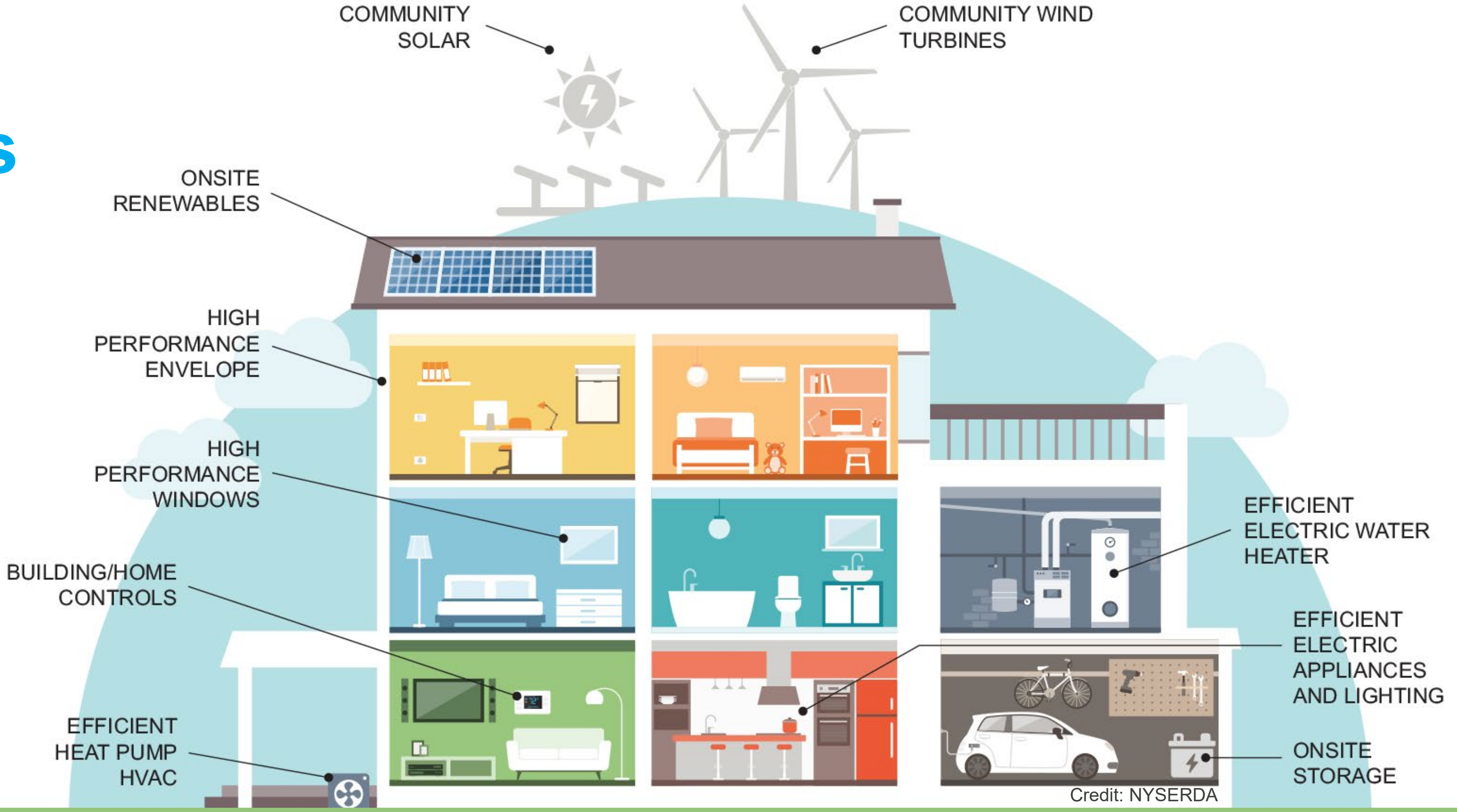
An insider's guide to talking about carbon neutral building operations



Credit: NYSERDA

This document was developed by New Buildings Institute in collaboration with a number of professional trade groups and other nonprofits.

Addressing carbon neutral building operations matters

The urgency around climate change is pressing us to rethink our approach to delivering and using energy in buildings and how this relates to greenhouse gas emissions (GHG) emissions. As buildings represent 40% of the energy used in the United States and 39% of the carbon footprint, action on the built environment is imperative to address and mitigate the impacts of climate change.

Carbon neutral building operations will reduce global greenhouse gas emissions (GHG) and be part of the solution to keeping global temperature rise under 1.5 degrees.

The building sector is shifting from decades of regulation and programmatic oriented on energy efficiency (kWh and therms) to governmental action centered on carbon and greenhouse gas emission reductions (CO2e). While energy and carbon metrics are related, they are not the same.

