Pacific Northwest
NATIONAL LABORATORY

Zero Energy and Emissions

Building Energy Code Technical Briefs

INTRODUCTION

Residential and commercial buildings are the single-largest energy-consuming sector of the U.S. economy, representing approximately 39% of U.S. total energy consumption and 74% of its electricity use, which makes buildings responsible for 35% of energy-related emissions. DOE provides technical assistance supporting cost-effective increases in energy efficiency and performance of homes and commercial buildings through building energy codes.[1] As states and local governments explore ways to meet their energy and emissions reduction goals, they have expressed interest in building standards supporting net zero energy and emissions.

Building codes can aid energy use and emissions reductions by including compliance criteria for:

- Net zero energy (NZE), based on site energy for mixed fuel buildings
- Net zero operational energy emissions (NZOEE)[2] for mixed fuel buildings
- Net zero energy (NZE) based on site energy for electric buildings
- Net zero operational energy emissions (NZOEE) for all electric buildings

Two published technical briefs provide NZE and NZOEE model code compliance language, including residential prescriptive and performance compliance requirements and commercial performance compliance requirements for mixed-fuel or electric buildings. Planned future technical briefs may include NZOEE prescriptive compliance requirements for commercial buildings and address other stretch code provisions for residential and commercial buildings.

These technical briefs are part of a series of briefs supporting national, state, and local initiatives to update and advance building energy codes developed by the U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory. Each brief is presented in a module format and includes requirements for technologies, measures, or practices that can be incorporated as plug-ins to existing building energy codes. The provided code language can be directly adopted by state and local governments pursuing advanced energy savings and emission reductions.

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[1] 42 USC 6833 and 6836

[2] Emissions associated with carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) can include 1) combustion emissions associated with the burning of a fuel, either within the building or site or to generate electricity, steam, hot water or chilled water used within the building or site 2) precombustion greenhouse gas emissions associated with fuel extraction, processing, and transport, including fugitive emissions, prior to combustion within the building or site or to generate electricity or thermal energy used within the building or site, 3) transmission and distribution losses, and 4) refrigerant emissions due to leakage over the product life product and end of life reclaim.

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Additional briefs supporting zero energy and emission requirements include the following:

Demand response (residential energy code): Outlines requirements for demand-responsive thermostats and water heaters, provides the estimated incremental cost of construction, and includes model code language that can be plugged into the IECC or adapted into other energy codes.

Energy credits (commercial code): Describes additional energy efficiency measures that exceed current prescriptive energy code requirements. Provides savings credits for each measure and specifies additional savings requirements by building type and climate zone as model code plug in language.

Electric readiness (residential energy code): Provides requirements for electric readiness, the benefits of the provisions, and model code language that can overlay the IECC or be incorporated into other energy codes.

Electric vehicle charging (residential and commercial energy codes): Presents a compilation of information on electric vehicles (EVs) and provides energy code language for new construction that addresses EV charging infrastructure.

The full collection of briefs supports DOE's mission to provide technical assistance to states and local governments, helping them to successfully implement their building codes, as well as pursue energy and climate goals. States and jurisdictions may consider combining multiple plug-ins, such as a net zero energy requirement with electric vehicle charging or demand response requirements. The series of technical briefs, including supporting technical information and sample code language, are available at www.energycodes.gov/stretch-codes.

ADAPTING THE MODEL ENERGY CODES TO MEET ZERO GOALS

In this document, the term model energy code refers to the current published versions of the IECC for residential buildings and ASHRAE Standard 90.1 for commercial buildings. Updated versions of each code are published every three years. The model codes are based on mandatory requirements plus additional requirements that must be met through a prescriptive or a performance-based compliance path. Most states and jurisdictions have adopted some version of a current or past code, frequently incorporating their own state- or jurisdiction-specific amendments.

At the completion of each model code development cycle, DOE is required by federal statute to publish a determination as to whether the updated edition will improve energy efficiency compared to the previous version of the energy code. This assessment, which includes a quantitative analysis of energy use reduction, informs states and jurisdictions of the increased efficiency achieved with new editions of the energy code.

A recently published study expands upon the determination analysis to assess the potential energy use reduction attributed to advanced efficiency measures and the potential onsite energy use offset associated with rooftop PV renewable electric energy generation (Franconi et al. 2022).[1] The advanced measures encompass technologies currently being installed in buildings but not yet adopted by codes.

