 34, as applicable (kgal/year)
$RAIN_I$	Rainwater captured and used in place of potable indoor water (kgal/year)
$GREY_I$	Greywater recycled and used in place of potable indoor water (kgal/year)

Annual potable indoor water use intensity is calculated using Equation 36.

Equation 36: Annual Potable Indoor Water Use Intensity

$$\mathbf{PIWUI} = \frac{\mathbf{PPIWU}}{\mathbf{1,000 \times GFA}}$$

WHERE	
PIWUI	Potable indoor water use intensity (gal potable/ft^2/year)
PPIWU	Project potable indoor water use from Equation 35 (kgal potable/year)
1,000	Conversion gal per kgal
GFA	Total gross floor area (ft^2)

Indoor potable water use savings over the life of the project is calculated using Equation 37.

Equation 37: Potable Indoor Water Use Savings

$$\mathbf{PIWUS} = (\mathbf{BWFU} - \mathbf{PPIWU}) \times \mathbf{YEARS}$$

WHERE	
PIWUS	Potable indoor water use savings (kgal potable)
BWFU	Baseline water fixture use from Equation 32 (kgal/year)
PPIWU	Project potable indoor water use from Equation 35 (kgal potable/year)
YEARS	Operational life (years)

The percentage savings in potable indoor water use is calculated using Equation 38.

Equation 38: Percentage Savings in Potable Indoor Water Use

$$PIWSP = 1 - \frac{PPIWU}{BWFU}$$

WHERE	
PIWSP	Potable indoor water savings percentage (%)
PPIWU	Project potable indoor water use from Equation 35 (kgal potable/year)
BWFU	Baseline water fixture use from Equation 32 (kgal/year)

9.2 LANDSCAPE WATER USE

For buildings with landscaping, reducing outdoor water use is also a green building practice. Best practice is to use locally adapted plants or xeriscaping such that no permanent irrigation system is required after a maximum two-year establishment period. The industry standard tool for calculating water use for landscaping is the EPA WaterSense Water Budget Tool.[62] The equations provided in this Section are the same equations that drive that tool.[63] Landscape water savings can only be quantified using this Methodology when landscape plans are available; this Section does not apply to projects that will include irrigation but do not yet have landscape plans.

Landscape water use and water use savings are calculated for the demand for potable water in a peak watering month. However, irrigation needs vary throughout the year and, in some cases, irrigation may not be needed for many months due to local precipitation, temperature, or snow cover. As is standard industry practice, water savings from landscape irrigation is measured in terms of savings during the peak watering month, rather than over a whole year or project lifetime.

Baseline landscape water use in the peak irrigation month is calculated using local evapotranspiration based on project zip code from the WaterSense Water Budget Data Finder[64] and Equation 39. All baseline landscape water use is assumed to be potable water.

[62] U.S. EPA (2020b). Available at https://www.epa.gov/watersense/water-budget-tool.
[63] U.S. EPA (2014b).
[64] U.S. EPA (2020c). Available at https://www.epa.gov/watersense/water-budget-data-finder.

Equation 39: Baseline Landscape Water Use During Peak Irrigation Month

$$\mathbf{BLWU = ET \times A \times 0.6233}$$

WHERE	
BLWU	Baseline landscape water use during peak irrigation month (gal potable/month)
ET	Local reference evapotranspiration from WaterSense Budget Data Finder (inches/month)
A	Landscaped area (ft^2)
0.6233	Conversion gal per inch Note: the factor of 0.6233 converts volume of water to gal from 1 square foot and 1 inch deep[65]

[65] U.S. DOE (2010), p. 19.

If a project has plans to have irrigated landscaping, project landscape water use in the peak irrigation month is calculated using local evapotranspiration and rainfall based on project zip code from the WaterSense Water Budget Data Finder[66] and Equation 40. If the project plans to have no irrigated landscaping, the project landscape water use is zero.

Equation 40: Project Landscape Water Use During Peak Irrigation Month

$$\mathbf{PLWU} = \sum_{h}\left[\frac{1}{\mathbf{DU}_h} \times \mathbf{A}_h \times \left(\sum_{l}(\mathbf{ET} \times \mathbf{K}_{lh} - \mathbf{R} \times 0.25)\right)\right] \times 0.6233$$

WHERE	
PLWU	Project landscape water use during peak irrigation month (gal/month)
DU_h	Lower quarter distribution uniformity, based on irrigation type, for hydrozone *h* from Appendix A, Table A-14 (dimensionless)
A_h	Landscaped area of hydrozone *h* (ft^2)
ET	Local reference evapotranspiration from WaterSense Budget Data Finder (inches/month)
K_{lh}	Landscape coefficient for landscape feature type *l* for hydrozone *h* from Appendix A, Table A-15 (dimensionless)
R	Average rainfall during peak irrigation month from WaterSense Budget Data Finder (inches/month)
0.25	Adjustment to rainfall assumption following recommendation from the EPA WaterSense program and Water Budget Tool to only assume 25% of average peak rainfall
0.6233	Conversion gal per inch Note: the factor of 0.6233 converts volume of water to gal from 1 square foot and 1 inch deep[67]

[66] U.S. EPA (2020c). Available at https://www.epa.gov/watersense/water-budget-data-finder.
[67] U.S. DOE (2010), p. 19.

Rainwater collection and greywater recycling systems can also reduce the demand for potable water. While not part of the WaterSense tool, these are important elements to quantify the total potable landscape water use savings possible from the project and are incorporated using Equation 41.

Equation 41: Project Potable Landscape Water Use During Peak Irrigation Month

$$\mathbf{PPLWU = PLWU - RAIN_L - GREY_L}$$

WHERE	
PPLWU	Project potable landscape water use during peak irrigation month (gal potable/month)
PLWU	Project landscape water use during peak irrigation month from Equation 35 (gal/month)
$RAIN_L$	Rainwater captured and used for landscaping in place of potable water during peak irrigation month (gal/month)
$GREY_L$	Greywater recycled and used for landscaping in place of potable water during peak irrigation month (gal/month)

Potable landscape water use savings for the peak irrigation month is calculated using Equation 42.

Equation 42: Potable Landscape Water Use Savings During Peak Irrigation Month

$$\mathbf{PLWUS = BLWU - PPLWU}$$

WHERE	
PLWUS	Potable landscape water use savings during peak irrigation month (gal/month)
BLWU	Baseline landscape water use during peak irrigation month from Equation 39 (gal/month)
PPLWU	Project potable landscape water use during peak irrigation month from Equation 41 (gal/month)

The percentage savings in potable landscape water use for the peak irrigation month is calculated using Equation 43.

Equation 43: Percentage Savings in Potable Landscape Water Use During Peak Irrigation Month

$$\mathbf{PLWSP} = 1 - \frac{\mathbf{PPLWU}}{\mathbf{BLWU}}$$

WHERE	
PLWSP	Potable landscape water savings percentage (%)
PPLWU	Project potable landscape water use during peak irrigation month from Equation 41 (gal/month)
BLWU	Baseline landscape water use during peak irrigation month from Equation 39 (gal/month)

10 KEY PERFORMANCE INDICATORS

The KPIs resulting from this Methodology are shown in Table 2. Projects funded with bond proceeds may align with the United Nations Sustainable Development Goals (SDGs).[68] Green building project KPIs map to particular SDGs, as signified by their icons.[69]

Table 2: Key Performance Indicators

KEY PERFORMANCE INDICATOR	EQUATION REFERENCE	SDG[70]
Net GHG Emission Reductions from Project ($MTCO_2e$)	Equation 13	
Avoided Embodied Carbon Emissions ($MTCO_2e$)	Equation 1	
Avoided Fugitive Refrigerant Emissions ($MTCO_2e$)	Equation 9	
GHG Emission Reductions from Project Energy Use ($MTCO_2e$)	Equation 10	
Project Energy GHG Emissions Compared to Baseline (%)	Equation 11	
Project Energy GHG Intensity (kg CO_2e/ft^2)	Equation 12	
Carbon Return ($MTCO_2e$/$1,000 bond financing/year)	Equation 14	
GHG Cost Effectiveness ($MTCO_2e$/$1,000 bond financing)	Equation 15	
Social Cost of Carbon Benefit ($, in thousands)	Equation 16	
Project Energy GHG Emission Reductions Compared to Benchmark Baseline of ASHRAE 90.1-2016	Equation 20	
Project Energy GHG Emission Reductions Compared to Benchmark ($MTCO_2e$)	Equation 21	
Project Energy GHG Emission Reductions Compared to Benchmark (%)	Equation 22	
Project Energy GHG Intensity Compared to Energy GHG Intensity Benchmark (%)	Equation 23	

[68] United Nations (2015).

