Pacific Northwest NATIONAL LABORATORY

PNNL-36568

Methodology to Establish Performance Targets for Building Energy Codes

December 2024

Ellen Franconi
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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Acronyms and Abbreviations

BPS	Building Performance Standards
DOE	Department of Energy
ECB	Energy Cost Budget
eGRID	Emissions & Generation Resources Integrated Database
ERI	energy rating index
EUI	energy use intensity
ICC	International Code Council
IECC	International Energy Conservation Code
MEC	model energy code
NEUI	normalized energy use index
NZE	net zero energy
NZOEE	net zero operational energy emissions
PNNL	Pacific Northwest National Laboratory
PRM	Performance Rating Method
PV	photovoltaic
RESNET	Residential Energy Services Network

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Executive Summary

States, local jurisdictions, codes and standards developers, and many organizations across the design and construction industry have expressed interest in setting a clear and more predictable pathway to advance building energy codes, including increasing building energy efficiency and performance through cost-effective improvements, and approaching industry-established zero energy and emissions goals within the designated timeframe. Historically, a broadly applicable and replicable model for guiding model energy code development at the national level has not existed. To address this, and to aid states and local jurisdictions pursuing advanced performance goals, DOE has developed a methodology that can be used to establish building energy performance targets for newly-constructed commercial and residential buildings, and which can be leveraged through future building energy code updates. The resulting compliance targets are intended to illustrate the combined improvements from both reducing gross site energy use and progressively increasing renewable energy offsets to achieve net zero new buildings in future code development cycles.

The framework presented in this report is intended to align with industry efforts to develop optional approaches for achieving advanced energy and emissions goals through building codes and standards, including related technical briefs and analysis published by DOE supporting net zero energy (NZE) and net zero operational energy emissions (NZOEE) targets in residential and commercial buildings (Salcido et al. 2024, Franconi et al. 2024). DOE's briefs contain supporting technical analysis and sample mandatory code language designed to overlay the model energy code (MEC). The documents address all building types and climate zones addressed by MECs, as well as multiple compliance paths contained therein.

Tables 1 and 2 estimate the percentage improvement need in the model energy codes—ANSI/ASHRAE/IES Standard 90.1 for commercial buildings and the International Energy Conservation Code (IECC) for residential buildings—in order to achieve the industry-established net-zero energy goals[1].

Table 1. National targets for new residential buildings (2024 – 2030)

	Energy and Renewable Targets			Potential Impact Relative to IECC 2021	
Residential MEC Year	**Gross Site Energy (kBtu/ft²-yr)**	**Gross Site Energy Reduction [1,3]**	**Offsets from Renewable Energy Resources[1,2]**	**Net Site Energy[1,3,4]**	**Avoided GHG Emissions[1,5]**
2021	33.0	0%	0%	0%	0%
2024	29.8	10%	33%	40%	51%
2027	26.5	20%	67%	73%	78%
2030	24.0	27%	100%	100%	100%

See additional clarifying notes in section 3.1.

[1] The International Code Council (ICC) has established a goal of achieving zero-energy buildings by 2030 and ASHRAE has established a goal of achieving net zero operational energy emissions buildings by 2031.

Table 2. National targets for new commercial buildings (2025 – 2031)

	Energy and Renewable Targets			Potential Impact Relative to 90.1-2022	
Commercial MEC	**Gross Site Energy (kBtu/ft²-yr)**	**Gross Site Energy Reduction [1,3]**	**Offsets from Renewable Energy Resources[1,2]**	**Net Site Energy[1,3,4]**	**Avoided GHG Emissions[1,5]**
2022	43.2	0%	5%	0%	5%
2025	38.1	12%	33%	38%	54%
2028	34.2	21%	50%	73%	79%
2031	30.2	30%	100%	100%	100%

See additional clarifying notes in section 3.2.

The underlying quantitative analysis relies on prototype buildings, reflecting a mix of typical U.S. building types and construction practices, with building type and climate zone weighting factors, to characterize U.S. new residential and commercial buildings (Salcido et al.2021, Lei et al. 2020). The table performance values provide trajectories for three building energy metrics;

1. Total on-site gross energy use,
2. Percent on-site gross energy use reduction and,
3. Offset from renewable energy resources.

The net emissions and net site energy use reductions are also reported in Tables ES1 and ES2. The adoption of the MEC compliance targets can be achieved by reducing new commercial and residential building gross energy use by approximately 30% over three code cycles. The remaining gap to achieve net zero is addressed with offsets from renewable energy and other clean energy technologies.

In addition to the national values, this report provides state-level commercial and residential building new construction performance metrics (Table 3 in section 4.1). The values reflect each state’s climate zones and new construction floor area by building type. These values are intended to support the establishment of state NZE and NZOEE targets over time.

The established targets can be approached incrementally and revisited at regular intervals to measure progress at the national, state, or local scale. National targets can be disaggregated into targets appropriate for states and municipalities to rely on building codes to establish minimum levels of energy efficiency and performance. State-level performance targets can be established using the same procedures used to develop the national values presented in this report. Additional supplemental resources to support states and local governments are provided throughout the report.

1 Introduction

Residential and commercial buildings are the single-largest energy-consuming sector of the U.S. economy, representing approximately 39% of total U.S. energy consumption and 74% of its electricity use, which makes buildings responsible for 35% of energy-related carbon dioxide emissions. The DOE Building Technology Office works to reduce the energy intensity of homes and commercial buildings by supporting cost-effective technologies and their inclusion in industry-accepted building energy codes and standards.

Energy codes and standards set minimum efficiency requirements for new and renovated buildings, which result in reduced operational energy use and emissions over the life of the building. Model energy codes (MEC) refer to the current versions of the IECC for residential buildings and ASHRAE Standard 90.1 for commercial buildings. MEC are continually maintained and updated versions are published every three years. The MEC includes 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 MEC. Authorities having jurisdiction (AHJs) can adopt net zero stretch codes overlaid on MEC to achieve new buildings designed and constructed to be net zero energy use or emissions.