Figure 1 and Figure 2 indicate the magnitude of the relative site energy use reduction required to achieve NZE by 2030. The figures show the impact of the advanced measures (black dashed lines) amended to current code, as well as the energy-use offset attributed to rooftop solar (yellow dashed line). For residential codes, Figure 1 encompasses six historic-to-current code development cycles and three future cycles (2024, 2027, and 2030). For commercial codes, Figure 2 encompasses six historic-to-current code development cycles and three future cycles (2025, 2028, and 2031). The data indicate that energy codes must achieve greater levels of performance at a faster pace than achieved historically. To meet the NZE goal by 2030 (residential code) or 2031 (commercial code) in three code cycles[2], the rate of onsite energy use reduction, resulting from increased efficiency and offsets from renewable energy resources must be achieved at four-times and two-times the rate of advancements achieved to date for residential and commercial code, respectively.

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[1] Franconi, Ellen, Jeremy Lerond, Chitra Nambiar, Dongsu Kim, David Winiarski, and Michael Rosenberg. 2022. "Filling the Efficiency Gap to Achieve Zero Energy Buildings with Energy Codes." PNNL-30547. Pacific Northwest National Laboratory. Available at https://www.energycodes.gov/sites/default/files/2022-03/Feasibility_Study_Final_220323v2_Posted.pdf

[2] Goals established by ASHRAE and the ICC

ENERGY CODE LANGUAGE

This net zero code technical briefs, introduced below, provide overlay language to model energy code to achieve mixed-fuel NZE NZOEE new buildings. The net zero code is intended to be adopted directly by states and local governments. The plug-in language provides multiple compliance options, including:

- Prescriptive (residential)
- Energy Rating Index (residential)
- Performance (residential and commercial)

The generally agreed-upon characteristics of NZE and NZOEE buildings includes designs that incorporate highly energy-efficient technologies and practices, offset energy and emissions with on-site renewable energy sources, and procure offsite site renewable energy where necessary. Specific considerations for model code development that are key to NZE and NZOEE goals are listed below.

Envelope, lighting, and mechanical equipment efficiency – Enhancing envelope thermal efficiency reduces heating and cooling loads, decreases mechanical equipment capacity requirements and energy costs. Harvesting natural daylight and selecting high efficiency electric lighting decreases cooling loads and energy use.

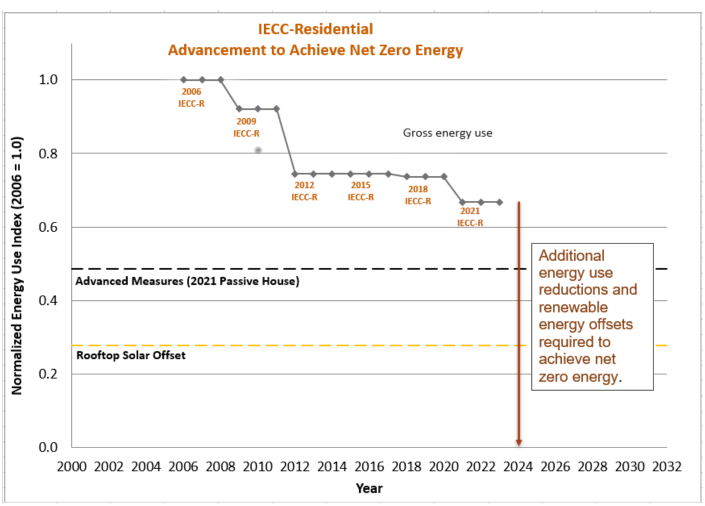

Figure 1. Advances Needed to Achieve Zero Site Energy with Residential Model Energy Code

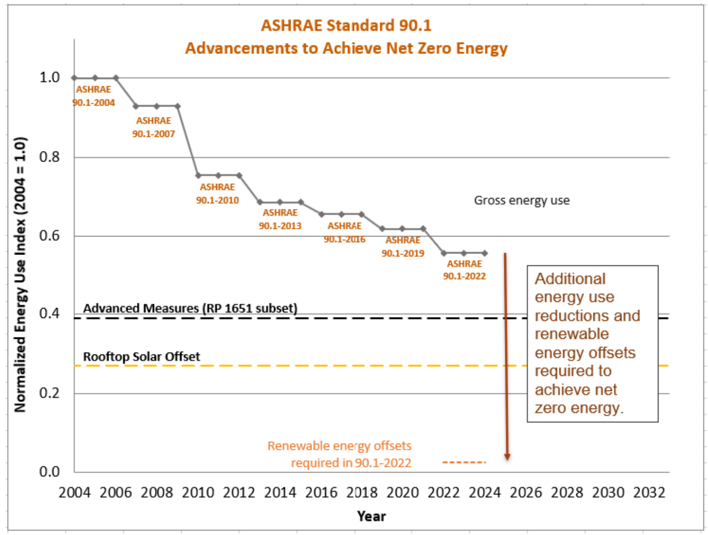

Figure 2. Advances Needed to Achieve Zero Site Energy with Commercial Model Energy Code

Selecting properly sized, high performance mechanical and service hot water equipment further minimize energy use.

Miscellaneous energy – As energy code advancements target decreases in building-regulated energy use, plug and process loads are becoming an increasingly larger component of total energy use. Addressing these loads is needed to meet net zero goals.

Battery and Thermal Storage – Electric and thermal energy storage can reduce peak demand and improve demand flexibility. They also support greater utilization of onsite renewable energy resources, as well as provide energy resilience during power outages.

Electrification – Designing all-electric buildings can provide efficiency improvement (e.g., heat pump space conditioning and hot water systems) and high demand flexibility potential.

Controls and load modulation – building controls support the optimization of building energy systems, including energy storage and generation. Smart controls coupled with grid-communication capabilities can co-optimize systems and dynamically shape energy use, reducing energy costs and greenhouse gas emissions while supporting a resilient grid.

Offsets from onsite renewable energy sources – Net-zero annual site energy use is achieved by using clean energy sources and offsetting energy use with renewable energy generation. Potential benefits of onsite renewable energy generation include site energy use offset, reduced peak demand, net metering, reduced electricity distribution system capacity requirements, and transparent tracking of renewable energy credits.

Offsets from offsite renewable energy sources – When there are insufficient onsite renewable resources available (for example, limited viable rooftop area for installing solar panels due to obstructions or shading) offsite renewable energy procurement may be necessary to achieve net zero energy or emission targets.

Performance Compliance – Utilizing a performance-based compliance supports an integrative design process that can result in lower energy use than a building built to the prescriptive path. Performance metrics also support establishing a glide path for meeting NZE and NZOEE goals over several code cycles.

The NZE and NZOEE plug in language options were developed with these characteristics and design objectives in mind. The performance compliance path requires meeting two metric targets: 1) an efficiency backstop to realize the long-term benefits of reduced energy use[1], and 2) a measure of NZE or NZOEE attainment to verify the building has achieved zero energy or emissions. To calculate the NZOEE attainment metric, annual emission factors for the continental U.S. are provided.[2] Jurisdictions can substitute the values with the local equivalent. This includes approving the use of hourly data.

FILLING THE PERFORMANCE GAP

A key component of the NZE and NZOEE code language development is the establishment of the target value for the efficiency backstop. For NZE and NZOEE compliance, efficiency is higher than that dictated by current published code. It aims to represent building performance levels that can be achieved with market-ready measures, including those currently being installed in new buildings but not yet included in MEC. It is intended to be updated each code cycle. The second compliance metric measures net zero performance. Its target value can be set to achieve net zero in one code cycle or stepped down incrementally to achieve net zero over multiple code cycles.

The beyond current code efficiency requirements specified in the plug-in code language were informed by the advanced measure analysis and code development trends. For the residential code, the efficiency backstop for prescriptive and performance-based compliance is informed by stretch code standards (like Passive House 2021). For commercial code, the efficiency backstop falls in between Standard 90.1-2022 and that achieved with advanced measures. The efficiency backstop established for both residential and commercial net zero code can be achieved with federal minimum efficiency mechanical equipment.

The aggregated U.S. new building performance associated with the NZE and NZOEE gross energy use requirements is shown for residential and commercial model codes in Figure 3 and Figure 4, respectively. The green dashed lines show the performance level associated with the efficiency backstop, achieved with beyond current code efficiency levels. The orange dashed lines show additional reductions needed to achieve NZE, which may be achieved with renewable energy offsets and additional efficiency improvements. Prototype building simulation analysis is used to establish the gross energy use compliance targets and determine the aggregated performance levels shown in the charts. The analysis accounts for different building types, U.S. climate zones, and regional new construction data.

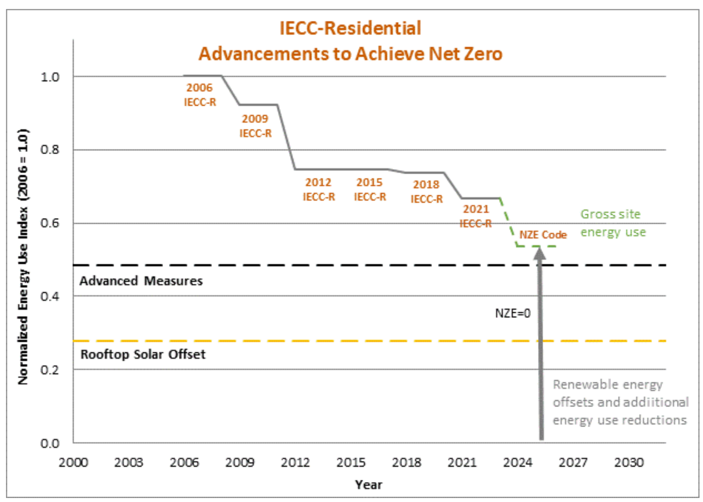

Figure 3. NZE and NZOEE Residential Energy Code Site Energy Use Reduction

[1] The net zero operational energy emissions (NZOEE) metric is typically more stringent than net zero site energy (NZE) metric and tends to favor electric space and water heating technologies, especially in areas with clean grids.

[2] The electricity values, provided by eGRID subregion, are based on 2022 Cambium long-run marginal emission rates mid-case scenario for a 20-year levelized analysis period, zero discount rate, and a 20-year greenhouse gas global warming potential. Note that these tech briefs do not purport to be the best or only method to achieve zero emissions, nor were they necessarily designed to align with other industry definitions or standards that set criteria for achieving zero emissions buildings.

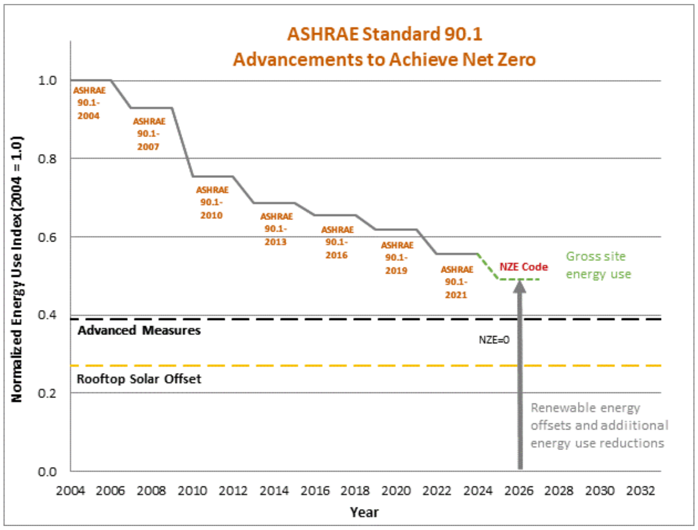

Figure 4. NZE and NZOEE Commercial Energy Code National Site Energy Use Reduction

The model code plug-in language for NZE and NZOEE mixed-fuel commercial buildings is available here: Commercial Zero Code Tech Brief. The model code plug-in language for NZE and NZOEE mixed-fuel residential buildings is available here: Residential Zero Code Tech Brief.

HOW TO USE THE NZE AND NZOEE PLUG INS

The plug-in tech briefs are developed to support state and local jurisdiction pursuing advanced energy savings and emission reductions. Each contains model energy code overlay language that can be readily incorporated into adopted energy codes. Specifically, their adoption can support identified performance objectives, including building energy efficiency, reductions in greenhouse gas emissions, load flexibility, and grid resilience.

LEARN MORE

The series of technical briefs, including supporting technical information and sample code language, are available at https://www.energycodes.gov/stretch-codes.

For more information, contact:

Michael Rosenberg
michael.rosenberg@pnnl.gov

Ellen Franconi
ellen.franconi@pnnl.gov

Robert Salcido
victor.salcido@pnnl.gov

www.pnnl.gov