But what does it mean to deliver on carbon neutral building operations?

This document aims to provide a framework to help us talk about the current transition consistently and with clarity.

A common framework for talking about carbon

A common language and framework are necessary to align market ideas around what it means to design, construct, and operate buildings that contribute little or no carbon emissions. This summary aims to help define some aspects that describe what it means for a building to be carbon neutral and the relationship between energy and carbon metrics in the built environment.

This material was developed with input from a collaborative of industry professional trade organizations. It does not represent the positions of any one group, but rather presents a framework for all groups to work from. This information can be integrated by organizations into guidance materials, training, and other programmatic aspects related to carbon neutral buildings.

Each carbon neutral component focuses primarily on building operations and is presented at a high-level. The details behind each element are extensive and purposely not explored in full. Each organization will need to explore and clarify the particulars to their audience. Resources provided within can support the details.

This material intends to:

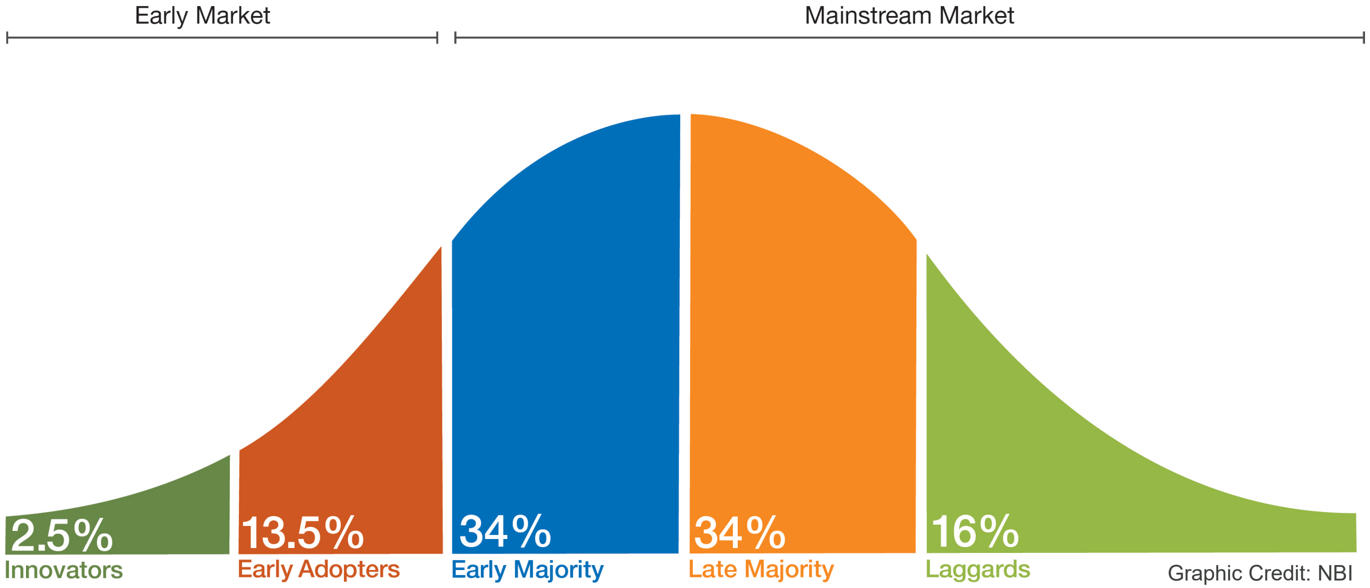
Reach the middle majority segment of the market through consistent communications among the AEC community.

The middle majority includes those who are generally unaware of the carbon policies and programs being increasingly adopted by jurisdictions. We are working to build knowledge on how these policies translate into design practice, building operation, energy procurement, etc. to prepare the entire market for future clean energy policies.

Find the common themes within the landscape of carbon neutral buildings.

Each user can adjust the components according to specific needs. For instance, one can choose to add electrification or whole life embodied carbon as part of the base definition/program element. Or plan to incorporate these components later, inline with their goals. A tenant-focused approach will change the boundary and controllability of the base-building, but carbon neutral status is still achievable.

Adoption Curve



Graphic Credit: NBI

Carbon neutral definitions vary

Review of over 15 organizational definitions of carbon neutral building operations found a number of aspects that varied in how they were represented including embodied carbon, on-site combustion, how renewables were defined and counted, etc.

The good news? There are more commonalities across the definitions. The divergence is often in the details.

This chart represents a few carbon neutral definitions from programs and shows the commonalities and variances.