[69] Nordic Public Sector Issuers (2020), p. 17.

[70] The elements of a green building project quantified in this Methodology may contribute to the following individual SDG targets: 6.3, 6.4, 7.2, 7.3, 13.1,13.2. Most green buildings support a host of additional SDG Goals and Targets not discussed within this Methodology.

KEY PERFORMANCE INDICATOR	EQUATION REFERENCE	SDG[70]
On-site Renewable Energy Generated (kWh)	Equation 24	7 AFFORDABLE AND CLEAN ENERGY
Site Energy Use (kBtu/ft^2/year)	Equation 25	
Source Energy Use (kBtu/ft^2/year)	Equation 26	
Source Energy Savings (kBtu)	Equation 29	
Project Energy Use Reductions Compared to Baseline (%)	Equation 30	
Nominal Energy Cost Savings ($)	Equation 31	
Annual Potable Indoor Water Use (kgal/year)	Equation 35	6 CLEAN WATER AND SANITATION
Annual Potable Indoor Water Use Intensity (gal/ft^2/year)	Equation 36	
Potable Indoor Water Use Savings (kgal)	Equation 37	
Potable Indoor Water Use Savings (%)	Equation 38	
Potable Landscape Water Use During Peak Irrigation Month (gal/month)	Equation 41	
Potable Landscape Water Use Savings During Peak Irrigation Month (gal/month)	Equation 42	
Potable Landscape Water Use Savings During Peak Irrigation Month (%)	Equation 43	

11 DATA REQUIREMENTS

In order to assess the impacts of a green building project against the benchmarks contained in this Methodology, project-specific data is required. Data requirements fall into two categories: data required at the time of ex-ante reporting prior to the project becoming operational and data required for ex-post reporting once the project is operational. These data are necessary inputs to quantify environmental impacts using this Methodology and the accompanying tool.

11.1 EX-ANTE REPORTING

This Methodology can be used with or without specific building designs. For projects without building designs, this Methodology utilizes prerequisite energy efficiency requirements from green building certifications to determine the project energy use. Design energy performance always exceeds the prerequisites so the pre-design KPIs are conservative. This approach is only available for building types where baseline and benchmarks have been provided (i.e., offices, K-12 schools, and multifamily residential buildings). The project-specific data required to quantify the environmental impacts without a building design are displayed in Table 3. Metrics with an asterisk (*) after them have default values available for use if project-specific data is unavailable.

Table 3: Data Requirements for Ex-Ante Quantification and Reporting (Without Building Designs)

METRIC	UNIT	REFERENCE
GENERAL PROJECT INFORMATION		
Total bond financing for the green building project	Dollars	Equations 14, 15
Total green building project costs	Dollars	Prorated KPI values in calculator
BASIC BUILDING INFORMATION		
Building type(s). Select from: • Office • K-12 school • High-rise multifamily • Mid-rise multifamily • Low-rise multifamily • Other (if other, specify building type)	N/A	Equations 2, 3, 4, 5, 17, 19, 27, 28, 31

METRIC	UNIT	REFERENCE
Gross floor area, by building use type	ft^2	Equations 2, 3, 4, 5, 6, 12, 19, 20, 23, 25, 26, 27, 28, 29, 30, 31, 36
Zip code	N/A	Equations 2, 3, 4, 5, 17, 19, 27, 28, 31, 39
If different from 30 years assumed by this Methodology, project operationals life*	Years	Equations 2, 3, 4, 5, 6, 14, 19, 20, 23, 27, 28, 29, 31, 35
Green building certification, version, and level for which the building qualifies.	N/A	Equations 2, 3, 4, 5, 27, 28, 31
RENEWABLE ENERGY GENERATION		
Quantity of annual on-site renewable electricity to be generated in baseline (zero, unless required by state code)	kWh/year	Equation 2
Quantity of annual on-site renewable electricity to be generated by project, if applicable	kWh/year	Equations 3, 23
ENERGY COST INFORMATION		
Electricity rate for local utility*	$/kWh	Equation 31
Natural gas rate*	$/kBtu[71]	Equation 31
Fuel cost for other on-site fuels used at project	$/kBtu[72]	Equation 31
Rate for district steam, hot water, and chilled water	$/kBtu[73]	Equation 31

[71] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.
[72] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.
[73] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.

For projects with building designs, the project-specific data required to quantify the environmental impacts prior to the building becoming operational are displayed in Table 4. Metrics with an asterisk (*) after them have default values available for use if project-specific data is unavailable.

Table 4: Data Requirements for Ex-Ante Quantification and Reporting (With Building Design)

METRIC	UNIT	REFERENCE
GENERAL PROJECT INFORMATION		
Total bond financing for the green building project	Dollars	Equations 14, 15
Total green building project costs	Dollars	Prorated KPI values in calculator
BASIC BUILDING INFORMATION		
Building type(s). Select from: • Office • K-12 school • High-rise multifamily • Mid-rise multifamily • Low-rise multifamily • Other (if other, specify building type)	N/A	Equations 2, 3, 4, 5, 17, 19, 27, 28, 31
Gross floor area, by building use type	ft^2	Equations 2, 3, 4, 5, 6, 7, 12, 19, 20, 23, 25, 26, 27, 28, 29, 30, 31, 36
Zip code	N/A	Equations 2, 3, 4, 5, 7, 17, 19, 27, 28, 31, 39
If different from 30 years assumed by this Methodology, project operationals life*	Years	Equations 2, 3, 4, 5, 6, 8, 14, 19, 20, 24, 27, 28, 29, 31, 37
Green building certification, version, and level for which the building qualifies.	N/A	Equations 2, 3, 4, 5, 27, 28, 31

METRIC	UNIT	REFERENCE
CONSTRUCTION MATERIAL INFORMATION		
Building material conservative benchmark outputs of EC3 Tool	$MTCO_2e$/unit of material	Equation 1
Number of units of each building material type	Units of material	Equation 1
RENEWABLE ENERGY GENERATION		
Quantity of annual on-site renewable electricity to be generated in baseline (zero, unless required by state code)	kWh/year	Equation 2
Quantity of annual on-site renewable electricity to be generated by project, if applicable	kWh/year	Equations 3, 24
PROJECT ENERGY USE		
Project electricity EUI, by building use type	kBtu/ft^2/year	Equations 3, 25, 26, 27
Electricity emission factor from utility*	$MTCO_2e$/kBtu	Equation 3 & 17
For each fuel type used on-site, name of fuel. Select from: • Natural gas • Fuel Oil (No. 1) • Fuel Oil (No. 2) • Fuel Oil (No. 3) • Fuel Oil (No. 4) • Diesel • Propane • Kerosene • Solid biomass fuel • Liquid biomass fuel • Biogas, if delivered directly to site	N/A	Equation 5
For each fuel type used on-site, project EUI, by building use type	kBtu/ft^2/year	Equations 5, 25, 26, 28, 31

METRIC	UNIT	REFERENCE
If project receives energy from a district energy system: • Project district steam EUI, by building use type • Project district hot water EUI, by building use type • Project district chilled water EUI, by building use type	kBtu/ft^2/year	Equations 6, 25, 26, 28, 29, 31
If project receives energy from a district energy system: • District steam GHG emission factor* • District hot water GHG emission factor* • District chilled water GHG emission factor*	$MTCO_2e$/kBtu	Equation 6
If project receives energy from a district energy system and does not supply site-specific GHG emission factors, select technology type for district chilled water: • Electric chiller • Absorption chiller using natural gas • Engine driven chiller using natural gas	N/A	Equation 6
REFRIGERANT INFORMATION		
Cooling load*	Btu/ft^2	Equation 7
Refrigerant charge volume rate*	lbs/ton capacity	Equation 7
Refrigerant type	N/A	Equation 9
ENERGY COST INFORMATION		
Electricity rate for local utility*	$/kWh	Equation 31
Natural gas rate*	$/kBtu[74]	Equation 31
Fuel cost for other on-site fuels used at project	$/kBtu[75]	Equation 31
Rate for district steam, hot water, and chilled water	$/kBtu[76]	Equation 31

[74] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.
[75] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.
[76] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.