Model code development organizations and numerous industry stakeholders have expressed a desire to have energy codes available which support the achievement of NZE and NZOEE targets in newly constructed buildings by 2030. In its *Leading the Way to Energy Efficiency* framework document, the International Code Council (ICC) sets a goal for its energy codes to provide jurisdictions with optional requirements that, “lead to achievement of zero energy buildings, presently, and, through glidepaths that achieve zero energy buildings by 2030 and on additional timelines sought by governments” (ICC 2021). Similarly, and to align with broader ASHRAE net zero energy goals, the ASHRAE 90.1 development committee set a goal to achieve a net zero carbon emissions standard by 2031 (ASHRAE 2022). In addition, states like Minnesota and Vermont and jurisdictions like Denver, Ann Arbor, and the District of Columbia have all set goals to achieve zero energy or emissions in newly constructed buildings by 2030, while a number of other jurisdictions like Milwaukee, Grand Rapids, and Atlanta have set goals of achieving significant energy and emissions reductions in buildings by 2030.

Given the goals established by industry and state and local jurisdictions, an approach is needed to ensure that these changes happen in a reasonable and gradual manner. This report provides a framework for these stakeholders can use to set consistent, incremental targets to achieve their desired outcomes of zero energy or zero emissions building codes.

1.1 Informing Compliance Targets Using a Gap Analysis

A 2020 analysis conducted by Pacific Northwest National Laboratory (PNNL) investigated the technical feasibility of achieving zero energy (or emissions) codes, and specifically identified the remaining “gap” between model energy codes and zero codes. To bridge this gap, buildings would need to continue to improve energy efficiency and offset the remaining energy (or emissions) with renewable energy. This has the potential to present significant challenges for states and local governments if not approached in a deliberate and incremental manner. The study demonstrated that as energy codes approach zero energy and emissions, efficiency advancements will need to improve at a rapid rate relative to past achievements (Franconi et al. 2020). The study also showed that, while market ready beyond-code measures and achievable rooftop solar offsets make substantial gains toward filling the gap, additional strategies beyond those evaluated in the study are needed. These strategies might include the zero code components outlined above, including integrative design, increased efficiency improvements, reduced plug and process loads, and off-site renewable energy procurement.

Figures 1 and 2 indicate the historical advancements made in MEC that affect gross site energy use. The historical values are based on DOE published data.[2] The figures also indicate the magnitude of the site energy use reduction required to achieve ZNE by 2030 for U.S. residential and commercial newly constructed buildings, respectively. The figures show the impact of advanced performance measures amended to the baseline code (black dashed lines), as well as the energy-use offset attributed to rooftop solar generation potential (yellow dashed line).

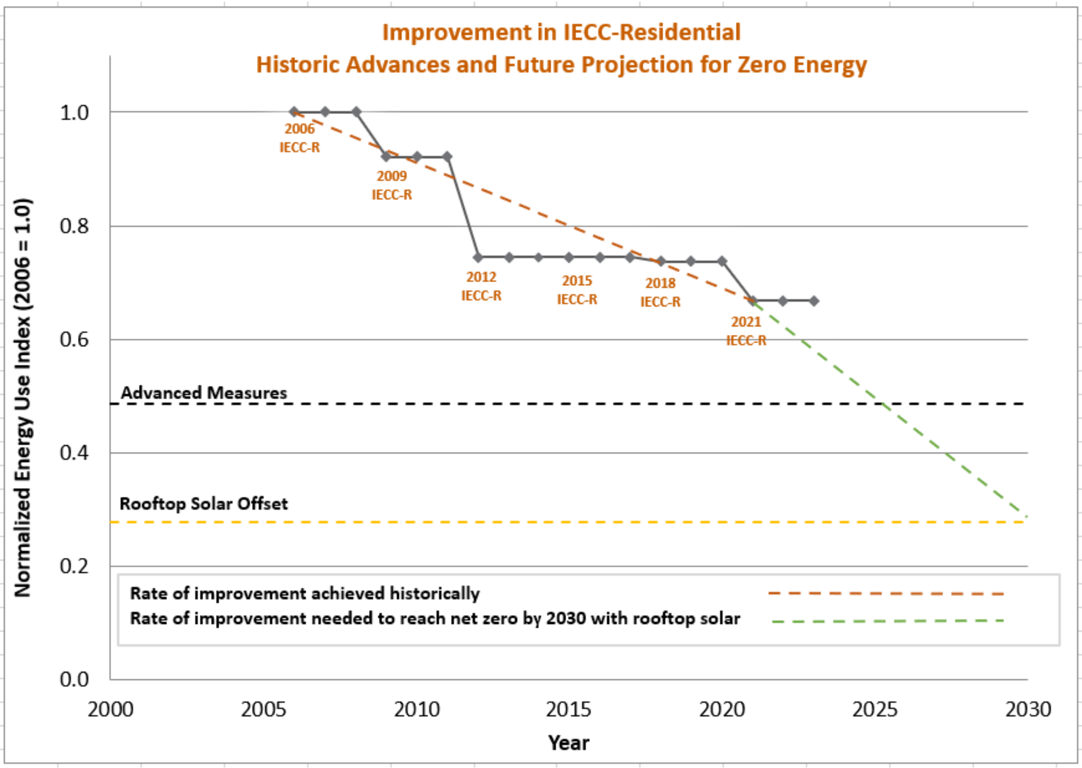

Figure 1. Advances Needed to Achieve Zero Energy Residential Model Energy Code

[2] DOE is statutorily required to conduct a technical analysis of each new version of the MEC, upon its completion, to assess the associated savings impact. DOE's technical analysis serves as a basis for DOE's determination, which is published within two years of MEC publication as directed under Title III of the Energy Conservation and Production Act, as amended ECPA (42 U.S.C. 6836(b)). The technical analysis helps inform states and jurisdictions that seek to update their adopting codes and comply with ECPA.