	Performance or Design	Metric	Boundary	Combustion Allowed?	Efficiency Required?	Off-site RE Allowed?	Other Reqs.
LIVING BUILDING CHALLENGE					NC: 70% EBB* EB: 50% EBB (both w/ PV)	Yes. Using the off-site RE exception.	Must include on-site storage; 20% embodied carbon reduction.
ZERO ENERGY CERTIFICATION					Highest efficiency	Yes, must be local. 75% of roof for solar.	
ZERO CARBON CERTIFICATION					NC: 25% < 90.1-2010 EB: 30% < CBECS	Yes. Must be *additional.*	10% Embodied Carbon Reduction + Carbon offsets for the remainder
LEED Zero ENERGY / LEED Zero CARBON					No, but LEED Certified	Yes. See tiered structure for on- and off-site RE	Must be LEED-NC or EBOM certified. Performance in Arc. TOU option for LZC.
ZERO CODE™					Must meet ASHRAE 90.1-2019	Yes. After on-site. Tiered structure applies discount factor to various	Off-site renewables are discounted
WORLD GREEN BUILDING COUNCIL					Highly energy efficient building	Yes	Embodied carbon may be included later
AIA 2030 Commitment				Not allowed in 2030	70% better than CBECS 2003	Yes, but not counted	Seeking to incorporate refined carbon specific metrics

= Transportation = Embodied Carbon = Site Energy Use = CO2e = Source Energy Use

Credit: WSP with NBI additions

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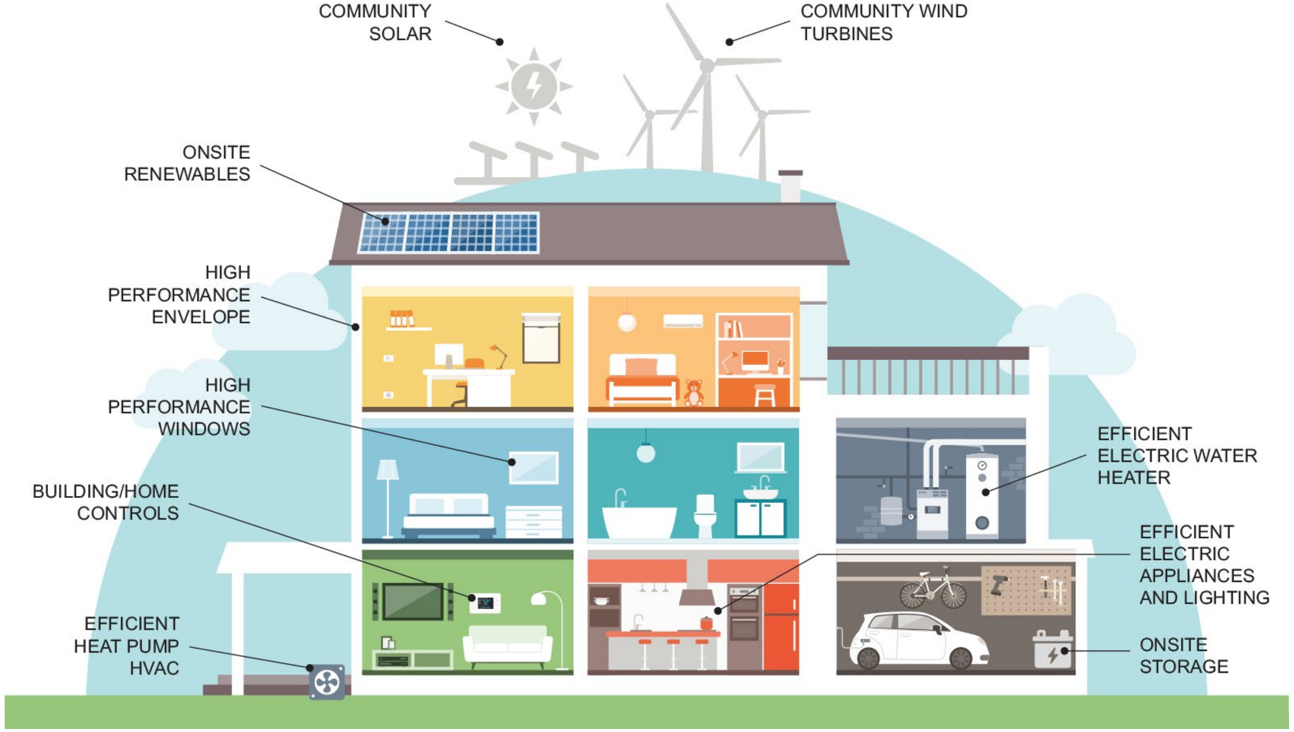
Core components of net zero energy building versus carbon neutral buildings

A **net zero energy building** is a highly **energy efficient** building that maximizes on-site **renewables** and **procures off-site renewables**. For the most part, so too are the components of a carbon neutral building operations. However, to achieve carbon neutral operations, any carbon produced from grid- or on-site-supplied energy must be offset through additional renewable energy procurement.