METRIC	UNIT	REFERENCE
INDOOR WATER INFORMATION		
Project flush rates for the following fixture types: • Toilet (male) • Toilet (female) • Urinal	gpf	Equation 33
Project flow rates for the following fixture types: • Public restroom faucet • Private (residential) restroom faucet • Kitchen faucet • Residential kitchen faucet • Showerhead • Residential showerhead	gpm	Equation 33
Quantity of users for the following user classes: • Employees • Visitors • Retail Customers • Students • Residents	Number of people (or number of FTEs for employees)	Equations 32, 33
Gender split for the following user classes: • Employees (FTEs)* • Visitors* • Retail Customers* • Students* • Residents*	%	Equations 32, 33
Number of days per year the building is accessible to most users*	Days/year	Equations 32, 33
Annual rainwater to be captured and used in place of potable indoor water	kgal/year	Equation 35
Annual greywater to be recycled and used in place of potable indoor water	kgal/year	Equation 35

METRIC	UNIT	REFERENCE
LANDSCAPE WATER INFORMATION		
Local reference evapotranspiration (sourced from WaterSense Budget Data Finder based on zip code)	inches/month	Equations 39, 40
Average rainfall during peak irrigation month (sourced from WaterSense Budget Data Finder based on zip code)	inches/month	Equation 40
For each hydrozone:		
• Landscaped area	ft^2	Equations 39, 40
• Irrigation type, select from: ◆ Drip – standard ◆ Drip – press comp ◆ Fixed spray ◆ Microspray ◆ Rotor, or rotating nozzles ◆ No irrigation	N/A	Equation 40
• Landscape feature type, select from: ◆ Tree (low) ◆ Tree (medium) ◆ Tree (high) ◆ Shrubs (low) ◆ Shrubs (medium) ◆ Shrubs (high) ◆ Groundcover (low) ◆ Groundcover (medium) ◆ Groundcover (high) ◆ Turfgrass (low) ◆ Turfgrass (medium) ◆ Turfgrass (high) ◆ Pool, spa, or water feature ◆ Permeable hardscape ◆ Non-vegetated softscape ◆ Xeriscape	N/A	Equation 40

METRIC	UNIT	REFERENCE
Annual rainwater to be captured and used for landscaping in place of potable water during peak irrigation month	gal/month	Equation 41
Annual greywater to be recycled and used for landscaping in place of potable water during peak irrigation month	gal/month	Equation 41
INPUTS FOR ALTERNATIVE BUILDING TYPES (ONLY for building types other than offices, K-12 schools, or multifamily residential)		
Baseline electricity EUI of the building, by building use type (as if built to the energy code currently enforced by the state government)	kBtu/ft^2/year	Equations 2, 23, 27, 30
Baseline natural gas EUI of the building, by building use type (as if built to the energy code currently enforced by the state government)	kBtu/ft^2/year	Equations 4, 23, 28, 30
Benchmark electricity EUI of the building, by building use type (as if built to the ASHRAE 90.1-2016 energy code)	kBtu/ft^2/year	Equations 19, 20
Benchmark natural gas EUI of the building, by building use type (as if built to the ASHRAE 90.1-2016 energy code)	kBtu/ft^2/year	Equations 19, 20

11.2 EX-POST REPORTING

The project-specific data required to quantify the environmental impacts of a green building project once the building is operational are displayed in Table 5. Metrics with an asterisk (*) after them have default values available for use if project-specific data is unavailable.

Table 5: Data Requirements for Ex-Post Quantification and Reporting

METRIC	UNIT	REFERENCE
Quantity of annual on-site renewable electricity to be generated by project, if applicable	kWh/year	Equations 3, 24
Project electricity EUI, by building use type	kBtu/ft^2/year	Equations 3, 25, 26, 27
Electricity emission factor from utility*	$MTCO_2e$/kBtu	Equation 3 & 17
For each fuel type used on-site, project EUI, by building use type	kBtu/ft^2/year	Equations 5, 25, 26, 28, 31
If project receives energy from a district energy system, steam, hot water and chilled water EUIs, by building use type	kBtu/ft^2/year	Equations 6, 25, 26, 28, 29, 31
Electricity rate for local utility*	$/kWh	Equation 31
Natural gas rate*	$/kBtu[77]	Equation 31
Rate for other on-site fuels used at project	$/kBtu[78]	Equation 31
Quantity of users of each user class	Number of people (FTEs for employees)	Equations 32, 33
Number of days per year the building is accessible to most users*	Days/year	Equations 32, 33

[77] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.
[78] Conversion from other energy units to kBtu is available in Table 11 of this Methodology.

METRIC	UNIT	REFERENCE
UPDATED INFORMATION (ONLY IF DIFFERENT FROM INFORMATION USED FOR EX-ANTE REPORTING)		
Total bond financing for the green building project	Dollars	Equations 14, 15
Gross floor area, by building use type	ft^2	Equations 2, 3, 4, 5, 6, 7, 12, 19, 20, 23, 25, 26, 27, 28, 29, 30, 31, 36
Green building certifying organization, certification, version, and level for which the building qualifies.	N/A	Equations 2, 3, 4, 5, 27, 28, 31
Building material conservative benchmark outputs of EC3 Tool	$MTCO_2e$/unit of material	Equation 1
Number of units of each building material type	Units of material	Equation 1
Cooling load*	Btu/ft^2	Equation 7
Refrigerant charge volume rate*	lbs/ton capacity	Equation 7
Refrigerant type	N/A	Equation 9
Project flush/flow rates for indoor water fixtures	gpf/gpm	Equation 33
Annual rainwater to be captured and used in place of potable indoor water	kgal/year	Equation 35
Annual greywater to be recycled and used in place of potable indoor water	kgal/year	Equation 35
For each hydrozone, landscaped area	ft^2	Equations 39, 40
For each hydrozone, irrigation type, and landscape feature type	N/A	Equation 40

12 DEFINITIONS

Baseline energy use intensity (BEUI)	The modeled energy use intensity (EUI), measured in kBtu/ft^2, of a hypothetical building of the same building use type and location as the project building, built to the standard state energy code in effect in the project location, without any additional green features. BEUI is the combination of the baseline electricity energy use intensity ($BEUI_E$) and baseline on-site fossil fuel energy use intensity ($BEUI_F$).
Benchmark	A representative standard of performance that facilitates measurement and comparison of impacts across investments in the same category.
Carbon Return	A project's GHG benefit ($MTCO_2e$) per unit of investment (thousand dollars) per year of project operation.
Certificate of Occupancy	A certificate of occupancy is a document issued by a local government agency or building department certifying a building's compliance with applicable building codes and other laws and indicating it to be in a condition suitable for occupancy.
District energy system	Systems that use a network of pipes to distribute steam, hot water, and/or chilled water from one or more central plants to a set of buildings. District energy systems are most commonly found on large campuses, such as university campuses, where they are an efficient way of providing heating and cooling to the whole campus. In some cities, a larger district energy system may be operated by a utility company and serve many of the buildings within a city, neighborhood, or district.
Embodied carbon	Embodied carbon is a metric for the amount greenhouse gas emissions released throughout the supply chain of a building material. For this Methodology, embodied carbon includes the upstream emissions from raw material supply, transport, and manufacturing and excludes emissions from material disposal or materials already present in a building that is being renovated. For the purposes of quantification, this Methodology limits the evaluation of embodied carbon to the primary framing and facing materials used, including the following, as applicable: concrete/cement, steel, stone, glass, brick, and wood.