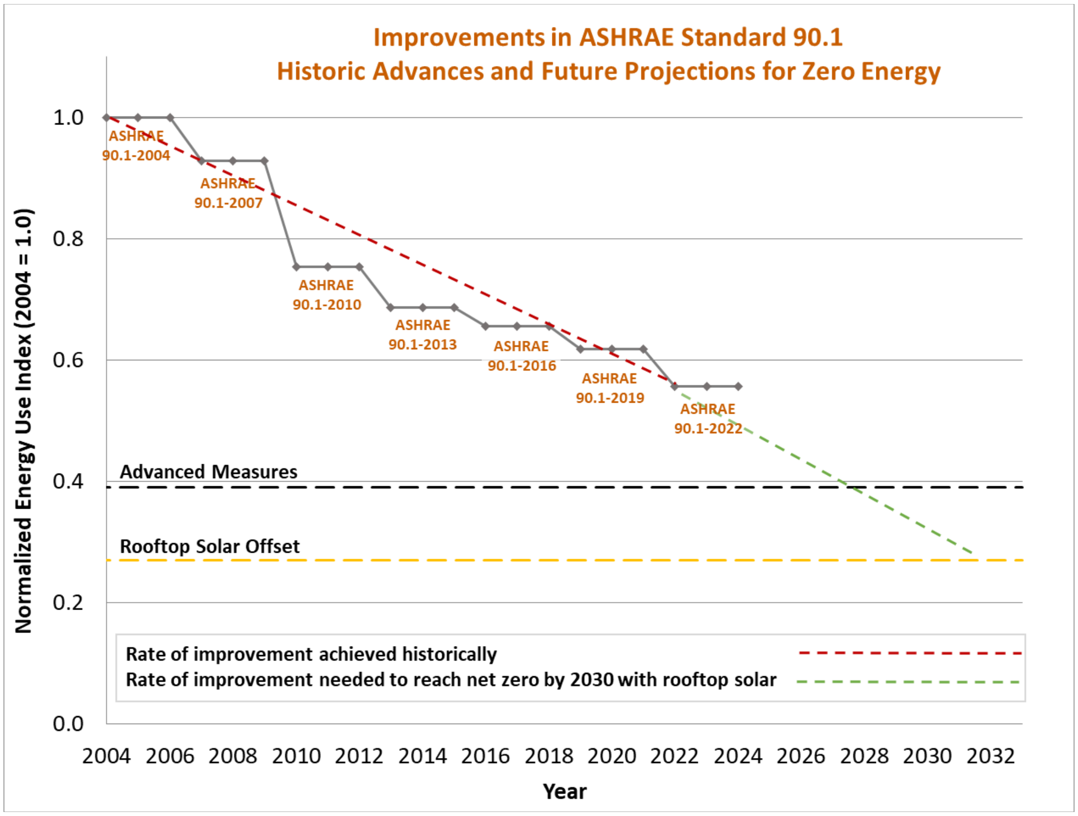

Figure 2. Advances Needed to Achieve Zero Energy Commercial Model Energy Code

For residential codes, Figure 1 encompasses six historical code cycles and three future cycles (2024, 2027, and 2030) beyond the current code. For commercial codes, Figure 2 encompasses seven historical code cycles and three future cycles (2025, 2028, and 2031). Both graphics focus on the needed advancements to achieve net zero energy, indicated by the brown dashed lines, which take into account the potential offset from rooftop solar.

The data indicate that the rate of advancements achieved historically with MEC will need to increase to meet NZ over the next three code cycles. This is indicated by the steeper slope of the future code trend (green dashed line) compared to the slope of the historical code trend (brown dashed line). Figure 1 indicates that the needed rate of performance advancements to meet the residential code ZE goal is more than two-times the rate achieved historically. For residential codes, historical achievements reduced the Normalized Energy Use Index (NEUI) by 0.33 over six code cycles. The needed future advancements must result in a site NEUI reduction of 0.39 over three code cycles. Figure 2 indicates the needed rate advancement for commercial code is about one and one-half times the rate achieved historically. Past achievements reduced the NEUI by 0.47 over six code cycles.[3] The needed future advancements require an additional NEUI reduction of 0.37 over three code cycles.

Model energy codes are starting to incorporate requirements for renewable energy resources. For example, ASHRAE 90.1-2022 adds an on-site renewable energy system rated capacity requirement of 0.25 W/ft^2 based on the conditioned floor area for all floors up to the three largest

[3] Includes weighted average national new construction NEUI reductions of 0.44 and 0.03 attributed to increases in efficiency and renewable energy requirements, respectively.

floors. However, to reach the rooftop renewable energy offset potential cited in the zero energy and emissions gap study, much larger capacities will be needed. Based on Franconi (2020), the rooftop PV suitable roof area associated with the DOE building prototype models for corresponds to an overall average PV system capacity of 5 W/ft^2 for commercial buildings based on total conditioned floor area. For residential buildings, the cited energy offset associated with the rooftop solar corresponds to an average PV system capacity of 3 W/ft^2.

1.2 Net Zero Metrics

Net zero performance can be achieved with stretch codes and MEC by including compliance metrics that address net zero design and construction considerations. The code's prescriptive compliance path can include requirements that reflect these performance levels. The performance metrics can also be used by national, state, and local governments to specify net-zero residential and commercial building performance goals and monitor progress towards achieving these goals. Recommended metrics, which capture the desirable net zero design attributes described in this section, include the following:

Gross Site Energy Intensity – NZE and NZOEE buildings require a higher level of energy efficiency achieved through the adoption of more stringent, cost effective, and technically feasible building energy efficiency measures. This metric indicates these advances by establishing targets and tracking the reduction in building annual gross site energy use.

Offsets from Renewable Energy Resources – NZE and NZOEE buildings use renewable energy resources to offset gross site energy or emissions. This metric indicates these advances by establishing targets and tracking reductions attributed to on-site and off-site resources.

Net Zero Energy – NZE buildings have 100% of their gross site energy use offset by renewable energy resources. This metric indicates advances towards net zero energy achievement. It accounts for gross site energy use reductions attributed to increases in energy efficiency and on-site and off-site offsets from renewable energy resources.

Net Zero Operational Energy Emissions – NZOEE buildings have 100% of their gross site operational GHG emissions provided or offset by renewable energy resources. This metric indicates advances towards net zero operational energy emissions achievement. It accounts for GHG emissions reductions attributed to improvements in energy efficiency, use of clean energy resources, procurement of renewable resources, and the reduction in average emissions of the electricity delivered by the grid.