Core Components:

- Maximize energy efficiency
- Prioritize on-site renewables
- Utilize off-site renewables
- Measure and manage net zero operations



Credit: NYSERDA

Additional Components:

- Electrification-ready and minimize/eliminate on-site fossil fuels
- Optimize building-grid integration and on-site storage
- Specify low GWP refrigerants
- Select low embodied carbon materials

Additional components of net zero energy building versus carbon neutral buildings

In addition to the Core Components, **carbon neutral buildings** should incorporate as much as possible the additional components listed below. As grid-supplied resources get cleaner, **building-grid integration** will become necessary to address peak demand and enable load shifting. Reducing onsite GHG emissions through **electrification** and **embodied carbon** will become priorities for driving down the climate changing impacts of the built environment.

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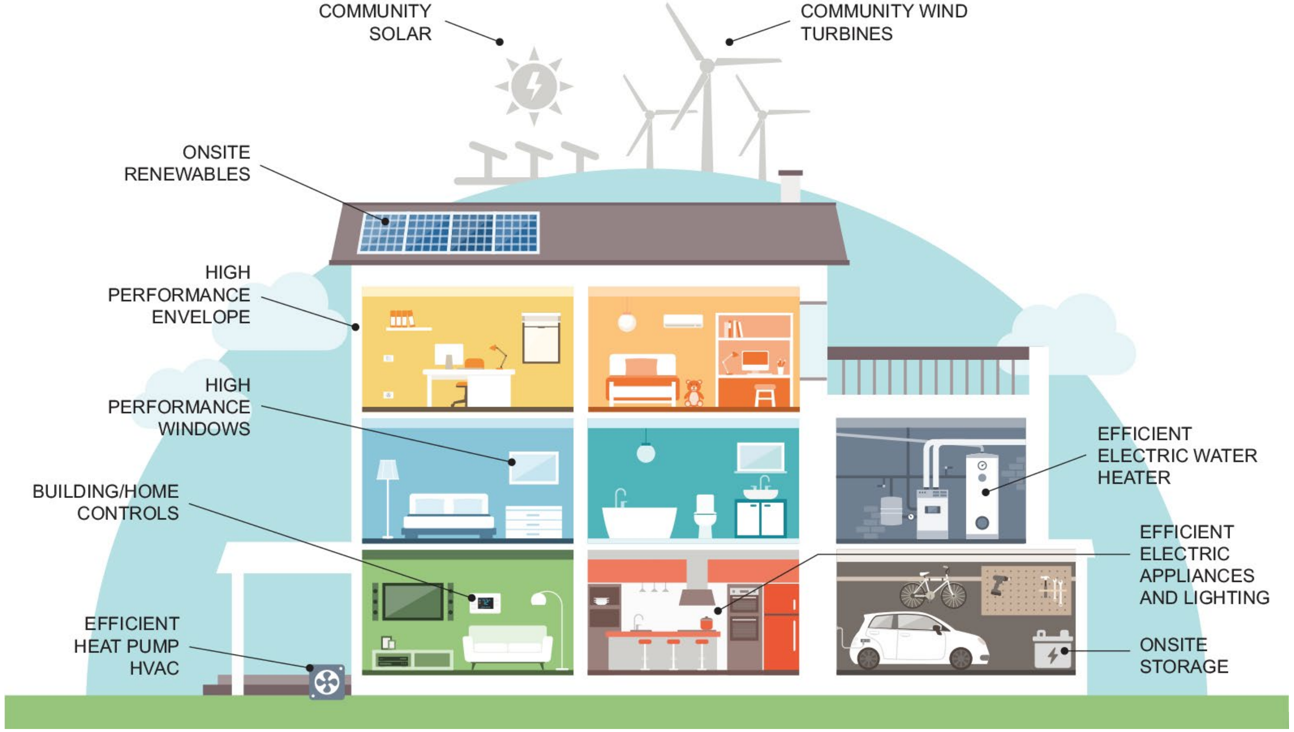

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Additional Components:

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Core Carbon Neutral Building Components

Maximize Energy Efficiency

Critical Considerations:

- High performance building envelope
- Efficiency equipment and appliances
- Smart building controls
- Energy efficient lighting
- Energy Star appliances

Energy efficiency minimizes grid impacts, regardless of time or source energy. Low carbon and carbon neutral building operations start with reducing energy demand. This reduction limits the quantity of on-site and off-site renewables needed to offset consumption.