GHG source, sink, or reservoir (SSR)	• GHG source: Physical unit or process that releases a GHG into the atmosphere. • GHG sink: Physical unit or process that removes a GHG from the atmosphere. • GHG reservoir: Physical unit or component of the biosphere, geosphere or hydrosphere with the capability to store or accumulate a GHG removed from the atmosphere by a GHG sink or captured from a GHG source.
Gross Floor Area	The total property square footage, as measured between the exterior walls of the building(s). This includes all areas inside the building(s) including supporting areas.[79]
Hydrozone	Grouping of plants with similar water and environmental requirements for irrigation with one of more common station/zone valves[80]
Major renovation/ substantial improvement	A renovation that substantially overhauls the entire building and is subject to the latest energy code requirements, such that it must have a new energy performance baseline. The legal term for this is a "substantial improvement," which means that the cost of the work equals or exceeds 50% of the market value of the property prior to the beginning of the work.[81] Such projects are often called "gut-rehabs." Major renovations can be conducted at buildings that may or may not be classified as green prior to the project activity.
Multifamily housing	Residential properties that contain two or more residential living units; occupants include tenants, cooperators, and/or individual owners. Multifamily housing is further divided into three sub-types based on the number of floors in the building (or the number of floors in the tallest building within a multifamily complex with multiple buildings). • Low-rise (1-3 floors) • Mid-rise (4-9 floors) • High-rise (10+ floors) Low-rise multifamily buildings are often subject to different code requirements and green building certifications than medium- and high-rise buildings.
Office	Buildings used for the conduct of commercial or governmental business activities, including administrative and professional offices.

[79] ENERGY STAR (2021).
[80] U.S. EPA (2014b), p. 9.
[81] FEMA (2010), p. 4-2.

Primary and secondary schools	Buildings or campuses used as a school for kindergarten through 12th grade students. Not included in this building type are college or university classroom/laboratory facilities; vocational, technical, trade, adult or continuing education schools; preschools; or day care facilities.
Project energy use intensity (PEUI)	The expected energy use intensity (EUI), measured in kBtu/ft^2 of the green building project. PEUI is the combination of the project electricity energy use intensity ($PEUI_E$), project on-site fossil fuel and biofuel energy use intensity ($PEUI_F$), and project district energy use intensity ($PEUI_D$).
Renewable electricity, on-site	On-site renewable electricity is electricity generated (or anticipated to be generated) on the project site by a non-combustion-based renewable energy technology, such as solar photovoltaic (PV) panels. “On-site” does not necessarily imply that the renewable energy be physically located on the building, just that it be on the same project site and contributing directly to the project. For the purposes of this Methodology, only “additional” on-site renewable energy may be counted. For new construction projects where an issuer has a pre-existing renewable energy facility serving other buildings, the issuer must increase the generation capacity for it to be additional. For major renovation projects, a pre-existing renewable energy facility that served the building prior to the renovation is considered additional after the renovation. The purchase of off-site renewable energy is not included.
State energy code	The section of the building code that regulates the energy performance of new construction projects. National model codes are developed by ASHRAE and by International Energy Conservation Code (IECC). Most states model their commercial and residential building codes on ANSI/ASHRAE/IES Standard 90.1 and/or the IECC codes; some states have no statewide code. In general, most multifamily buildings are subject to the commercial code due to their size, but multifamily structures that are three or less floors tall and that have a gross floor area of less than 10,000 ft^2 may be subject to the residential code. A list of state energy codes is provided in Appendix A, Table A-1.

APPENDIX A: TABLES

Table A-6: State Energy Codes[82]

State	State Energy Code	Standard for Baseline	Version for Baseline
Alabama	90.1-2013	ASHRAE	2013
Alaska	None statewide	ASHRAE	2004
Arizona	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004
Arkansas	2009 IECC and 90.1-2007	ASHRAE	2007
California	2016 California Energy Code	TITLE 24	2016
Colorado	2006 IECC for jurisdictions that have adopted codes under home rule	IECC	2006
Connecticut	2015 IECC with amendments	IECC	2015
Delaware	2018 IECC and 90.1-2013	IECC	2018
District of Columbia	2015 IECC with amendments and 90.1-2010 with amendments	ASHRAE	2016
Florida	2015 IECC with amendments and 90.1-2013	IECC	2015
Georgia	2015 IECC with amendments and 90.1-2013	IECC	2015
Hawaii	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004
Idaho	2015 IECC and 90.1-2013	IECC	2015
Illinois	2018 IECC with amendments	IECC	2018
Indiana	90.1-2007 with amendments	ASHRAE	2007
Iowa	2012 IECC and 90.1-2010	IECC	2012
Kansas	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004
Kentucky	2012 IECC and 90.1-2010	IECC	2012
Louisiana	90.1-2007	ASHRAE	2007
Maine	2009 IECC and 90.1-2007	ASHRAE	2007
Maryland	2018 IECC	IECC	2018

[82] U.S. DOE (2020c).

State	State Energy Code	Standard for Baseline	Version for Baseline
Massachusetts	2015 IECC with amendments and 90.1-2013	IECC	2015
Michigan	2015 IECC and 90.1-2007	IECC	2015
Minnesota	2018 IECC with amendments	IECC	2018
Mississippi	None statewide	ASHRAE	2004
Missouri	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004
Montana	2012 IECC and 90.1-2010	IECC	2012
Nebraska	2018 IECC	IECC	2018
Nevada	2018 IECC and 90.1-2016	ASHRAE	2016
New Hampshire	2015 IECC and 90.1-2007	IECC	2015
New Jersey	90.1-2013	ASHRAE	2013
New Mexico	2009 IECC and 90.1-2007	ASHRAE	2007
New York	2018 IECC with amendments	IECC	2018
North Carolina	2015 IECC with amendments and 90.1-2013	IECC	2015
North Dakota	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004
Ohio	2012 IECC with amendments and 90.1-2010 with amendments	IECC	2012
Oklahoma	2006 IECC and 90.1-2004	IECC	2006
Oregon	ASHRAE 90.1-2016	ASHRAE	2016
Pennsylvania	2015 IECC and 90.1-2013	IECC	2015
Rhode Island	2015 IECC with amendments	IECC	2015
South Carolina	2009 IECC and 90.1-2007	ASHRAE	2007
South Dakota	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004
Tennessee	2012 IECC and 90.1-2010	IECC	2012
Texas	2015 IECC and 90.1-2013	IECC	2015
Utah	2018 IECC and 90.1-2013	IECC	2018
Vermont	2015 IECC with amendments and 90.1-2016 with amendments	ASHRAE	2016
Virginia	2015 IECC and 90.1-2013	IECC	2015

State	State Energy Code	Standard for Baseline	Version for Baseline
Washington	2015 Washington State Energy Code	ASHRAE	2016
West Virginia	90.1-2010	ASHRAE	2010
Wisconsin	2015 IECC with amendments and 90.1-2013 with amendments	IECC	2015
Wyoming	No statewide code (home rule allows local jurisdictions to adopt their own codes)	ASHRAE	2004

Table A-7: Green Building Certification Energy Savings Prerequisites[83]

Organization	Certification	Version	Reference Standard	Improvement from Standard	Applicable to
U.S. Green Building Council (USGBC)	LEED BD+C: New Construction	v4	ASHRAE 90.1-2010	3%	New Construction, Major Renovation
	LEED BD+C: New Construction	v4.1	ASHRAE 90.1-2016	0%	New Construction, Major Renovation
	LEED ZERO	NA	N/A	100%	New Construction, Major Renovation
	LEED BD+C: Homes	v4	IECC 2012	20%	New Construction
	LEED O+M	v4	CBECS US Median EUI	25%	Existing Building
	LEED O+M	v4.1	CBECS US Median EUI	25%	Existing Building
U.S. Environmental Protection Agency (EPA)	ENERGY STAR Existing Buildings	NA	CBECS US Median EUI	Variable by building type	Existing Building
	ENERGY STAR Multifamily New Construction	v1	ASHRAE 90.1-2013	15%	New Construction
	ENERGY STAR Homes	v3	Custom Prescriptive (Estimated	Prescriptive based (Average	New Construction - Low-Rise

[83] Numbers come from published technical manuals for applicable certification version

Organization	Certification	Version	Reference Standard	Improvement from Standard	Applicable to
			relative to IECC 2006)	relative to IECC 2006: 29%)[84]	Multifamily only
	ENERGY STAR Homes	3.1	Custom Prescriptive (Estimated relative to IECC 2006)	Prescriptive based (Average relative to IECC 2006: 44%)[85]	New Construction - Low-Rise Multifamily only
	ENERGY STAR Homes	3.2-CA	Title 24-2016	10%	New Construction - Low-Rise Multifamily only
Passive House Institute US (PHIUS)	PHIUS+	2018	Custom Performance Standard	N/A	New Construction, Major Renovation
Passive House Institute (PHI)	Certified Passive House	2016	Custom Performance Standard	N/A	New Construction, Major Renovation
International Living Future Institute (ILFI)	Living Building	v4	N/A	105%	New Construction, Major Renovation
	Zero Energy Certification	v4	N/A	100%	New Construction, Major Renovation
	Zero Carbon Certification	v4	CBECS US Median EUI	30%	New Construction, Major Renovation, Existing Building
Home Innovation Research Labs	National Green Building Standard (NGBS)	2015	IECC 2015	0%-20%, depending on	New Construction

[84] ENERGY STAR Homes estimates only applicable to low-rise multifamily setting; from: Cluett, R., Duer-Balkind, M., Perakis, J., Tosh, J., and Simpson, M. (2020).

[85] Ibid.

Organization	Certification	Version	Reference Standard	Improvement from Standard	Applicable to
				level of certification	
	National Green Building Standard (NGBS)	2020	IECC 2018	0%-20%, depending on level of certification	New Construction
Enterprise Green Community Partners	Enterprise Green Communities	2015	ASHRAE 90.1-2010	15%	New Construction
	Enterprise Green Communities	2015	Prior Performance	50%	Major Renovation, Existing Building
	Enterprise Green Communities	2020	ASHRAE 90.1-2013	15%	New Construction
	Enterprise Green Communities	2020	Prior Performance	50%	Major Renovation, Existing Building

Table A-8: eGRID2019 Subregion GHG Emission Factors[86]

eGRID Subregion Acronym	$MTCO_2e$/kBtu
AKGD	0.00014900
AKMS	0.00007329
AZNM	0.00012721
CAMX	0.00006052
ERCT	0.00011598
FRCC	0.00011493
HIMS	0.00015894
HIOA	0.00022701
MROE	0.00020109
MROW	0.00014709
NEWE	0.00006565

[86] U.S. EPA (2021a).

NWPP	0.00009570
NYCW	0.00007379
NYLI	0.00016205
NYUP	0.00003098
PRMS	0.00020517
RFCE	0.00009286
RFCM	0.00015913
RFCW	0.00014283
RMPA	0.00016625
SPNO	0.00014326
SPSO	0.00013383
SRMV	0.00010763
SRMW	0.00021217
SRSO	0.00012948
SRTV	0.00012704
SRVC	0.00009029

Table A-9: Direct Fuel GHG Emission Factors[87,88]

Fuel Type	$MTCO_2e/kBtu$
Natural Gas	0.00005311
Fuel Oil (No. 1)	0.00007350
Fuel Oil (No. 2)	0.00007421
Fuel Oil (No. 4)	0.00007529
Fuel Oil (No. 5, No. 6)	0.00007535
Diesel	0.00007421
Propane	0.00006425
Kerosene	0.00007769
Solid Biomass Fuel (Agricultural Byproducts, Peat, Solid Byproducts)	0.00000205
Solid Biomass Fuel (Wood and Wood Residue)	0.00000125
Liquid Biomass Fuel	0.00000006
Biogas, if delivered directly to site	0.00000027

Table A-10: Direct District Energy GHG Emission Factors[89]

District Energy Steam Type	$MTCO_2e/kBtu$
District Steam	0.00006640
District Hot Water	0.00006640
District Chilled Water (Electric Chiller)	0.00005270
District Chilled Water (Absorption Chiller Using Natural Gas)	0.00007389
District Chilled Water (Engine-Driven Chiller Using Natural Gas)	0.00004931

[87] Fossil fuel GHG factors: ENERGY STAR (2020a).
[88] Biofuel GHG factors: U.S. EPA (2021b).
[89] ENERGY STAR (2020a).

Table A-11: Cooling Loads by Climate Zone[90]

Climate Zone	Btu/ft^2
Zones 1 & 2	22
Zone 3	20
Zone 4	18
Zone 5	16
Zone 6	14
Zone 7	12

Table A-12: Refrigerant Volume per Ton of Cooling[91,92]

	ELECTRIC MINI-SPLIT HEAT PUMP	VARIABLE REFRIGERANT FLOW	AIR SOURCE HEAT PUMP WITH HYDRONIC DISTRIBUTION	NATURAL REFRIGERANT SYSTEM
MULTIFAMILY (UP TO 6 FLOORS)	3.4	5.6	2.4	2.4
MULTIFAMILY (7+ FLOORS)	3	4.7	1.65	1.65
OFFICE (<100,000 FT^2)	4.5	4.1	2.1	2.1
OFFICE (≥100,000 FT^2)	5.9	5.6	2.1	2.1
K-12 SCHOOL	5.0	4.3	3.4	3.4

90 PickHVAC (2021). The low end of each cooling load range was selected based on comparison to other industry sources using similar approaches.

91 PAE.

92 D. Mead (personal communication, August 19, 2021).

Table A-13: Refrigerant GWPs[93]

REFRIGERANT	FORMULA	GWP
R-717 (Ammonia)	NH_3	0
R-744 (Carbon Dioxide)	CO_2	1
R-1270 (Propylene)	C_3H_6	1.8
R-290 (Propane)	C_3H_8	3
R-600a (Isobutane)	C_4H_{10}	3
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-125	C_2HF_5	3,500
HFC-134	CHF_2CHF_2	1,100
HFC-134a	$C_2H_2F_4$	1,430
HFC-143	CH_2FCHF_2	353
HFC-143a	$C_2H_3F_3$	4,470
HFC-152	CH_2FCG_2F	53
HFC-152a	$C_2H_4F_2$	124
HFC-161	CH_3CH_2F	12
HFC-227ea	C_3HF_7	3,220
HFC-236cb	$CH_2FCF_2CF_3$	1,340
HFC-236ea	CHF_2CHFCF_3	1,370

[93] U.S. EPA (2014a), pp. 3-4.

HFC-236fa	$C_3H_2F_6$	9,810
HFC-245ca	$CH_2FCF_2CHF_2$	693
HFC-245fa	$CHF_2CH_2CF_3$	1,030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
HFC-43-10mee	$CH_3CHFCHFCF_2CF_3$	1,640
PFC-14	CF_4	7,390
PFC-116	C_2F_6	12,200
PFC-218	C_3F_8	8,830
PFC-318	$C\text{-}C_4F_8$	10,300
PFC-3-1-10	C_4F_{10}	8,860
PFC-4-1-12	C_5F_{12}	9,160
PFC-5-1-14	C_6F_{14}	9,300
PFC-9-1-18	$C_{10}F_{18}$	>7,500
Refrigerant Blend	**Blend Composition**	**GWP**
R-401A	53% HCFC-22, 34% HCFC-124, 13% HFC-152a	16
R-401B	61% HCFC-22, 28% HCFC-124, 11% HFC-152a	14
R-401C	33% HCFC-22, 52% HCFC-124, 15% HFC-152a	19
R-402A	38% HCFC-22, 6% HFC-125, 2% Propane	2,100
R-402B	6% HCFC-22, 38% HFC-125, 2% Propane	1,330
R-403B	56% HCFC-22, 39% PFC-218, 5% Propane	3,444
R-404A	44% HFC-125, 4% HFC-134a, 52% HFC 143a	3,922
R-406A	55% HCFC-22, 41% HCFC-142b, 4% Isobutane	0
R-407A	20% HFC-32, 40% HFC-125, 40% HFC-134a	2,107

R-407B	10% HFC-32, 70% HFC-125, 20% HFC-134a	2,804
R-407C	23% HFC-32, 25% HFC-125, 52% HFC-134a	1,774
R-407D	15% HFC-32, 15% HFC-125, 70% HFC-134a	1,627
R-407E	25% HFC-32, 15% HFC-125, 60% HFC-134a	1,552
R-408A	47% HCFC-22, 7% HFC-125, 46% HFC 143a	2,301
R-409A	60% HCFC-22, 25% HCFC-124, 15% HCFC-142b	0
R-410A	50% HFC-32, 50% HFC-125	2,088
R-410B	45% HFC-32, 55% HFC-125	2,229
R-411A	87.5% HCFC-22, 11 HFC-152a, 1.5% Propylene	14
R-411B	94% HCFC-22, 3% HFC-152a, 3% Propylene	4
R-413A	88% HFC-134a, 9% PFC-218, 3% Isobutane	2,053
R-414A	51% HCFC-22, 28.5% HCFC-124, 16.5% HCFC-142b	0
R-414B	5% HCFC-22, 39% HCFC-124, 9.5% HCFC-142b	0
R-417A	46.6% HFC-125, 5% HFC-134a, 3.4% Butane	2,346
R-422A	85.1% HFC-125, 11.5% HFC-134a, 3.4% Isobutane	3,143
R-422D	65.1% HFC-125, 31.5% HFC-134a, 3.4% Isobutane	2,729
R-423A	47.5% HFC-227ea, 52.5% HFC-134a	2,280
R-424A	50.5% HFC-125, 47% HFC-134a, 2.5% Butane/Pentane	2,4440
R-426A	5.1% HFC-125, 93% HFC-134a, 1.9% Butane/Pentane	1,508
R-428A	77.5% HFC-125, 2% HFC-143a, 1.9% Isobutane	3,607
R-434A	63.2% HFC-125, 16% HFC-134a, 18% HFC-143a, 2.8% Isobutane	3,245
R-500	73.8% CFC-12, 26.2% HFC-152a, 48.8% HCFC-22	32
R-502	48.8% HCFC-22, 51.2% CFC-115	0

R-504	48.2% HFC-32, 51.8% CFC-115	325
R-507	5% HFC-125, 5% HFC143a	3,985
R-508A	39% HFC-23, 61% PFC-116	13,214
R-508B	46% HFC-23, 54% PFC-116	13,396

Table A-14: Source-Site Ratios[94]

Energy Type	U.S. Ratio
Electricity	2.80
Natural Gas	1.05
Fuel Oil (No. 1,2,4,5,6), Diesel, Kerosene, Propane	1.01
Steam, Hot Water	1.20
Chilled Water	0.91
Wood, Other	1.00

[94] ENERGY STAR (2020b), Figure 1.

Table A-15: State Average Energy Costs

State	Electricity: Average Commercial Price, 2019 ($/kWh)[95]	Electricity: Average Residential Price, 2019 ($/kWh)[96]	Natural Gas: Average Commercial Price, 2019 ($/kBtu)[97]	Natural Gas: Average Residential Price, 2019 ($/kBtu)[98]
Alabama	$0.11517	$0.12528	$0.01157	$0.01523
Alaska	$0.19796	$0.22917	$0.00964	$0.01083
Arizona	$0.10245	$0.12434	$0.00711	$0.01315
Arkansas	$0.08785	$0.09795	$0.00749	$0.01077
California	$0.16672	$0.19153	$0.00917	$0.01262
Colorado	$0.10434	$0.12175	$0.00674	$0.00757
Connecticut	$0.16746	$0.21873	$0.00950	$0.01424
Delaware	$0.09533	$0.12549	$0.00979	$0.01179
District of Columbia	$0.12261	$0.12984	$0.01095	$0.01249
Florida	$0.09268	$0.11702	$0.01117	$0.02118
Georgia	$0.10023	$0.11763	$0.00800	$0.01449
Hawaii	$0.29230	$0.32062	$0.02949	$0.04302
Idaho	$0.07668	$0.09889	$0.00530	$0.00634
Illinois	$0.09083	$0.13027	$0.00684	$0.00784
Indiana	$0.11030	$0.12580	$0.00679	$0.00846
Iowa	$0.09995	$0.12459	$0.00588	$0.00798
Kansas	$0.10290	$0.12712	$0.00749	$0.00901
Kentucky	$0.10151	$0.10797	$0.00838	$0.01058
Louisiana	$0.08909	$0.09795	$0.00820	$0.01122
Maine	$0.12827	$0.17889	$0.01230	$0.01564
Maryland	$0.09966	$0.13116	$0.00988	$0.01223
Massachusetts	$0.16795	$0.21917	$0.01103	$0.01435
Michigan	$0.11392	$0.15743	$0.00664	$0.00788
Minnesota	$0.10343	$0.13041	$0.00646	$0.00786
Mississippi	$0.10519	$0.11266	$0.00827	$0.01050

95 U.S. EIA (2020a).
96 U.S. EIA (2020b).
97 U.S. EIA (2021a).
98 U.S. EIA (2021b).

State	Electricity: Average Commercial Price, 2019 ($/kWh)[95]	Electricity: Average Residential Price, 2019 ($/kWh)[96]	Natural Gas: Average Commercial Price, 2019 ($/kBtu)[97]	Natural Gas: Average Residential Price, 2019 ($/kBtu)[98]
Missouri	$0.09073	$0.11139	$0.00748	$0.01015
Montana	$0.10409	$0.11133	$0.00672	$0.00691
Nebraska	$0.08849	$0.10765	$0.00568	$0.00770
Nevada	$0.08037	$0.12005	$0.00633	$0.00926
New Hampshire	$0.15934	$0.20049	$0.01216	$0.01535
New Jersey	$0.12234	$0.15850	$0.00882	$0.00948
New Mexico	$0.09793	$0.12510	$0.00444	$0.00624
New York	$0.14059	$0.17940	$0.00703	$0.01229
North Carolina	$0.08807	$0.11418	$0.00854	$0.01255
North Dakota	$0.09010	$0.10301	$0.00553	$0.00682
Ohio	$0.09715	$0.12378	$0.00582	$0.00934
Oklahoma	$0.07983	$0.10206	$0.00710	$0.00916
Oregon	$0.08848	$0.11012	$0.00768	$0.00972
Pennsylvania	$0.08714	$0.13804	$0.00925	$0.01140
Rhode Island	$0.16384	$0.21733	$0.01254	$0.01497
South Carolina	$0.10576	$0.12991	$0.00836	$0.01281
South Dakota	$0.09592	$0.11554	$0.00536	$0.00711
Tennessee	$0.10652	$0.10873	$0.00789	$0.00921
Texas	$0.08056	$0.11762	$0.00602	$0.01034
Utah	$0.08258	$0.10401	$0.00619	$0.00762
Vermont	$0.15982	$0.17714	$0.00586	$0.01281
Virginia	$0.08183	$0.12069	$0.00831	$0.01230
Washington	$0.08751	$0.09708	$0.00730	$0.00957
West Virginia	$0.09164	$0.11248	$0.00782	$0.00965
Wisconsin	$0.10724	$0.14176	$0.00598	$0.00749
Wyoming	$0.09641	$0.11175	$0.00614	$0.00786