1.3 NZE and NZOEE Plug-In Code Language

Two published technical briefs provide NZE and NZOEE model code compliance language as an overlay to published residential and commercial MEC (Salcido et al. 2024, Franconi et al. 2024). The technical briefs present code language that can be amended to adopted residential and commercial energy codes to achieve NZE and NZOEE in newly constructed buildings, either immediately or over several code cycles. The documents include requirements for all building types and climate zones as addressed in MEC. The residential zero code plug-in language includes both prescriptive and performance-based compliance options. The commercial zero code plug-in code language follows a performance-based compliance path. An informative prescriptive based zero-code pathway has been developed by the ASHRAE Standard 90.1 committee for inclusion in the 2025 version of the standard.

A key component of the zero-code performance compliance path is the efficiency backstop. It aligns with gross site energy use intensity metric described above. Its target value 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. The efficiency target is intended to be established as part of each code development cycle and account for new design practices and technologies. The second performance compliance metric is the net zero fraction. Its target value can be set to zero or stepped down from one to zero over several code cycles. It aligns with the net zero energy or net zero emissions metrics described above.

2 National Model Energy Code Performance Targets

This section establishes the necessary metrics and their target values that support tracking progress towards achieving NZE or NZOEE new commercial and residential buildings with MEC over the next three code cycles. The U.S. national targets, indicated in Figure 3 and Table 3 for new residential buildings and Figure 4 and Table 4 for new commercial buildings, have been derived from previous research that quantifies the gap that must be filled to achieve NZE and NZOEE with model energy codes (Franconi et al. 2020). The targets are based on total annual site energy use and renewable energy offset values. The study's incremental approach, for reducing building energy use and increasing offsets from renewable energy resources over three code cycles, is based on efficiency improvements that can be achieved with today's technologies. The underlying analysis provides a technical basis for establishing the zero code targets.

Tables 3 and 4 list the target values for residential and commercial MEC. The targets are based on a characterization of the national building stock in aggregate, representing building types and climate zones across the United States[4]. Regional differences in climate, new construction floor areas and availability of renewable and clean energy resources are embedded in the values. The table values indicate U.S. average impact potential and are not suitable for use at the regional or state level. The targets in Tables 3 and 4 align with NZE and NZOEE compliance requirements included in the NZ model code overlay language developed for residential and commercial MEC, which is described in Section 2. Figures 3 and 4 graphically depict the metric targets and their contributions towards achieving NZE and NZOEE commercial and residential buildings. The improvements in building performance proposed over the next three code cycles will require progressively decreasing gross site energy use while increasing renewable energy offsets.

2.1 Residential Performance Targets

The performance targets for residential code are shown in Figure 3. The figure shows the impact of the advanced measures (black dashed lines)[5] amended to the baseline code, as well as the energy-use offset potential attributed to rooftop solar (yellow dashed line). The green dashed steps show the performance levels for gross site energy use estimated for IECC-2024 (GE 2024) and targeted for future code cycles (GE 2027 and GE 2030). The establishment of these performance levels is based on current code, market trends, and the advanced measure analysis. The brown dashed steps (RE 2024, RE 2027, and RE 2030) show additional reductions needed to achieve the code cycle NZE target (red-dashed steps). The gap between the future code-cycle gross site energy use and NZE target can be filled by renewable energy offsets and additional efficiency improvements.

[4] Characterizations are based on the methodologies used to determine national MEC energy savings and cost effectiveness. https://www.energycodes.gov/methodology

[5] The advanced measures applied to the code prototypes buildings are based on highly efficient building design practices and standards, such as the 2021 Passive House Institute U.S. Standard. See Franconi et al. 2020 for details.

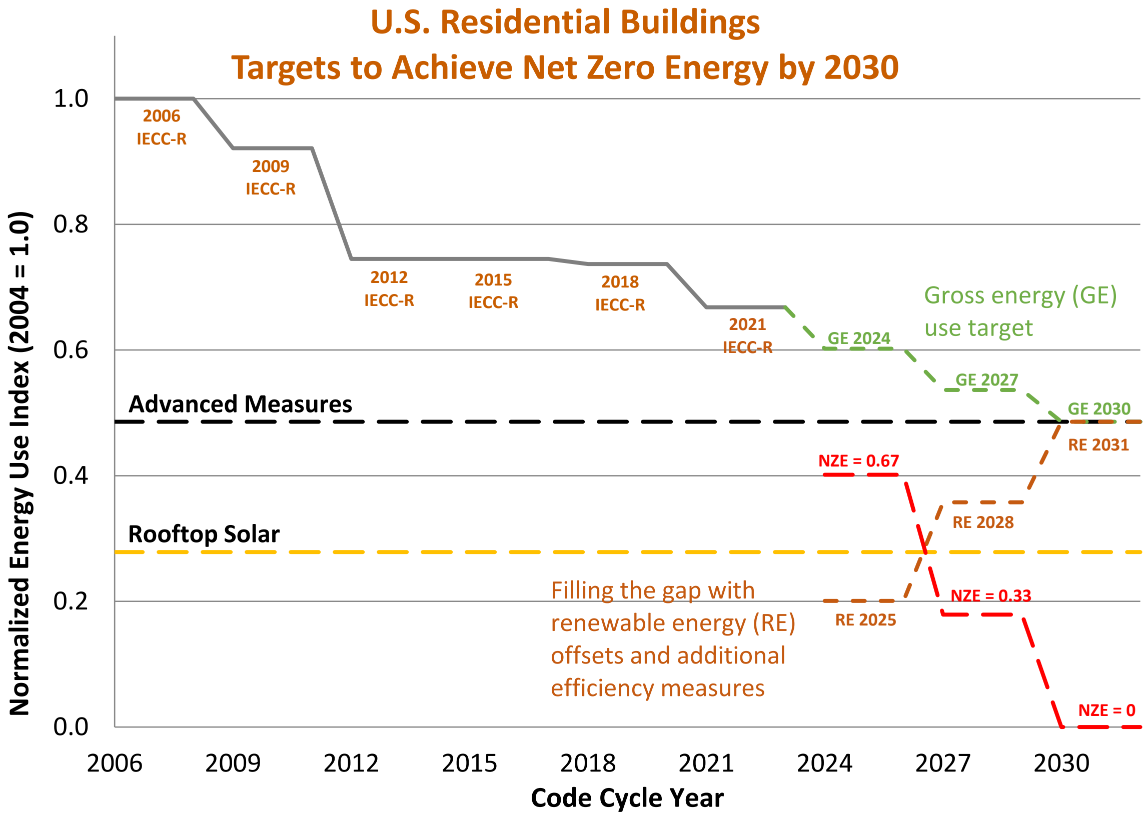

Figure 3. Historical performance and future residential energy code targets to achieve NZE