For example:

a commercial building built
to ASHRAE 90.1-2019 uses

~47 kBtu/sf/yr

while a highly efficient
net zero energy building uses

~20-24 kBtu/sf/yr

Prioritize On-Site Renewables

Critical Considerations:

- Shading from trees that impact sun exposure
- Shading from neighboring structures and future buildings
- Building orientation
- Floor area ratio

Incorporate on-site renewables to produce emission-free energy, which offsets operational emissions. Solar photovoltaics (PV) is a typical option for creating energy on-site.

Since the price of PV depends on the amount of energy generation needed, reduced energy demand can minimize the upfront cost.

Find the optimal cost-effectiveness balance point between energy efficiency investments and on-site renewable capacity.

Calculate the impacts of various PV siting options:

- ✓ **The roof –** usually the simplest and most cost-effective option.
- ✓ **Ground-mounted arrays or parking structures –** these are common and effective but may incur additional costs due to structural needs.
- ✓ **The building façade –** typically less cost-effective due to (product costs,) suboptimal panel orientation and higher mounting costs; may be suitable for some projects).
- ✓ **Off-site options –** if on-site energy generation does not offset the building energy consumption, off-site renewables should be considered. See next page for more.

Utilize Off-Site Renewables

Critical Considerations:

The contract duration shouldn't be less than 15 years

The contract must survive a transfer of building ownership

Renewable energy certificates (RECs) from off-site renewables should be exclusive to the building owner for 15+ years

The energy source should be from solar, wind, or geothermal energy

Meeting the energy needs of a project may not be possible with only on-site renewables. Off-site renewables may be necessary to achieve a carbon neutral building operation status.

Off-site renewables may have a variety of contractual arrangements including:

- Direct ownership of off-site systems
- Power purchase agreement
- Community solar
- Utility delivered renewables

ASHRAE 189.1-2020 and the 2021 International Green Construction Code (IGCC) require on-site renewable systems, and 50% of the energy supplied to the building be from renewable sources. Additionally, a "renewable energy factor" is applied to off-site renewable energy sources. This factor discounts off-site renewables depending on the source's characteristics, thus requiring additional off-site procurement to comply.

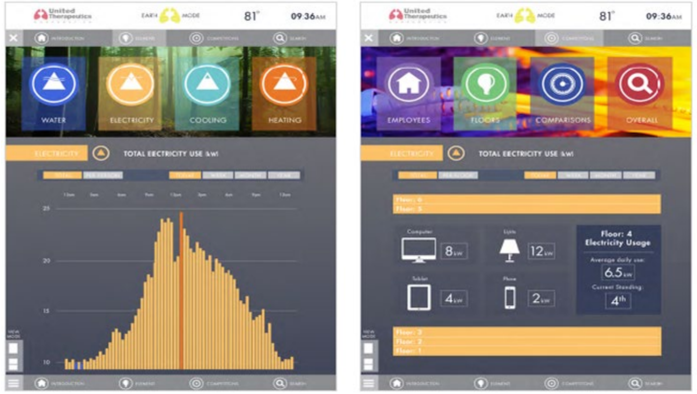
Measure and Manage Net Zero Operations

Critical Actions:

- Maintain energy efficiency
- Minimize peak energy events
- Manage energy consumption and production
- Adjust system controls for efficient operations
- Purchase additional renewables, if necessary
- Track embodied carbon related to product replacement

Ongoing monitoring and tracking of energy consumption and renewable production is necessary to understand a building's carbon emissions. Utility bills or a building energy management system can support the review of building system emissions. New construction projects can use predicted energy and carbon performance to compare against actual energy consumption and emissions to identify if systems are operating as expected. Study if refrigerants from heat pumps and other refrigerants, and fire suppression systems have leaked or evaporated.

Uncovering irregularities through periodic data review can help to promptly correct issues and neutralize emissions.



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Additional Carbon Neutral Building Components

Electrification-Ready, Electrification, and Minimization of On-Site Fossil Fuel Combustion

Critical Considerations:

- Energy efficient equipment
- High-capacity electrical panels
- Electrical chases and conduit runs for future renewables and electric vehicles
- Electrical outlets near gas equipment

Carbon neutral buildings minimize or eliminate on-site natural gas and other fossil fuels because fossil fuel combustion (i.e., propane and gas) directly contributes to GHG emissions. Building electrification combined with energy efficiency can reduce air pollution, assist with better grid management, and permanently lower utility expenses.

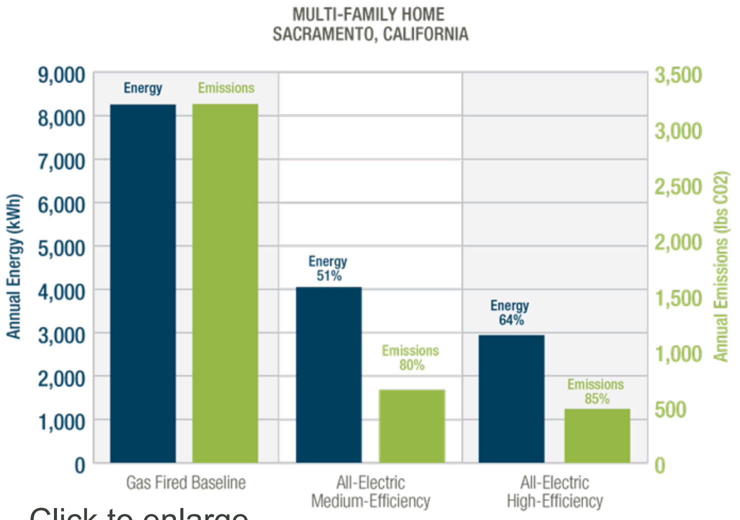
Electric-powered building technologies deliver the same thermal comfort of traditional gas equipment with lower emissions, and they are often more efficient than their counterparts. These include heat pump water heaters and space heating, induction stoves, fireplaces, etc. As the grid becomes cleaner, building technologies that don't rely on gas fuel will become more important to mitigate carbon and other GHG emissions.

Natural gas combustion emits approximately 0.4 lbs of CO_2e per kWh of energy consumed, or 28% more than the national electric emission rate.

CO_2e per kBtu delivered:
Natural Gas = 0.117 lbs
Electricity = 0.088 lbs

Source: EIA

"Electrification-ready" buildings incorporate high-capacity electrical panels, electrical chases and conduit runs, and locate electrical outlets near gas equipment for future equipment conversion (EV, solar, DHW, etc.) All-electric buildings support a clean energy future as operational GHG emissions will be eliminated when the grid supplies 100% renewables.



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Source: New Buildings Institute

Building-Grid Integration and Energy Storage

Critical Considerations:

- Energy efficiency
- Shift peak energy loads
- Design for flexible loads
- Allow for dispatchable energy storage

Building-grid integration allows buildings and the electrical grid to coordinate energy supply and demand to optimize energy consumption, reduce peak demand, offer more clean energy, and provide a reliable electricity supply.

Smart design, distributed energy resources (DER), and demand response allow grid operators to adjust building heating, cooling, lighting, etc., to reduce power consumption and minimize community-wide service impacts. Building operators can adjust when grid energy is consumed to avoid peak energy rates. The balance of energy resources will improve how we use energy and support a modern grid that is capable of supplying more renewable energy.

Distributed Energy Resources:

- Solar photovoltaics
- Wind turbines
- Energy storage
- Electric Vehicles
- Combined heat and power plants

How buildings support a reliable grid

Grid-friendly Building Strategies:

Permanent Efficiency

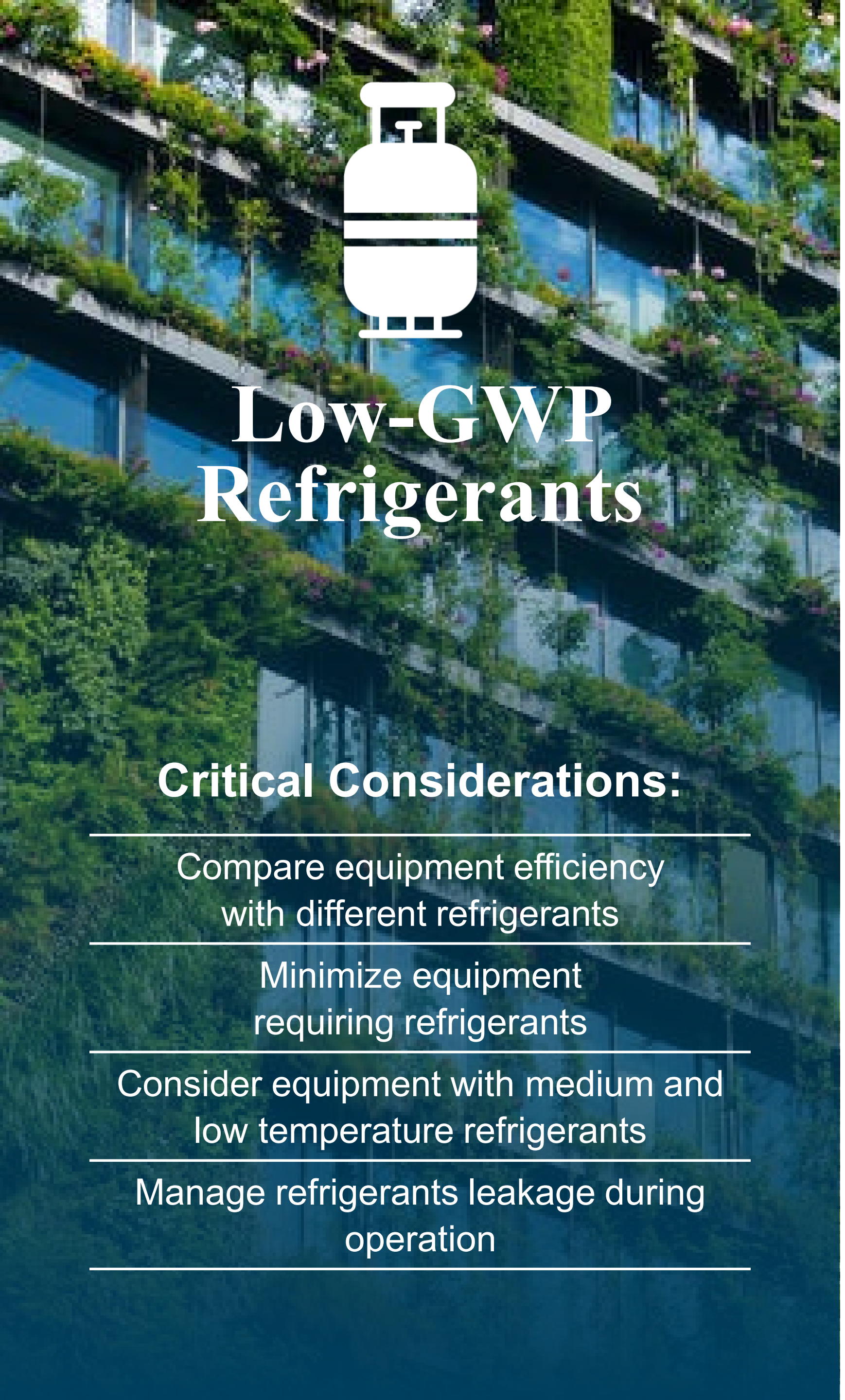
- Efficient systems

Peak Shifting and Flexible Loads

- Smart controls
- Thermal mass
- Energy storage / batteries

Dispatchable Energy Storage

- Intelligent, grid-integrated communication
- Smart systems and devices for HVAC, water heating, lighting, and electric vehicles, can align building energy



Low-GWP Refrigerants

Critical Considerations:

- Compare equipment efficiency with different refrigerants
- Minimize equipment requiring refrigerants
- Consider equipment with medium and low temperature refrigerants
- Manage refrigerants leakage during operation

Most refrigerants are high global warming potential (GWP) chemicals that can be up to thousands of times more polluting than carbon dioxide alone. Fire suppression systems and heat pumps are common sources of refrigerants. They may also be sources of emissions from leakage or evaporation.

Choosing a 20-year GWP rather than a 100-year GWP will place more emphasis on reducing emissions of short-term, climate-changing gases (methane and refrigerants) relative to reducing emissions that contribute CO_2e.

Refrigerant leak detection systems can improve a system's performance and minimize the release high GWP chemicals directly intro the environment. Leaks require more refrigerants to recharge the system, releasing even more potent emissions.

Link to refrigerant GWP table

Consider refrigerants outside of the main cooling systems. Refrigerants are used in many different systems:

- Refrigeration
- Freezers
- Air-conditioning
- Heat pumps
- Chillers
- Fire extinguishing systems
- Aerosols

Low-GWP refrigerants include:

- Ammonia
- CO_2
- Propane

Low-Embodied Carbon Materials

Critical Considerations:

- Reduce the number of materials
- Reuse materials
- Select materials that sequester carbon
- Prioritize durable materials to minimize product replacement
- Design for deconstruction

As building energy efficiency increases and more buildings eliminate fossil fuels in building operations, the impact of upfront embodied carbon emissions in building materials is becoming increasingly significant. Construction materials alone are responsible for about 11% of all global carbon emissions. Embodied carbon refers to the total impact of all human induced greenhouse gases emitted from material extraction through the end of its useful life. Thoughtful material selection can easily change a buildings' embodied carbon and reduce global climate emissions.