Table A-16: Energy Unit Conversions[99]

Energy Type	Rate Unit	Rate Unit Name	Multiplier to get to kBtu
Electricity	kWh	Kilowatt-hour	3.412
	MWh	Megawatt-hour	3,412
Natural Gas	Therm	Therm	100
	Ccf	Hundred cubic feet	102.6
	m^3	Cubic meter	36.303
Fuel Oil No. 1	Gal	Gallons (US)	139
Fuel Oil No. 2	Gal	Gallons (US)	138
Fuel Oil No. 4	Gal	Gallons (US)	146
Fuel Oil No. 5, No. 6	Gal	Gallons (US)	150
Diesel	Gal	Gallons (US)	138
Propane	Ccf	Hundred cubic feet	251.6
	Gal	Gallons (US)	92
District Steam	Lb	Pound	1.194
	MLbs	Million pounds	1,194,000
	MBtu/MMBtu	Million Btu	1,000
	Therm	Therm	100
District Hot Water	MBtu/MMBtu	Million Btu	1,000
	Therm	Therm	100
	GJ	Gigajoule	947.817
District Chilled Water	MBtu/MMBtu	Million Btu	1,000
	Ton-hour	Ton-hour	12
	GJ	Gigajoule	947.817
Solid Biomass (Wood)	Ton	Ton	17,480
	Tonne/MT	Metric Ton	15,857

[99] ENERGY STAR (2015).

Table A-17: LEED Water Tool Baseline Fixture Assumptions[100]

Fixture Type	Baseline Flush/Flow Rate	Unit	Duration (seconds)
Toilet (male)	1.60	gpf	N/A
Toilet (female)	1.60	gpf	N/A
Urinal	1.00	gpf	N/A
Public Restroom Faucet	0.50	gpm	30
Private (residential) Restroom Faucet	2.20	gpm	60
Kitchen Faucet	2.20	gpm	15
Residential Kitchen Faucet	2.20	gpm	60
Showerhead	2.50	gpm	300
Residential Showerhead	2.50	gpm	480

Table A-18: LEED Water Tool Uses Per Day Assumptions[101]

Fixture Type	Employees (FTE)	Visitors	Retail Customers	Students (K-12)	Residents
Toilet (male)	1	0.1	0.1	1	5
Toilet (female)	3	0.5	0.2	3	5
Urinal	2	0.4	0.1	2	0
Public restroom faucet	3	0.5	0.2	3	0
Private (residential) restroom faucet	0	0	0	0	5
Kitchen faucet	1	0	0	0	0
Residential kitchen faucet	0	0	0	0	4
Showerhead	0.1	0	0	0	0
Residential showerhead	0	0	0	0	1

[100] USGBC (2019).
[101] Ibid.

Table A-19: WaterSense Water Budget Tool Irrigation Distribution Uniformity Assumptions[102]

Irrigation Type	DU
Drip – Standard	70%
Drip – Press Comp	90%
Fixed Spray	65%
Microspray	70%
Rotor or Rotating Nozzles	70%
No Irrigation	N/A

Table A-20: WaterSense Water Budget Tool Landscape Coefficient Assumptions[103]

Plant Type or Landscape Feature	Water Requirement: Low	Water Requirement: Medium	Water Requirement: High
Trees	0.2	0.5	0.9
Shrubs	0.2	0.5	0.7
Groundcover	0.2	0.5	0.7
Turfgrass	0.6	0.7	0.8
Pool, Spa, or Water Feature	0.8	0.8	0.8
Permeable Hardscape	0.0	0.0	0.0
Non-vegetated Softscape	0.0	0.0	0.0
Xeriscape	0.0	0.0	0.0

[102] U.S. EPA (2020b).
[103] Ibid.

APPENDIX B: REFERENCES

Alatorre, M. & Neumann, I. (2016a). *Energy efficiency comparison nonresidential construction 2016 CA Title 24 Part 6 vs. 2013 ASHRAE 90.1.* California Energy Commission. Publication Number: CEC-400-2016-017. https://www.energycodes.gov/sites/default/files/documents/California_Energy_Efficiency_Comparison_Commercial.pdf.

Alatorre, M. & Neumann, I. (2016b). *Energy efficiency comparison residential construction 2016 CA Title 24 Part 6 vs. 2015 International Energy Conservation Code.* California Energy Commission. Publication Number: CEC-400-2017-006. https://www.energycodes.gov/sites/default/files/documents/California_Energy_Efficiency_Comparison_Residential.pdf.

Albrice, D. (2015, January 28). *How long do buildings last?* RDH Making Buildings Better. https://www.rdh.com/blog/long-buildings-last.

Bon, M. (2020, November 29). Refrigerants used in buildings and HVAC equipment. Archtoolbox. https://www.archtoolbox.com/materials-systems/sustainability/refrigerants-used-in-buildings-and-hvac-equipment.html.

Building Transparency. (2020). *Embodied Carbon in Construction Calculator*. https://buildingtransparency.org/ec3.

Carbon Leadership Forum. (2017). *Embodied carbon benchmark study.* https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/38017/CLF%20Embodied%20Carbon%20Benchmark%20Study.pdf?sequence=4&isAllowed=y.

Carbon Leadership Form. (2018). *Recommended guidelines for building component lifespans in whole building life cycle assessment*. https://www.carbonleadershipforum.org/wp-content/uploads/2018/07/CLF_Recommendations_BuildingComponentLifespans_07-06-2018.pdf.

Charlotte HVAC Guide. (2021). How many pounds of refrigerant, does an AC or heat pump need? http://www.charlottehvacguide.com/guides/how-many-pounds-of-refrigerant-does-an-ac-or-heat-pump-need/.

Chemnick, J. (2021, March 1). *Biden raises key metric for greenhouse gases*. E&E News. Reprinted by Scientific American. https://www.scientificamerican.com/article/cost-of-carbon-pollution-pegged-at-51-a-ton.

Cluett, R., Duer-Balkind, M., Perakis, J., Tosh, J., & Simpson, M. (2020). *Driving market transformation, ranking and rewarding certifications for energy-efficient and healthy multifamily buildings.* Proceedings of the 2020 American Council for an Energy-Efficient Economy's Summer Study in Buildings. Fannie Mae. https://multifamily.fanniemae.com/media/14001/display.

Education Commission of the States (2020). *What is the state's requirement of minimum number of days or hours/minutes in a school year?* https://internal-search.ecs.org/comparisons/instructional-time-policies-01

ENERGY STAR. (2015). *Technical reference: Thermal energy conversions.* https://portfoliomanager.energystar.gov/pdf/reference/Thermal%20Conversions.pdf.

ENERGY STAR. (2020a). *Technical reference: Greenhouse gas emissions*. U.S. Environmental Protection Agency. https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf.

ENERGY STAR. (2020b). *Technical reference: Source energy*. U.S. Environmental Protection Agency. https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf.

ENERGY STAR. (2020c). *The difference between site and source energy.* U.S. Environmental Protection Agency. Retrieved March 25, 2021, from: https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/difference.

ENERGY STAR. (2021). *What should I include in my GFA?* U.S. Environmental Protection Agency. https://energystar-mesa.force.com/PortfolioManager/s/article/What-should-I-include-in-my-GFA-1600088537610#:~:text=The%20Gross%20Floor%20Area%20(GFA,(s)%20including%20supporting%20areas.

Fannie Mae. (2019). *Instructions for performing a multifamily property condition assessment (Version 2.0) Appendix F – Estimated useful life tables*. https://multifamily.fanniemae.com/media/6701/display.

Federal Emergency Management Agency. (2010). *Substantial improvement/substantial damage desk reference.* U.S. Department of Homeland Security. https://www.fema.gov/sites/default/files/2020-07/fema_nfip_substantial-improvement-substantial-damage-desk-reference.pdf.

Fixd Repair. (2019, March 10). *Air conditioner refrigerant costs – on the rise?* https://portal.fixdrepair.com/blog/air-conditioner-refrigerant-costs/.

Green Building Information Gateway. (2021). *Buildings map.* U.S. Green Building Council. Retrieved January 17, 2021, from http://www.gbig.org/collections/14544.

Hess, B. (2021, April 16). *HFC refrigerants used in commercial air conditioning*. AC & Heating Connect. https://www.ac-heatingconnect.com/facility-managers/hfc-refrigerants-used-commercial-air-conditioning/.

Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories, Volume 1, Chapter 1: Introduction*. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf.

Intergovernmental Panel on Climate Change. (2018). *Fourth assessment report, Working Group 1, Chapter 2: Changes in atmospheric constituents and in radiative forcing*. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf.

International Capital Markets Association. (2021a). *Guidance handbook*. https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/guidance-handbook-and-q-and-a.

International Capital Markets Association. (2021b). *Handbook: Harmonised framework for impact reporting*. https://www.icmagroup.org/sustainable-finance/impact-reporting/.

International Living Future Institute. (2020). *Frequently asked questions.* Retrieved March 25, 2021, from https://living-future.org/contact-us/faq/.

Mozingo, L. & Arens, E. (2014). Quantifying the comprehensive greenhouse gas co-benefits of green buildings. *UC Berkeley: Center for the Built Environment*. https://escholarship.org/uc/item/935461rm

New Buildings Institute. (2021). *ZEPI*. Retrieved March 25, 2021, from https://newbuildings.org/code_policy/zepi/.

Nordic Public Sector Issuers. (2020). *Position paper on green bonds impact reporting.* https://www.kuntarahoitus.fi/app/uploads/sites/2/2020/02/NPSI_Position_paper_2020_final.pdf.

NWA Cooling and Heating. (2019, April 30). *How much refrigerant?* http://nwacoolingandheating.net/how-much-refrigerant/.

PAE Engineers. (2020, May 5). *City of Seattle refrigerant Emissions Analysis, GHG emissions calculation methodologies*. https://www.seattle.gov/documents/Departments/OSE/Building%20Energy/SEA_Refrigerant_Analysis_May2020.pdf.

Palanki, G. (2019, March 14). *Arc for LEED.* Arc Skoru. https://arcskoru.com/arc-leed.

PickHVAC. (2021). *Central Air Conditioner Reviews and Prices 2021*. https://www.pickhvac.com/central-air-conditioner/#How_to_Choose_Right_Ton_Size_for_Your_Home.

Sachs, J. (2020). *America's zero carbon action plan.* Sustainable Development Solutions Network. https://irp-cdn.multiscreensite.com/6f2c9f57/files/uploaded/zero-carbon-action-plan.pdf.

Strongin, S. & McConahey, E. (2021. May 21). *Decarbonization pathways for existing buildings in Los Angeles*. U.S. Green Building Council Los Angeles Municipal Green Building Conference and Expo. https://whova.com/web/mgbca1_202105 and https://www.youtube.com/watch?v=KLofB1LwO7g.

The White House Briefing Room Blog. (2021, February 26). *A return to science: Evidence-based estimates of the benefits of reducing climate pollution*. www.whitehouse.gov/briefing-room/blog/2021/02/26/a-return-to-science-evidence-based-estimates-of-the-benefits-of-reducing-climate-pollution/.

Turpin, J. (2021, June 1). *Replacing R-410A in Rooftop Units*. The Air Conditioning, Heating, Refrigeration News. https://www.achrnews.com/articles/144977-replacing-r-410a-in-rooftop-units.

United Nations. *Sustainable development goals*. Retrieved November 9, 2020, from https://www.un.org/sustainabledevelopment/.

U.S. Department of Energy. (2010). *Guidelines for estimating unmetered landscaping water use.* https://www.energy.gov/sites/prod/files/2013/10/f3/est_unmetered_landscape_wtr.pdf.

U.S. Department of Energy. (2016). *Saving energy and money with building energy codes in the United States.* https://www.energy.gov/sites/prod/files/2016/08/f33/Codes%20Fact%20Sheet%208-25-16.pdf.

U.S. Department of Energy. (2020a). *Commercial prototype building models*. Retrieved March 25, 2021, from www.energycodes.gov/development/commercial/prototype_models.

U.S. Department of Energy. (2020b). *Residential prototype building models*. Retrieved March 25, 2021, from https://www.energycodes.gov/development/residential/iecc_models.

U.S. Department of Energy. (2020c). *Status of state energy code adoption*. Retrieved December 14, 2020, from https://www.energycodes.gov/status-state-energy-code-adoption.

U.S. Energy Information Administration. (2020a). *Average retail price of electricity to ultimate customers: Commercial average monthly bill by Census Division, and State*. Release Date: October 5, 2020. https://www.eia.gov/electricity/data.php#sales.

U.S. Energy Information Administration. (2020b). *Average retail price of electricity to ultimate customers: Residential average monthly bill by Census Division, and State.* Release Date: October 5, 2020. https://www.eia.gov/electricity/data.php#sales.

U.S. Energy Information Administration. (2021a). *Natural gas prices (Data series: Commercial price, Period: Annual)*. Release Date: March 31, 2021. https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm.

U.S. Energy Information Administration. (2021b). *Natural gas prices (Data series: Residential price, Period: Annual)*. Release Date: March 31, 2021. https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm.

U.S. Environmental Protection Agency. (2010). Transitioning to low-GWP alternatives in commercial refrigeration. https://www.epa.gov/sites/default/files/2015-07/documents/transitioning_to_low-gwp_alternatives_in_commercial_refrigeration.pdf.

U.S. Environmental Protection Agency. (2014a). Center for Corporate Climate Leadership. *Greenhouse gas inventory guidance: Direct fugitive emissions from refrigeration, air conditioning, fire suppression, and industrial gases.* https://www.epa.gov/sites/default/files/2015-07/documents/fugitiveemissions.pdf.

U.S. Environmental Protection Agency. (2014b). *WaterSense water budget approach.* https://www.epa.gov/sites/production/files/2017-01/documents/ws-homes-water-budget-approach.pdf.

U.S. Environmental Protection Agency. (2019). Office of Resource Conservation and Recovery. *Documentation for greenhouse gas emission and energy factors used in the Waste Reduction Model (WARM). Background chapters*. https://www.epa.gov/sites/production/files/2019-06/documents/warm_v15_background.pdf.

U.S. Environmental Protection Agency. (2020a). *WaterSense product specifications.* Retrieved March 31, 2021, from https://www.epa.gov/watersense/product-specifications.

U.S. Environmental Protection Agency. (2020b). *WaterSense water budget tool, version 1.04*. https://www.epa.gov/watersense/water-budget-tool.

U.S. Environmental Protection Agency. (2020c). *WaterSense water budget data finder.* https://www.epa.gov/watersense/water-budget-data-finder.

U.S. Environmental Protection Agency. (2021a). *Emissions & generation resource integrated database (eGRID2019). https://www.epa.gov/egrid/summary-data*.

U.S. Environmental Protection Agency. (2021b). *Emission factors for greenhouse gas inventories.* https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

U.S. Environmental Protection Agency. (2021c). *The emissions & generation resource integrated database: eGRID Technical Guide with Year 2019 Data.* https://www.epa.gov/egrid/egrid-technical-guide.

U.S. Green Building Council. (2019). *LEED v4 indoor water use reduction calculator.* https://www.usgbc.org/resources/leed-v4-indoor-water-use-reduction-calculator.

U.S. Green Building Council. (2021). *Definitions for enhanced management calculation (EAc4).* https://www.usgbc.org/resources/definitions-enhanced-refrigerant-management-calculation-eac4.

World Green Building Council. (2020). *About green building.* Retrieved December 14, 2020, from https://www.worldgbc.org/what-green-building.