Table 3. National targets for new residential buildings (2024 – 2030)

	Energy and Renewable Targets			Potential Impact Relative to IECC 2021	
Residential MEC Year	Gross Site Energy (kBtu/ft²-yr)	Gross Site Energy Reduction [1,3]	Offsets from Renewable Energy Resources[1,2]	Net Site Energy[1,3,4]	Avoided GHG Emissions[1,5]
2021	33.0	0%	0%	0%	0%
2024	29.8	10%	33%	40%	51%
2027	26.5	20%	67%	73%	78%
2030	24.0	27%	100%	100%	100%

1. National weighted values based on new construction floor area applied to code prototype building model simulation results.
2. Percentage of renewable energy offsets are relative to the code cycle gross site energy use.
3. The reductions in the gross site energy use and net site energy are relative to the performance requirements IECC-2021 for residential buildings.
4. Total net site energy use reduction accounts for reductions in gross energy use from increased efficiency and offsets from renewable energy resources.
5. GHG emission reduction values listed for each code cycle are relative to the gross site energy use (kBTU/ft2-yr) of residential MEC (IECC 2021). They also reflect on-site sources of combustion comprising 20% of total energy use in 2021 then reduced to none by 2030. The avoided emission values account for the gross site energy use reductions, renewable energy offsets, and a cleaner electricity grid. Current and future electricity GHG emission rates reflect national average GHG emissions rates for a 20-year GWP period based on current values reported by EIA/EPA and future values estimated by NREL Cambium software.

2.2 Commercial Performance Targets

The performance targets for commercial code are shown in Figure 4. The figure shows the impact of advanced measures (black dashed lines)[6] amended to the baseline code, as well as the energy-use offset potential attributed to rooftop solar (yellow dashed line). The green dashed steps show the performance levels targeted for gross site energy use for future code cycles (GE 2025, GE 2028, and GE 2031). The establishment of these performance levels is based on current codes, market trends, and the advanced measure analysis. The brown dashed steps (RE 2022, RE 2025, RE 2028, and RE 2031) show the additional reductions needed to achieve the code cycle NZE target (red dashed steps). The gap between the code cycle gross site energy use and the NZE target can be filled by renewable energy offsets and additional efficiency improvements.

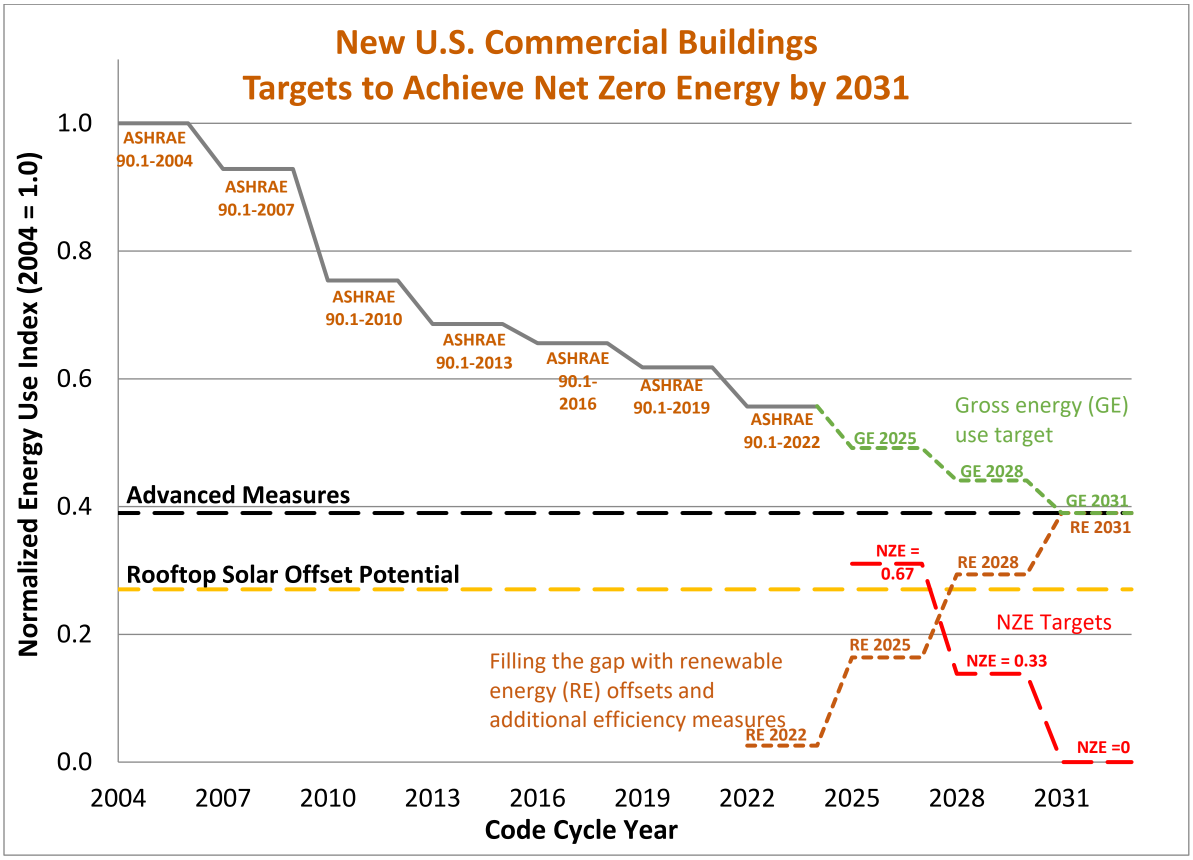

Figure 4. Historical performance and future commercial energy code targets to achieve NZE

[6] The advanced measures applied to the commercial building prototypes comprise a subset of measures analyzed in an ASHRAE research project 1651 led by Glazer, titled *Development of Maximum Technical Achievable Energy Targets for Commercial Buildings (RP-1651)*. See Franconi et al. 2020 for details.