Low embodied carbon materials include:

- Low-Portland cement concrete
- Wood and bio-based
- Reuse/reclaim
- High recycled content
- Local
- Unfinished materials (polished concrete)

Link to graph of carbon reduction during construction phases

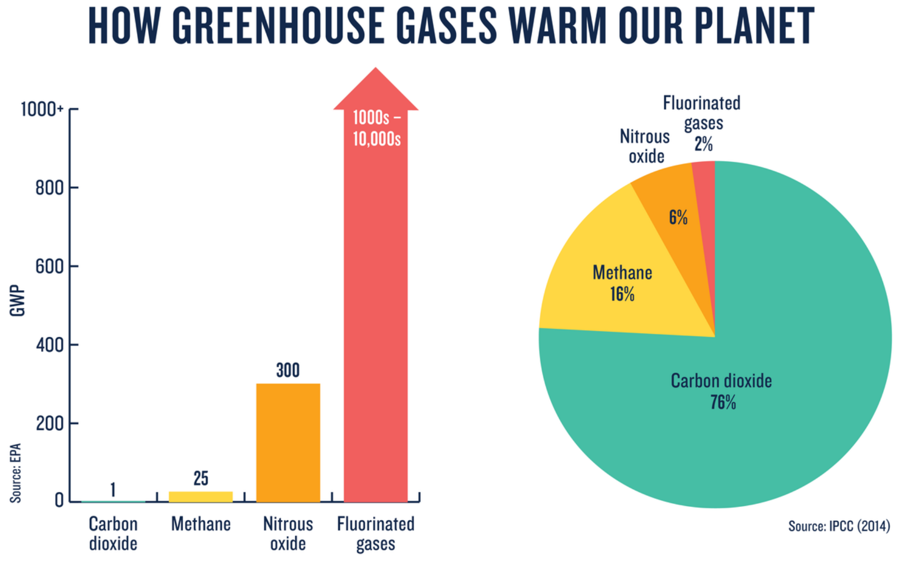
Embodied carbon is calculated by summing all emissions emitted from non-renewable energy sources resulting from sourcing raw materials, manufacturing, transporting, construction and installation activities, ongoing material/product energy use, maintenance, repair, and finally, disposal.

Additional Considerations

Additional considerations

Program details include specific requirements to determine carbon neutral compliance. Incorporating common program elements can help clarify how carbon neutral is understood in the market. Variations are inevitable. The more insight users have into why specific elements are included or not, they can compare carbon neutral buildings.

Measuring building GHG emissions depends on project goals. Buildings may only calculate operational emissions from energy consumption and production, while others consider the whole life of embodied carbon from materials through end of life. There are several considerations on the right.



The global warming potential (GWP) of human-generated greenhouse gases is a measure of how much heat each gas traps in the atmosphere, relative to carbon dioxide.

How much each human-caused greenhouse gas contributes to total emissions around the globe.

Critical Considerations:

Project boundary could be determined by the scope including: Unit, building, Site, Campus, Portfolio

Convert energy to carbon dioxide equivalent (CO2e) to determine the amount of CO2 which would have the equivalent global warming impact

Energy consumption time of use (TOU) impact the emissions associated with a regional electric grid.

Proximity to public transit, site delivery efficiency considerations, and electric vehicle charging will impact emissions.

Construction and operational materials can reduce waste at the end of their useful life through upcycling, reuse, recycling, to minimize the demand for new products.

Calculating carbon neutral operations:

Calculations will vary per program, jurisdictions, etc. Here is one example.

1.

Determine annual energy consumption and GHG emissions.

- Energy can be predicted or performance-based.
- Use annual or hourly kWh and therms, or other energy.
- Convert to CO_2e.

2.

Deduct energy production emissions avoided.

- On-site or off-site renewables.

3.

Calculate your annual GHG emissions per location.

- Use eGrid or utility emissions.

4.

Secure off-site renewables to cover the remaining emissions.

- Procure a 15-year contract.
- Retain or retire procured renewable energy certificates (RECs.)
- Discount off-site renewables by 25%.

Source: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
** 25% discount applied

This approach is based on USGBC's LEED Zero.

Example calculation

	Energy	MT CO_2e
Consumption: kWh/yr	694,021	491
Consumption: therms/yr	10,922	58
Production: kWh/yr	726,846	-514
Off site renewables	41,031**	-44**
		Carbon Neutral

Resources

7 Steps to Zero

NBI Zero Energy Project Guide

Prioritize on-site renewables

Project Sun Roof

The Regulatory Assistance Project

Utilize off-site renewables

ASHRAE Standard 189.1, Standard for the Design of High Performance Green Buildings

Emissions & Generation Resource Integrated Database (eGrid)

Measure and manage carbon neutral operations

Zero Net Energy Building Controls: Characteristics, Energy Impacts, and Lessons

Electrification-ready, electrification, and minimization of on-site fossil fuel combustion

Climate Friendly Buildings

The Economics of Electrifying Buildings

Zero Emissions All-Electric Multifamily Construction Guide

Building Electrification Technology Roadmap (BETR)

Building-grid integration and energy storage

GridOptimal Buildings Initiative

Low-embodied carbon materials

AIA Guide to Building Life Cycle Assessment in Practice

Motivating Low Carbon Construction: Opportunities and Challenges

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