Table 4. National targets for new commercial buildings (2025 – 2031)

	Energy and Renewable Targets			Potential Impact Relative to 90.1-2022	
Commercial MEC	**Gross Site Energy (kBtu/ft^2-yr)**	**Gross Site Energy Reduction [1,3]**	**Offsets from Renewable Energy Resources[1,2]**	**Net Site Energy[1,3,4]**	**Avoided GHG Emissions[1,5]**
2022	43.2	0%	5%	0%	5%
2025	38.1	12%	33%	38%	54%
2028	34.2	21%	50%	73%	79%
2031	30.2	30%	100%	100%	100%

1. National weighted values based on new construction floor area applied to code prototype building model simulation results.
2. Percentage of renewable energy offsets are relative to the gross site energy use of each code cycle.
3. The reductions in the gross site energy use and net site energy are relative to the performance requirements for ASHRAE 90.1-2022.
4. Total net site energy use reduction accounts for reductions in gross energy use from increased efficiency and offsets from renewable energy resources.
5. GHG emission reduction values listed for each code cycle are relative to the gross site energy use (kBTU/ft2-yr) of commercial MEC 2022 (ASHRAE Standard 90.1). They also reflect on-site sources of combustion comprising 20% of total energy use in 2022 then reduced to none by 2031. The avoided emission values account for the gross site energy use reductions, renewable energy offsets, and a cleaner electricity grid. Current and future electricity GHG emission rates reflect national average GHG emissions rates for a 20-year GWP period based on current values reported by EIA/EPA and future values estimated by NREL Cambium software.

3 Establishing State Net Zero Targets

The approaches described in Section 2 and Section 3 can be applied by states and jurisdictions interested in understanding and quantifying building energy efficiency and renewable energy requirements needed to bridge the gap between their current energy code and a zero energy or emissions code. This section outlines that process and applies it to establish state performance targets for future energy codes to work towards progressively achieving net zero energy or emissions. Table 3 in Section 4.2 provides the U.S. state-level NZE and NZOEE performance targets, which are aligned with the national NZE performance targets reported in Tables 1 and 2. The values developed for each state are aggregated, weighted values that reflect the state's climate zones and anticipated new construction building floor areas by building type. The three-step process for establishing NZE or NZOEE energy code with MEC and specifying state net zero targets is outlined below.

1. Incorporate NZE or NZOEE compliance path(s) in adopted code. Refer to the zero code plug-in language technical briefs discussed in Section 2.4. Adopt the published compliance requirements associated with the state's building types and climate zones. Specify the NZE or NZOEE compliance target fraction(s) to achieve net zero over one (e.g., net zero target equals zero) or multiple code cycles (e.g., the net zero target is reduced over three code cycles and equals 0.67, 0.33, and 0, respectively).
2. Adopt the state-level goals for residential and commercial building gross site energy use reductions listed in Table 3. The Table 3 values have been determined based on the plug-in code compliance metric target values. Note: the required renewable energy offset goals are dependent on the net zero compliance metric target specified in step 1 above.
3. Check and refine the state-level net zero goals based on policy considerations over time. Evaluate zero code progress by assessing the impact of adopted code, including amended measures, at the completion of each code cycle.

3.1 Establish State Building Performance Goals

Establishing state net zero building performance goals provides benchmarks to inform the development of supporting policy and the monitoring of achievements. Ideally, a state's goals and schedule for fulfillment should align with its current and future adopted code compliance requirements. Table 5 identifies state-level aggregated gross site energy (kBTU/sq.ft.-yr) target values that could be used to establish a trajectory toward zero energy goals. The state values are derived from the performance compliance targets specified in the residential and commercial NZE and NZOEE plug-in code technical briefs. The Table 5 values include on-site gross energy use (without renewables) targets for NZ code cycles 1, 2 and 3 for both residential and commercial buildings. Table 5 also includes the performance values associated with the state's currently adopted energy code and most recent model energy codes, IECC 2021[7] for residential code and ASHRAE 90.1 2022 for commercial code. In home rule states that do not adopt a statewide energy code, performance values for the adopted code are not included. Values indicate weighted, average normalized energy use and account for the state's building types, anticipated new construction floor areas, and climate zones. Performance values are based on estimated performance associated with currently available technologies. While the code cycle 1 and 2 targets assume the use of

[7] DOE published the determination of the Residential IECC-2024 on December 20th, 2024, at the time of this report's publication the Residential IECC 2024 will be considered the model energy code for residential buildings.

equipment that meets current (2024) federal minimum efficiencies, targets for code cycle 3 assume future increases in the stringency in the current federal minimum equipment efficiencies and additional end use loads being addressed through energy code requirements.

Table 5 - Annual gross energy use (kBTU/sq.ft.-yr) targets for achieving NZE new buildings

	Residential					Commercial				
State	**Adopted Code**	**IECC 2021**	**Code Cycle 1**	**Code Cycle 2**	**Code Cycle 3**	**Adopted Code**	**ASHRAE 90.1-2022**	**Code Cycle 1**	**Code Cycle 2**	**Code Cycle 3**
Alabama	27.7	23.9	24.0	22.1	20.1	57.1	44	41.8	38.3	34.7
Alaska[2]	---	52.1	44.4	35.1	25.8	---	60.8	52.6	45.6	38.6
Arizona[2]	---	32.1	27.9	24.6	21.2	---	35.9	34.1	31.1	28.2
Arkansas	44.1	29.9	25.9	23.2	20.6	84.8	47	41.8	37.8	33.8
California[1]	24.4	24.4	24.4	23.5	20.5	38.6	29.0	31.6	29.2	26.8
Colorado[2]	---	35.8	34.1	28.2	22.3	---	43.5	40.9	37.1	33.3
Connecticut	37.7	37.7	37.1	30.1	23.0	48.9	43.9	40.7	36.2	31.7
Delaware	29.4	26.2	27.9	24.5	21.1	59.9	47.7	42.3	37.8	33.4
District of	30.4	27.7	31.7	28.0	24.3	55.4	44.6	42.4	38.2	34.0
Florida	24.4	23.8	24.5	22.8	21.1	47.9	41	38.7	35.2	31.6
Georgia	28.9	24.5	24.1	22.1	20.1	46.2	35.9	34.3	31.4	28.6
Hawaii	33.5	31.2	24.7	23.1	21.5	55.9	43.8	41.3	37.0	32.7
Idaho	46.2	35.2	34.4	28.2	22.0	55.5	44.3	40.8	36.7	32.6
Illinois	36.9	36.7	35.8	29.4	23.0	48.9	44.8	38.9	34.5	30.2
Indiana	48.5	37.8	33.5	27.9	22.3	78.3	44.9	38.4	34.1	29.7
Iowa	46.9	39.8	37.4	30.2	23.0	76.4	49.9	42.0	37.1	32.2
Kansas[2]	---	33.3	28.2	24.8	21.4	---	43.4	37.9	34.0	30.0
Kentucky	39.6	28.1	28.3	24.8	21.4	64.3	42.4	37.4	33.5	29.6
Louisiana	31	29	24.1	22.4	20.6	53.6	46.7	43.5	39.7	35.9
Maine	47.6	43.6	41.7	32.9	24.0	66.9	52.4	50.3	44.1	38.0
Maryland	25.8	25.3	28.4	24.9	21.4	40.8	39.4	37.1	33.3	29.6
Massachusetts	38	36.6	37.2	30.1	23.1	55.1	45	42.5	38.1	33.7
Michigan	50	41.8	37.9	30.5	23.1	70.4	55.7	48.1	42.5	36.9
Minnesota	48.2	43.8	41.7	33.2	24.7	60	52.2	47.7	42.1	36.5
Mississippi[2]	---	24.7	24.0	22.1	20.2	---	38.5	36.3	33.4	30.4
Missouri[2]	---	34.1	28.4	25.0	21.5	---	46.9	40.9	36.6	32.3
Montana	43.2	38.9	38.0	30.4	22.8	58.9	53.4	48.7	43.5	38.3
Nebraska	40.1	36.8	37.2	30.1	23.0	63.7	52.2	44.6	39.3	34.0
Nevada	36.2	31.4	27.8	24.2	20.7	52.9	42.8	39.9	36.8	33.8
New	43.1	38.8	38.5	30.9	23.2	59.1	48.1	45.0	39.7	34.4
New Jersey	35.2	35.2	30.7	26.4	22.0	45.5	39.2	35.3	31.8	28.2
New Mexico	34.8	31.8	29.0	24.5	19.9	51.4	44.9	42.1	38.6	35.1

State	Residential Adopted Code	Residential IECC 2021	Residential Code Cycle 1	Residential Code Cycle 2	Residential Code Cycle 3	Commercial Adopted Code	Commercial ASHRAE 90.1-2022	Commercial Code Cycle 1	Commercial Code Cycle 2	Commercial Code Cycle 3
New York	42.2	38.4	35.3	29.2	23.1	58.1	46.2	42.7	38.5	34.2
North Carolina	30.9	24.7	24.5	22.3	20.1	54.9	40.3	38.6	35.1	31.6
North Dakota[2]	---	45.7	41.9	33.4	24.9	---	57.2	50.5	44.4	38.3
Ohio	46.9	38	33.8	28.1	22.4	54.7	47.6	41.2	36.5	31.9
Oklahoma	48.4	32.3	24.0	21.9	19.8	100	48.7	43.0	39.4	35.8
Oregon	34.5	32.7	32.6	27.0	21.5	42.4	36.6	34.3	31.1	27.8
Pennsylvania	38.5	34.5	32.3	27.1	22.0	51.9	41.9	38.2	34.1	30.0
Rhode Island	48.6	37.5	37.1	29.9	22.7	56.6	45.3	42.3	37.7	33.1
South Carolina	32.1	24	23.9	21.9	19.9	68.1	38.6	37.0	33.9	30.9
South Dakota[2]	---	45	41.0	32.6	24.2	---	53.7	47.5	41.5	35.5
Tennessee	35.4	26	26.0	23.3	20.7	64.6	42.4	39.5	35.9	32.3
Texas	32.1	28.9	24.7	22.8	20.9	50.7	39.5	37.4	34.2	31.1
Utah	43.2	33.3	32.9	27.4	21.9	43.5	39.2	36.7	33.2	29.7
Vermont	39.3	43.3	41.6	32.8	24.1	58.2	48.1	47.7	42.2	36.8
Virginia	27.9	24.8	27.6	24.4	21.2	43.4	41	39.3	35.3	31.4
Washington	37.8	34.6	32.7	27.2	21.7	42.1	37.3	35.1	32.0	28.9
West Virginia	31	25.7	29.7	25.6	21.5	60.2	47.7	43.4	38.7	33.9
Wisconsin	58.9	41	39.0	31.3	23.6	68.6	52.8	44.5	39.1	33.8
Wyoming[2]	---	41.3	38.1	30.6	23.1	---	49.3	45.0	40.5	36.0

1. California has a custom energy code that is not currently analyzed by PNNL. Title 24 Residential and Commercial Adopted Code values are based on estimated levels of performance using analysis reported by third parties.
2. Home rule state without an adopted state-wide energy code.

3.1.1 Establish Energy Targets by Building Type and Climate Zone

Performance compliance targets published in MEC are specified by building type and climate zone. The compliance values reflect differences across climate zone locations and building use types and account for typical geometry, construction, equipment, operating schedules, regulated loads, and miscellaneous loads. The values are intended to the capture the performance of typical newly constructed buildings and actual technology solutions. This is also the case for the targets established in the zero-code plug in technical briefs. As a result, the MEC and zero code requirements support market transformation by providing a signal to designers, builders, and suppliers regarding current and future trends for products and practices.

Per the methodology described in the zero code plug-in tech briefs and Section 2, the compliance targets are based on code prototype building simulation analysis with advanced measures amended to current MEC requirements. For residential code, the code cycle 1 targets are aligned with the anticipated IECC-2024 efficiency levels. The residential plug-in provides prescriptive compliance values for zero code cycles 2 and 3. It provides performance compliance targets for code cycle 2. For the commercial code, the zero-code plug-in provides code cycle 1 performance requirements. Including a prescriptive compliance option is planned for a future publication.

This report provides sample targets that may be considered by a model code development body, state, or other interested stakeholders. Additional customization may be needed to account for unique climate conditions, construction trends, or energy and emission reduction goals. The U.S. Department of Energy provides technical assistance to states, municipalities and the design and construction industry supporting building energy codes and is available to provide assistance in these types of customization efforts.[8]

3.2 Tracking Achievements

At the end of each energy code cycle within the zero-code attainment period, the state can evaluate achievements against performance goals established for the code cycle. To complete the assessment, the state can leverage analysis results published by the U.S. DOE that indicates the state adopted code efficiency level relative to the last six versions of MEC.[9] States can use the data to map their improved code performance (see Figures 3 and 4) to assess the trajectory towards achieving a zero code. Completing end-of-cycle checks can help ensure advances are aligned with goals and inform on-going energy code development. Interim checks can also be conducted to assess the impact of the more significant energy reduction measures. The interim checks can spur additional activities, such as outreach and training and additional code changes.

3.3 Additional Considerations for NZE Code Adoption

The energy use intensity values listed in Table 3 are based on a characterization of the state's new construction building stock and climate zones in aggregate. Therefore, the values may not be representative of a local region or individual county within the state. Additionally, the Table 3 target values have been developed using code prototype building models and simulation analysis, which are intended to represent performance of as-designed buildings but not actual building operation. Other considerations that may need to be addressed as part of zero code development and adoption are discussed below.

3.3.1 Minimum Equipment Efficiency Requirements

Historically, Federal minimum equipment efficiency requirements associated with HVAC and water heating equipment apply to both prescriptive and performance compliance paths in MEC. They serve to provide an efficiency backstop, which establishes limits to HVAC system performance trade-offs. The zero code plug-in code performance targets (cycles 1 and 2 for residential and cycle 1 for commercial codes in Table 3) can be met from design solutions that incorporate Federal minimum efficiency equipment. It is anticipated that Federal minimum equipment efficiencies will increase in the future, which should be accounted for in the net zero gross site energy target value and provided in future NZE/NZOEE published resources developed for states. States or jurisdictions who utilize this framework should investigate and rely on current federal equipment standards at the time they update their building codes.

[8] DOE building energy code technical assistance requests can be submitted here: https://www.energycodes.gov/technical-assistance/help-desk

[9] Available through the DOE Building Energy Codes Program State Portal at https://www.energycodes.gov/state-portal.

3.3.2 Miscellaneous Loads

Miscellaneous building energy loads, which include most plug and process loads, are not addressed as requirements in energy code. Yet their reduction is a contributing factor to achieve zero codes. Some progress is being made when accounting for this category of energy use. For example, as part of recent commercial MEC development, elevators, commercial refrigeration, computer room cooling systems, industrial laboratory fume hoods, and residential lighting have all become regulated. Furthermore, expansion to commercial cooking equipment, compressed air systems, and other industrial processes is currently being considered. It is anticipated that reductions in residential MEC miscellaneous loads could be difficult to identify and comply with, though advancements in building control systems and other technologies may aid in reducing miscellaneous energy loads. One option is to indicate their energy use on construction drawings and verify by field inspection.

Requiring the use of a performance-based compliance path can also promote miscellaneous load reductions. For instance, compliance metrics targets that include miscellaneous loads reflect current appliance and equipment efficiency, which falls under the purview of the DOE Appliance and Equipment Standards Program. This is the case for the NZE site energy compliance target defined in the residential zero code plug-in.

3.3.3 Renewable Energy Offsets, Electrification, and Impacts

The zero code gap analysis, summarized earlier in Section 2.2, indicates that significant energy use offsets from clean and renewable energy sources are required to meet zero code goals. Incorporating these requirements in state and local energy codes introduce new considerations that will need to be addressed.

- Off-site renewable energy resource procurement methods and their associated derating factors need to be agreed upon.
- Substantial increases in renewable energy generation are required over the next three code cycles. These requirements, along with minimum building energy efficiency targets, will need to be accepted.
- Analysis procedures are needed to quantify and compare the cost-effectiveness of increased efficiency and renewable energy generation, including the benefits associated with energy equity and broader societal impacts.

3.3.4 Validating Performance

The important role code compliance plays in meeting zero code goals should not be underestimated. Strategies need to be implemented to bolster compliance efforts. This might include recruiting third-party inspectors to assist code officials in areas where code compliance resources are thin. In addition, while standardized software tools have long been available to help designers document compliance with prescriptive energy codes[10], only recently have similar tools been made available for performance-based compliance[11]. However, those tools have not yet penetrated the market, and they are not as sophisticated as their prescriptive counterparts (Karpman and Rosenberg 2021).

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[10] https://www.energycodes.gov/software-tools

[11] https://www.energycodes.gov/performance_based_compliance

In addition to compliance at the design and construction phase, the performance that is most meaningful is that which is observed during the actual operation of a building. To help address this challenge, states and local jurisdictions are adopting building performance standards to encourage increased energy efficiency in existing buildings. However, there remains the issue that performance simulated during a building’s design phase often does not match post occupancy performance. This dilemma, often referred to as the performance gap, is complex in its causes and has been reported on extensively (Cuerda, et al. 2020 and van Dronkelaar et al. 2016). Despite the challenge, it is important to continue to work on overcoming this barrier, since energy simulation and performance-based compliance pathways provide the ability to design a building that can maximize holistic, energy-efficient design.

4 Conclusions

Achieving zero energy or zero emissions buildings through building codes will require significant improvement in energy codes, including requirements that increase energy efficiency and renewable energy offsets. Establishing performance targets can help set goals to achieve incremental progress over multiple code cycles to ultimately achieve a zero code. Using model energy codes as an example, this technical brief provides a methodology for establishing zero codes by approximately the 2030 timeframe using realistic and market-ready technologies and practices. This methodology can be adapted for use at the state – and even local – level to set targets based around their unique climate, building stock, policy goals, and other critical factors. However, it is expected that there will be challenges in pursuing these goals, as it will require improving energy efficiency at a faster rate than it has improved in the past, establishing strong on-site renewable energy requirements, and evaluating nontraditional strategies like reducing plug and process loads and procuring off-site renewable energy. This methodology is designed to help users work backwards from their end goal of NZE or NZOEE buildings to achieve energy code improvements in more predictable and manageable increments.

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Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov