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Subject:	Approval - 2024 Energy Conservation Code
Date:	Monday, August 21, 2023 4:32:20 PM
Attachments:	BCC_2023-08-21.pdf Outlook-qqzpeoxp.png Outlook-4eddpwa2.png

OSBM has reviewed the Building Code Council's proposed changes to the North Carolina Energy Conservation Code in accordance with G.S. 150B-21.4. OSBM has determined the amendments may have substantial impacts, with little to no impact on state government. The fiscal note is approved for publication.

Please ensure that the local government and substantial economic impacts are included in the Notice of Text and that the NC League of Municipalities, Association of County Commissioners, and the Fiscal Research Division of the General Assembly are notified.

The .pdf file of the fiscal note (attached) will be posted on our website at the following URL (please allow for some time):

https://www.osbm.nc.gov/documents/files/BCC_2023-08-21

Please let me know if you have any questions.

Julie Ventaloro
Economic Analyst
NC Office of State Budget and Management
Chat with me in Teams
984-236-0694

Fiscal Note for
2024 NC Energy Conservation Code

Agency:	NC Building Code Council
Statute:	G.S. 143-136; 143-138
Contact:	David Rittlinger NC Department of Insurance 1202 Mail Service Center Raleigh, NC 27699-1202 919-647-0008 david.rittlinger@ncdoi.gov
Impact:	Federal Government: No State Government: Minimal Local Government: Yes, Potential Savings Small Business: Yes, Potential Savings Substantial Impact: Yes, Potential Savings

Executive Summary

The commercial provisions of the proposed 2024 edition of the *North Carolina Energy Conservation Code* (NCECC) are expected to be cost-effective. For most commercial construction governed by the North Carolina Building Code, no additional construction costs are expected to be required by the additional energy code requirements of the 2024 NCECC. Across all commercial building types and climate zones, there will be an estimated average reduction in first costs of $0.86 per square foot, an average annual energy cost savings of $0.23 per square foot, and a net Life-Cycle Cost savings of $5.75 per square foot for privately-owned buildings. A summary of the key changes to the commercial provisions included in the proposed 2024 NCECC is attached as **Appendix A**.

Similarly, the residential provisions of the proposed 2024 edition of the NCECC are expected to be cost-effective. While the proposed energy conservation provisions for commercial construction will be mandatory, the proposed residential provisions of the 2024 NCECC are only mandatory for Group R-2 (e.g., apartment houses, boarding houses, dormitories, and vacation timeshare properties) and Group R-4 (e.g., assisted living centers, congregate care facilities, halfway houses, and residential board and care facilities) buildings three stories or less in height above grade plane. 2024 NCECC §§ R101.2, R202. Minimum energy efficiency requirements for the construction of detached one- and two-family dwellings and townhouses not more than three stories above grade plane in height, their accessory structures not more than three stories above grade plane in height, and bed and breakfast homes are instead governed by Article IV, Chapter 11 of the *North Carolina Residential Code for One- and Two- Family Dwellings* (the "North Carolina Residential Code"). *See* 2018 North Carolina Residential Code §§ R101.2, N1101.1.[1]

[1] Section 8 of N.C. Sess. L. 2023-108, enacted on August 16, 2023, prohibits the Building Code Council from adopting new code provisions "relating to energy conservation or efficiency of buildings, dwellings, and structures

Across all residential building types and climate zones, there is the potential for an average increase in construction costs of between $4,755 and $6,487, an average annual energy cost savings of approximately 18.7% (about $399 in annual utility bill savings for the average North Carolina household), and a net Life-Cycle Cost savings of between $1,858 and $4,530. Estimates involving detached one- or two-family dwellings, townhouses, or bed and breakfast homes assume 100% voluntary compliance with the proposed 2024 NCECC energy conservation recommendations as an alternative design and construction method to the minimum energy efficiency requirements set out in Article IV, Chapter 11 of the North Carolina Residential Code. A companion summary highlighting the key changes to the residential provisions of the 20204 NCECC is attached as **Appendix B**.

Purpose and Background

The NCECC is a technical code that regulates minimum energy conservation requirements for new buildings. One of the eight technical codes included in the North Carolina State Building Code, the NCECC addresses energy conservation requirements for all aspects of energy uses in both commercial and residential construction, including heating and ventilating, lighting, water heating, and power usage for appliances and building systems.

The NCECC is a design document. For example, before one constructs a building, the designer must determine the minimum insulation *R*-values and fenestration *U*-factors for the building exterior envelope. Depending on whether the building is for residential use or for commercial use, the NCECC sets forth minimum requirements for exterior envelope insulation, window, and door *U*-factors and SHGC ratings, duct insulation, lighting and power efficiency, and water distribution insulation.

First adopted into the North Carolina State Building Code in 1995, the NCECC was originally patterned on the Council of American Building Officials' *Model Energy Code*. Following the 1994 merger of several regional model code groups to form the International Code Council, subsequent editions of the NCECC have used the International Code Council's *International Energy Conservation Code* (IECC) as the base model code.

In 2008, North Carolina received a contract from the U.S. Department of Energy with a target that the state would develop an energy conservation code that was at least 30% more energy efficient than the 2006 edition of the IECC. Using the 2009 IECC as the base document, the N.C. Building Code Council's ad hoc and standing committees recommended a package of improvements to the full council for adoption as the 2012 NCECC. Due to significant opposition expressed by the North Carolina Homebuilders Association during the public comment period and at meetings of the North Carolina Building Code Council, the proposed minimum efficiency requirements for one- and two-family dwellings and

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to which the North Carolina State Residential Code applies." Section 8 of N.C. Sess. L. 2023-108 became effective upon its enactment and "applies retroactively to March 1, 2023." N.C. Sess. L. 2023-108, s. 8 (eff. Aug. 16, 2023). Accordingly, the residential provisions of the proposed 2024 NCECC do not set out the minimum energy efficiency requirements for the detached one- and two-family dwellings, townhouses, accessory buildings, and bed and breakfast homes, which are instead governed by Article IV, Chapter 11 of North Carolina Residential Code. North Carolina residential owners and their agents may choose, at their option, and with the approval of the responsible code enforcement official, to comply with the residential provisions of the 2024 NCECC as an alternate method of construction. N.C. Gen. Stat. § 143-140.1.

townhouses contained in the proposed 2012 edition of the NCECC were reduced through compromise to be approximately 10-15% more energy efficient than the standards contained in the 2006 IECC. The 30% efficiency improvement recommendations for commercial construction remained intact. The 2012 NCECC was adopted effective January 1, 2013.

In 2015, the N.C. Building Code Council initiated review of the 2015 IECC as the base document for the 2018 NCECC. During the code development process, the ad hoc and standing committees of the N.C. Building Code Council weighed concerns regarding increased materials costs against the risk that failure to meet the 2008 U.S. Department of Energy target of at least 30% efficiency improvement could result in required repayment of funds to the federal government or the withholding of future federal funds, and concluded that the additional costs of moving to the 2015 IECC did not justify the additional energy efficiency savings. Ultimately, these committees recommended a package based on the 2009 IECC plus incremental measures contained in the 2012 and 2015 editions of the IECC for adoption as the 2018 NCECC. In the fiscal note prepared for the 2018 NCECC, the council estimated that the 2018 NCECC would result in incremental efficiency improvements for commercial buildings and "get closer to the 2008 target 30% efficiency improvement" for one-and two-family dwellings and townhomes. The 2018 NCECC was adopted effective January 1, 2019.

In 2021, the N.C. Building Code Council initiated review of the 2021 IECC as the base document for the 2024 North Carolina Energy Conservation Code. One of the key differences between the 2009, 2012 and 2015 editions of the IECC and the 2021 IECC is an update to North Carolina's climate zones. Based on measured temperature data from over 4,000 North American weather stations over the previous 25 years, the 2021 IECC made changes to the climate zone map for North Carolina for the first time in nearly 20 years. According to the map, North Carolina's climate more closely resembles that of South Carolina and Alabama than that of Virginia. Whereas 44% of North Carolina's 100 counties fell within Zone 4 (Mixed Moist) under prior climate zone maps, only 16% fall within Zone 4 under the 2021 IECC map. On the other hand, the percentage of North Carolina counties designated as falling within Zone 3A (Warm Moist) increased from 50% to 79%. In total, building requirements in 58 of North Carolina's 100 counties are impacted because these counties are now located in a different climate zone. Under the new map, most of North Carolina is in climate zone 3A, the Blue Ridge Mountains are in climate zone 4A, and a few counties in the northwest corner are in climate zone 5A.

Rather than adopt the provisions of the 2021 IECC wholesale, the ad hoc committee appointed to prepare the proposed 2024 NCECC decided to bring forward several North Carolina-specific modifications to thermal envelope requirements and envelope leakage testing methods from the 2018 NCECC. The proposed energy conservation requirements for one- and two-family dwelling and townhomes met significant opposition from the North Carolina Homebuilders Association, and, as a result, the NCECC ad hoc committee and the ad hoc committee appointed to prepare the proposed 2024 North Carolina Residential Code held joint meetings in March and April 2023 to attempt to reach a compromise. Those efforts were not successful, as the Residential ad hoc committee voted to recommend that the N.C. Building Code Council carry forward Article IV, Chapter 11, *Energy Efficiency*, from the 2018 North

Carolina Residential Code into the 2024 North Carolina Residential Code. As noted above, Chapter 11 of the North Carolina Residential Code provides minimum design requirements directed toward the design of building envelopes with adequate thermal resistance and low air leakage and the design and selection of mechanical, water heating, electrical, and illumination systems for detached one- and two- family dwellings, townhouses, and bed and breakfast homes. In prior editions of the State Building Code, the provisions of Chapter 11 of the North Carolina Residential Code substantively mirrored the residential provisions the NCECC.

The proposed 2024 NC Energy Conservation Code is available at: https://www.ncosfm.gov/b-6-2024-ncecc-0/open.

Impact Analysis: Commercial

Federal Government

Federal buildings in North Carolina would not be affected by the changes in the Code as they are not required to comply with State requirements. Most branches of the federal government, however, do follow local laws as a matter of policy, so some cost increases from increases in energy efficiency are expected. At this point, it is unknown how many federal buildings are planned in North Carolina for the upcoming years.

State Government

The impact on State Government would be minimal. Code Official training would continue to take place through the existing Community College programs. There are no expected changes in time or cost associated with curriculum updates as the annual training is updated regularly, independent of rule changes. There are also continuing education requirements in place to supplement the Code Official's knowledge. There are no expected cost increases for Code enforcement.

Pursuant to N.C. Gen. Stat. § 143-135.37, State-owned buildings must be designed, constructed, and certified to exceed the energy efficiency requirements of ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) 90.1-2004. However, where the ASHRAE 90.1-2004 standard is determined to be not practicable for the construction or renovation of a State-owned building, N.C. Gen. Stat. § 143-135.38 allows the State Building Commission to determine an alternative standard for the project. For these projects, moving to the proposed 2024 NCECC from the 2018 NCECC is expected to be cost-effective for those State-owned buildings built to the requirements of the 2024 NCECC. According to the U.S. Department of Energy' Pacific Northwest National Laboratory, use of the 2024 NCECC would result in an average net LCC savings of $\$6.15/ft^2$ for publicly-owned buildings in North Carolina, which is a $\$0.40/ft^2$ improvement in savings over the average LCC estimate for similar privately-owned buildings, across all climate zones and building types. *See* **Appendix C, Table 2**. Appendix C, Tables 4 and 5 provide tabulated values for incremental construction costs and annual energy cost savings, which are comparable to those for private commercial buildings.

The Department of Administration, through the State Energy Office, has developed a comprehensive program to help State agencies and State institutions of higher learning manage their energy consumption.

Local Government

Construction Costs – Publicly-Owned

Incremental construction costs for publicly-owned buildings are expected to decrease overall across all building types due to the transition to the 2024 NCECC. Across all building types, construction costs for buildings located in climate zone 3A are expected to decrease by $0.878/ft^2 because of the move from the 2018 NCECC to the 2024 NCECC. Likewise, incremental construction costs across all publicly-owned building types located in climate zone 4A are projected to decline by $0.651/ft^2, and those costs for buildings located in climate zone 5A will decrease by $0.719/ft^2. *See* **Appendix C, Table 5** (reproduced at page 3 above).

Energy Savings – Publicly-Owned

The energy savings for publicly-owned buildings is expected to be similar for privately-owned buildings and were not calculated separately. See Appendix C, Table 4 (reproduced below in Energy-Savings – Commercial).

Life Cycle Cost (LCC) – Publicly-Owned

Taking a longer view, the net Life Cycle Cost (LCC) savings, which is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period, indicate that moving to the proposed 2024 NCECC from the 2018 NCECC will be cost-effective for publicly-owned buildings. LCC cost analysis is the most straightforward and easy-to-interpret measure of economic valuation. Costs considered include initial equipment and construction costs, maintenance, and replacement costs, less the residual value of components at the end of the 30-year period. Using the statutorily-mandated real discount rate of 7.00%,[2] the U.S. Department of Energy' Pacific Northwest National Laboratory found that moving to the 2024 NCECC would result in an average net LCC savings of $6.15/ft^2 for publicly-owned buildings in North Carolina. When net LCC is positive, the updated code edition is considered cost-effective. *See* **Appendix C, Tables 2 and 3**.

Net LCC Savings: Publicly Owned Buildings ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$3.78	$5.06	$6.32	$6.17	$11.76	$6.70	$6.16
4A	$4.13	$5.57	$5.54	$6.49	$11.54	$5.93	$6.00
5A	$3.59	$6.04	$5.73	$4.83	$11.15	$2.77	$5.18
State Average	$3.80	$5.06	$6.24	$6.18	$11.73	$6.64	$6.15

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code* (March 22, 2023) *See* **Appendix C, Table 2**.

The Building Code Council has no knowledge at the present of the number of buildings

[2] N.C. Gen Stat. § 150B-21.4 requires that "[f]or costs that occur in the future" the net present value of the costs be calculated "using a discount factor of seven percent (7%)."

local governments plan to erect in the future, so the volume of local government new building construction is unknown.

Other Costs/Savings – Local Government

Local governments may choose to purchase additional copies of the 2024 Code edition for enforcement (each local code enforcement agency receives a complete set of NC State Building Codes at no charge). The cost for an additional copy of the 2024 NCECC is expected to be $35. It is difficult to estimate how many additional copies local governments would choose to purchase.

The impact on Code Officials who are employed by local governments is expected to be minimal, if any. Currently, each Code Official is required 6-hours of continuing education per Certificate per year, so the yearly training would cover changes to the 2024 Codes, creating no additional cost. There are no expected cost increases for Code enforcement.

Privately-Owned

Construction Costs - Commercial

Incremental construction costs are expected to decrease across all commercial building types in all climate zones by $0.86/ ft^2 on average. *See* **Appendix C, Table 5** (reproduced below). According to the analysis by the U.S. Department of Energy's Pacific Northwest National Laboratory, the decrease in first costs for commercial builders is attributable to several factors. First, the 2024 NCECC reduces allowed lighting power in buildings, translating into fewer required light fixtures, as well as reduced lighting costs due to the change from fluorescent to LED technology. Second, the 2024 NCECC's more stringent building envelope and fenestration U-factors mean that buildings can use smaller heating, ventilating, and air conditioning (HVAC) equipment sizes and distribution systems, resulting in a negative first cost.

For multifamily apartments and condominiums, construction costs are anticipated to increase by $1,803 per dwelling unit for buildings located in Zones 3A and 3AWH with crawlspace or unheated basement foundations, and $1,867 per dwelling unit for buildings with concrete slab foundations. Construction costs for multifamily apartments and condominiums located in Zone 4A are anticipated to increase by $1,552 per dwelling unit for buildings with crawlspace or unheated basement foundations, and $1,616 per dwelling unit for buildings with concrete slab foundations. The cost of building multifamily apartments and condominiums located in Zone 5A are anticipated to increase by $2,029 per dwelling unit for buildings with crawlspace and unheated basement foundations, and $2,092 per dwelling unit for buildings with concrete slab foundations. *See* **Appendix D, Table 9**.

Incremental construction costs for small offices and small hotels are anticipated to increase by $0.33/ft^2$ and $0.604/ft^2$, respectively, averaged across the three North Carolina climate zones, due to the move from 2018 NCECC to 2024 NCECC efficiency standards. For those builders facing higher first costs, they should be able to pass that cost onto building owners.

Commercial Construction: Incremental Construction Cost ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.342	($1.275)	($0.993)	($2.137)	$0.603	($0.695)	($0.878)
4A	$0.183	($1.669)	($0.957)	($1.999)	$0.610	($0.255)	($0.651)
5A	$0.539	($1.805)	($1.037)	($0.670)	$0.572	($0.468)	($0.719)
State Average	$0.333	($1.276)	($0.991)	($2.117)	$0.604	($0.670)	($0.863)

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code* (March 22, 2023) *See* **Appendix C, Table 5**.

Energy Savings - Commercial

From the perspective of commercial building owners and tenants, moving to the proposed 2024 NCECC from the 2018 NCECC is expected to result in annual energy cost savings of roughly $0.23 per square foot for commercial buildings and multifamily condominiums and apartments governed by the North Carolina Building Code. The building owners are the ones who would incur the benefits of reduced energy bills.

Commercial Construction: Annual Energy Cost Savings ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.176	$0.180	$0.242	$0.170	$0.240	$0.267	$0.227
4A	$0.184	$0.180	$0.204	$0.191	$0.227	$0.263	$0.220
5A	$0.181	$0.197	$0.215	$0.208	$0.231	$0.080	$0.189
State Average	$0.177	$0.180	$0.238	$0.172	$0.238	$0.266	$0.226

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code* (March 22, 2023) *See* **Appendix C, Table 4**.

Societal Benefits - Commercial

Any changes to commercial construction that result in improvements to energy efficiency are likely to reduce emissions of carbon dioxide and other greenhouse gases. Reducing carbon dioxide and other greenhouse gas emissions will result in air quality improvements that will benefit human health and prevent losses to society related to agriculture, property, wellbeing, medical expenses, labor and the economy. While not monetized for this analysis, these societal benefits are expected to be significant and will occur in both the near-term and long-term.

Life Cycle Cost (LCC) - Commercial

The net 30-year Life Cycle Cost (LCC) savings, as estimated by PNNL, indicate that moving to the proposed 2024 NCECC from the 2018 NCECC will be cost-effective for privately-owned commercial buildings. Using the statutorily-mandated real discount rate of

7.00%,[3] PNNL estimated that moving to the 2024 NCECC would result in an average net LCC savings of $5.75/ft^2 for privately-owned buildings in North Carolina. When net LCC is positive, the updated code edition is considered cost-effective. *See* **Appendix C, Tables 2 and 3**.

Net LCC savings for privately-owned small offices and small hotels across all climate zones are expected to average $3.97/ft^2 and $12.02/ft^2, respectively, as a result of the transition to the 2024 NCECC.

Net LCC Savings: Privately Owned Buildings ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$3.95	$4.44	$5.83	$5.11	$12.06	$6.44	$5.76
4A	$4.22	$4.75	$5.07	$5.50	$11.83	$5.89	$5.70
5A	$3.85	$5.16	$5.22	$4.50	$11.43	$2.63	$4.85
State Average	$3.97	$4.44	$5.75	$5.13	$12.02	$6.40	$5.75

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code* (March 22, 2023) *See* **Appendix C, Table 3**.

Methodology and Assumptions - Commercial

The Pacific Northwest National Laboratory report in **Appendix C** modeled a variety of uses to evaluate the costs and benefits of increased energy saving features. The 2018 NCECC was used as the baseline for comparison. The energy prices used in the analysis are $0.0877/kWh for electricity and $0.8800/therm for natural gas. The analysis assumes an inflation-adjusted energy price escalation factor of 19.17 for electricity and 23.45 for natural gas. To comply with North Carolina law, the analysis utilizes a 7.00% real discount rate, rather than the 3.34% real discount rate currently used by the U.S. Department of Energy when otherwise evaluating the cost effectiveness of energy codes for privately-owned commercial buildings. *See* **Appendix C, Table 1, and Appendix E, Table 3.** For more information regarding the methodology utilized by the U.S. Department of Energy's Pacific Northwest National Laboratory for evaluating the cost-effectiveness of commercial energy code changes, see **Appendix E** and **Appendix F**.

Impact Analysis - Residential

OTHER THAN FOR R-2 AND R-4 OCCUPANCIES THREE STORIES OR LESS IN HEIGHT ABOVE GRADE PLANE, COMPLIANCE WITH THE RESIDENTIAL PROVISIONS OF THE 2024 NCECC WOULD BE VOLUNTARY. ALL ANALYSIS ADDRESSING RESIDENTIAL OCCUPANCIES GOVERNED BY THE NORTH CAROLINA RESIDENTIAL CODE IS OFFERED TO DEMONSTRATE THE COST EFFECTIVENESS FOR THOSE WHO OPT TO UTILIZE THE PROVISIONS VOLUNTARILY.

[3] N.C. Gen Stat. § 150B-21.4 requires that "[f]or costs that occur in the future" the net present value of the costs be calculated "using a discount factor of seven percent (7%)."

As noted above, the residential provisions of the 2024 NCECC provide the minimum energy efficiency requirements for Group R-2 and Group R-4 buildings three stories or less in height above grade plane. 2024 NCECC §§ R101.2, R202. Minimum energy efficiency requirements for the construction of detached one- and two-family dwellings and townhouses not more than three stories above grade plane in height, their accessory structures not more than three stories above grade plane in height, and bed and breakfast homes are instead governed by Article IV, Chapter 11 of the North Carolina Residential Code. 2018 North Carolina Residential Code §§ R101.2, N1101.1. Although the residential provisions of the NCECC and Chapter 11 of the North Carolina Residential Code have mirrored one another in prior editions of the North Carolina State Building Code, Session Law 2023-108 prohibits the Building Code Council (and the new Residential Code Council) from adopting new code provisions "relating to energy conservation or efficiency of buildings, dwellings, and structures to which the North Carolina State Residential Code applies" until after January 1, 2026. N.C. Sess. L. 2023-108, s. 8 (eff. Aug. 16, 2023). Accordingly, the residential provisions of the proposed 2024 NCECC do not set out the minimum energy efficiency requirements for the detached one- and two-family dwellings, townhouses, accessory buildings, and bed and breakfast homes, which are instead governed by Article IV, Chapter 11 of North Carolina Residential Code. However, North Carolina residential owners and their agents may choose, at their option, and with the approval of the responsible code enforcement official, to comply with the residential provisions of the 2024 NCECC as an alternate method of construction. N.C. Gen. Stat. § 143-140.1. Accordingly, discussion below of the impact of the transition to the 2024 NCECC from the 2018 NCECC for North Carolina detached dwellings and townhouses assumes that the owner and builder have voluntarily elected to comply with the optional minimum requirements of the 2024 NCECC, rather than the mandatory minimum requirements of Article IV, Chapter 11 of the North Carolina Residential Code.

Construction Costs - Residential

Should residential owners and their agents choose to comply with the residential provisions of the 2024 NCECC, construction costs for single-family homes located in Zones 3A and 3AWH are anticipated to increase by $4,763 for homes with crawlspaces and unheated basements and increase by $5,194 for homes with concrete slab foundations. Moving to the requirements of the 2024 NCECC from the 2018 NCECC will result in an increase of $4,755 for single-family homes located in Zone 4A with crawlspace or unheated basement foundations, and increase by $5,186 for those with concrete slab foundations. For single-family homes located in climate zone 5A, the move to the 2024 NCECC requirements would result in an increase in first costs of $6,057 for those with crawlspaces and unheated basements, and an increase of $6,487 for single-family homes with slab foundations.

Residential Construction: Total Single-Family Construction Cost Increase for the 2024 NCECC Compared to the 2018 NCECC

Climate Zone	Crawlspace	Slab	Unheated Basement
3A	$4,763	$5,194	$4,763
3AWH	$4,763	$5,194	$4,763
4A	$4,755	$5,186	$4,755
5A	$6,057	$6,487	$6,057

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code* (March 24, 2023) *See*

Appendix D, Table 8.

Mortgage-related Costs - Residential

Builders are expected to pass any incremental construction costs on to North Carolina homeowners, who are anticipated to face increased incremental down payment and other first costs of between $421 and $534 depending on the climate zone in which the residence is located. For homeowners with mortgages, this would translate into annual mortgage increases for single-family homeowners of between $231 and $294 and net annual costs related to mortgage interest deductions, mortgage insurance, and property taxes of between $30 and $38 at year one, depending on climate zone.

Energy Savings - Residential

Mortgage-related increases and net annual costs are expected to be offset by annual energy savings at year one, with homeowners expected to save between $129 and $283 in the first year of homeownership, even after accounting for these costs (but not incremental down payment and other first costs). As a result of the transition to 2024 NCECC, single-family homeowners would be expected to see positive savings, even after accounting for the increased incremental down payment and other first costs, at year 2 for those in climate zone 4A, year 3 for those in climate zone 5A, and year 4 for those in climate zones 3A and 3AWH.

Consumer Cash Flow from Compliance with 2024 NCECC Compared to 2018 NCECC

	Cost/Benefit	3A	3AWH	4A	5A
A	Incremental down payment and other first costs	$429	$429	$421	$534
B	Annual energy savings (year one)[4]	$395	$381	$545	$523
C	Annual mortgage increase	$236	$236	$231	$294
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$31	$31	$30	$38
E = [B-(C+D)]	Net annual cash flow savings (year one)	$129	$114	$283	$191
F = [A/E]	Years to positive savings, including up-front cost impacts	4	4	2	3

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code* (March 24, 2023) *See* **Appendix D, Table 6**.

From the perspective of North Carolina residential homeowners, the move to the 2024 NCECC would result in first year energy savings of $15,372,000 statewide, with individual homeowners in climate zone 3A seeing first year annual energy savings of $395, homeowners in climate zone 3AWH saving $381 in the first year, homeowners in climate zone 4A seeing first year energy savings of $545, and homeowners in climate zone 5A saving $523 in first year energy costs even after considering inflation and price escalations. *See* **Appendix D, Tables 2**

[4] Annual energy savings as reported at year 1, after considering inflation and price escalations.

and 6. According to the U.S. Department of Energy's Pacific Northwest National Laboratory, taking into account increased mortgage costs and increased mortgage insurance and property tax costs, the move to the 2024 NCECC would cause North Carolina homeowners to see first-year net annual cash flow savings of $129 in climate zone 3A, $114 in climate zone 3AWH, $283 in climate zone 4A, and $191 in climate zone 5A. *See* **Appendix D, Table 6**.

Societal Benefits – Residential

If widely adopted, the changes are also expected to reduce carbon dioxide emissions in North Carolina by 130,700 metric tons in the first year, which is equivalent to the annual carbon dioxide emissions of nearly 29,000 cars on the road. *See* **Appendix D, Tables 1 and 2**. Reducing carbon dioxide and other greenhouse gas emissions will result in air quality improvements that will benefit human health and prevent losses to society related to agriculture, property, wellbeing, medical expenses, labor, and the economy. While not monetized for this analysis, these societal benefits are expected to be significant and will occur in both the near-term and long-term.

Potential Societal Benefits from Proposed Changes to NC Residential Code

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	15,372,000	5,331,440,000
CO_2 emission reduction, Metric tons	130,700	65,815,000
CH_4 emissions reductions, Metric tons	9.4	4,700
N_2O emissions reductions, Metric tons	1.310	660
NO_x emissions reductions, Metric tons	78.5	39,500
SO_x emissions reductions, Metric tons	50.3	25,300

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code* (March 24, 2023)

Life Cycle Cost (LCC) - Residential

The net LCC savingsindicate that moving to the proposed 2024 NCECC from the 2018 NCECC will be cost-effective for North Carolina single-family homeowners. Using the statutorily-mandated real discount rate of 7.00%, the U.S. Department of Energy' Pacific Northwest National Laboratory found that moving to the 2024 NCECC would result in an average LCC savings of $2,063 for homeowners in climate zone 3A, $1,858 for homeowners in climate zone 3AWH, $4,530 for homeowners in climate zone 4A, and $3,256 for homeowners in climate zone 5A. As noted above, when net LCC is positive, the updated code edition is considered cost-effective.

Residential Construction: Life-Cycle Cost Savings of the 2024 NCECC Compared to the 2018 NCECC

Climate Zone	Life-Cycle Cost Savings ($)
3A	$2,063
3AWH	$1,858
4A	$4,530
5A	$3,256

Source: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code* (March 24, 2023) *See* **Appendix**

D, Table 5.

Methodology and Assumptions - Residential

The Pacific Northwest National Laboratory report in **Appendix D** modeled single-family prototype houses with four foundation types and four HVAC types with TMY3 weather data for climate zones 3A, 3AWH, 4A and 5A to evaluate the costs and benefits of a move to the 2023 NCECC. The 2018 NCECC was used as the baseline for comparison. The energy prices used in the analysis are $0.116/kWh for electricity, $1.253/therm for natural gas, and $2.422/MBtu for fuel oil. The analysis utilizes a 1.6% inflation rate to model future costs. To comply with North Carolina law, the analysis utilizes a 7.00% real discount rate, as opposed to the 5% discount rate currently used by the U.S. Department of Energy when otherwise evaluating the cost effectiveness of residential energy codes. *See* **Appendix D, Tables 3 and 4, Appendix E, Table 4.** For more information regarding the methodology utilized by the U.S. Department of Energy's Pacific Northwest National Laboratory for evaluating the cost-effectiveness of residential energy code changes, see **Appendix E** and **Appendix G**.

Risks and Alternatives

Two alternative options available to adopting the 2024 NCECC as proposed are (1) to remain at the current level of energy conservation based on the requirements of the 2018 NCECC for 0% additional energy savings, or (2) to increase the level energy conservation based on the 2018 NCECC plus incremental measures adopted from the 2021 IECC for additional energy cost savings.

Given the across-the-board opposition to adoption of the Residential Provisions of the 2021 IECC voiced by the North Carolina Homebuilders Association and other groups, option two was pursued by the Building Code Council's energy code ad hoc committee and residential code ad hoc committees for the Residential Provisions of the 2024 NCECC and Chapter 11, *Energy Efficiency*, of the North Carolina Residential Code. In prior editions of the State Building Code, the provisions of Chapter 11 of the North Carolina Residential Code have been duplicated from the Residential Provisions of the North Carolina Energy Conservation Code, and the provisions addressing residential construction contained in the two code volumes have complimented, rather than contradicted, one another.

In Spring 2023 and Summer 2023, the energy and residential ad hoc committees held several joint meetings in an attempt to reach a compromise addressing both Chapter 11 of the Residential Code and the Residential Provisions of the 2024 NCECC. Although the energy ad hoc committee presented several compromise proposals to the residential ad hoc committee, these proposals were rejected by the residential ad hoc committee which voted instead to recommend that the N.C. Building Code Council carry forward Chapter 11, *Energy Efficiency*, from the 2018 North Carolina Residential Code into the 2024 North Carolina Residential Code. In sum, the residential ad hoc committee recommended that the Council pursue option one regarding residential energy provisions, which would result in no additional energy savings.

At the Building Code Council's March 14, 2023 quarterly meeting, the Council voted to advance two notices of proposed rulemaking addressing Chapter 11 of the 2024 North Carolina Residential Code for public comment: one that would adopt the Residential Provisions of the

2024 NCECC and another that would carry forward Chapter 11 of the 2018 North Carolina Residential Code into the 2024 North Carolina Residential Code with no updates. Public comment on both proposals was expected to be received at future meetings. However, on August 16, 2023, the North Carolina General Assembly enacted Session Law 2023-108, overriding the veto of the Governor. Section 8 of Session Law 2023-108 prohibits the Building Code Council from adopting rules to "amend Part IV – Energy Conservation (Chapter 11)" of the North Carolina Residential Code and bars the Council from adopting new code provisions "relating to energy conservation or efficiency of buildings, dwellings, and structures to which the North Carolina State Residential Code applies." N.C. Sess. L. 2023-108, s. 8 (eff. Aug. 16, 2023). Section 8 of N.C. Sess. L. 2023-108 became effective upon its enactment and "applies retroactively to March 1, 2023." *Id.* The provision expires on January 1, 2026.

Regarding risks inherent to adoption of the 2024 NCECC, the expected increased first costs for commercial builders constructing small offices and small hotels are expected to be absorbed and amortized over the depreciation schedule. One risk to the building owners, whether public or private, is that the energy payback period may exceed the depreciation schedule.

In privately-owned dwellings, the homeowner's year one annual energy cost savings exceeds the expected mortgage payment increase. Residential builders risk profit loss if the appraisal of the new residence does not justify an increase in the approved mortgage amount.

Another risk inherent to cost-benefit analyses is that the analyses relied on here assume that the regulated community will voluntarily opt to comply with the residential provisions of 2024 NCECC when building residential buildings other than Group R-2 and Group R-4 occupancies, resulting in the anticipated energy efficiency savings. This assumption can lead to costs and savings being overestimated, since it is unlikely that 100% voluntary compliance for structures outside of Group R-2 and Group R-4 will be attained.

Sensitivity Analysis

The estimated economic impacts of the proposed rules are based on the costs and savings for commercial prototypes comprising six building types across two scenarios: publicly-owned buildings and privately-owned buildings. In implementation, the impact will vary among structures of the same type. Initial construction compliance costs may be high or low for a given structure, and energy savings will vary by the size, location, and design of the structure. Furthermore, estimates rely on assumptions about future construction costs, commercial energy prices, maintenance costs, replacement costs, borrowing costs, and tax impacts.

The discount rate used in quantifying costs and benefits over time will have a large effect on the net impacts. Required by NC General Statute, the 7.0% discount rate utilized in this analysis is higher than the discount rate otherwise used by the Department of Energy to quantify energy costs or savings, *see* **Appendix E, Table 4**. For this analysis, a lower discount rate would result in significantly higher life-cycle cost savings. For example, using a discount rate of 3.34%, the Pacific Northwest National Laboratory calculated that life-cycle cost savings for privately-owned commercial buildings would range from $6.14/ft^2 for all buildings types located in climate zone 3A and $5.24/ft^2 for all buildings types located in climate zone 5A. *See* **Appendix H, Table 3.** Whereas, using a discount rate of 7%, the life-cycle cost savings for privately-owned buildings would range between $5.76/ft^2 for all building types located in climate zone 3A and $4.85 /ft^2 for all buildings types located in climate zone 5A. *See* **Appendix C, Table 3**.

Commercial Construction: Net Life-Cycle Cost Savings of the 2024 NCECC compared to 2018 NCECC

Climate Zone	Net Life-Cycle Cost Savings, All Building Types, 7% Real Discount Rate	Net Life-Cycle Cost Savings, All Building Types, 3.34% Real Discount Rate
3A	$5.76/ft^2	$6.14/ft^2
4A	$5.70/ft^2	$6.11/ft^2
5A	$4.85/ft^2	$5.24/ft^2
State Average	$5.75/ft^2	$6.13/ft^2

Sources: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code* (March 22, 2023) *See* **Appendix C, Table 3**; U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code* (December 12, 2022) *See* **Appendix H, Table 3**.

Similarly, life-cycle cost savings for residential construction would be significantly higher when using a lower discount rate. PNNL set the discount rate equal to the mortgage interest rate in nominal terms.

Residential Construction: Life-Cycle Cost Savings of the 2024 NCECC compared to 2018 NCECC

Climate Zone	Life-Cycle Cost Savings, 7% Real Discount Rate (8.71% nominal) [5]	Life-Cycle Cost Savings, 5% Nominal Discount Rate [6]
3A	$2,063	$3,918
3AWH	$1,858	$3,596
4A	$4,530	$8,005
5A	$3,256	$6,079

Sources: U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code* (March 24, 2023) *See* **Appendix D, Table 5**; U.S. Department of Energy, Pacific Northwest National Laboratory, *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code* (December 12, 2022) *See* **Appendix I, Table 5**.

The Department of Energy analysis assumes that costs across-the-board will increase by 1.85% annually. If construction costs increase more slowly than expected, or decrease, net benefits could be higher than expected and positive savings, even accounting for higher down payments and other first costs, could be seen sooner than calculated here. On the other hand, if energy costs increase more slowly than expected, or decrease, then net benefits could be lower than expected, and it could take more time for new homeowners to break even or see positive savings.

[5] Assuming a rate of inflation of 1.6%, a 7% real discount rate works out to a nominal discount rate of 8.71.
[6] The December 12, 2022 Department of Energy analysis used a nominal discount rate of 5% which was equivalent to the average mortgage rate as of December 2022.

Appendix A:
2024 NC Energy Code Summary - Commercial: Selected Differences Between Existing 2018 NC Energy Code and Proposed 2024 NC Energy Code, North Carolina Department of Insurance
September 5, 2022

Appendix B:
2024 NC Energy Code Summary - Residential: Selected Differences Between Existing 2018 NC Energy Code and Proposed 2024 NC Energy Code, North Carolina Department of Insurance
September 2, 2022

Appendix C:
Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code, Matthew Tyler
U.S. Department of Energy, Pacific Northwest National Laboratory
March 22, 2023

Appendix D:
Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code, Vrushali Mendon, Rob Salcido, and YuLong Xie
U.S. Department of Energy, Pacific Northwest National Laboratory
March 24, 2023

Appendix E:
Methodology
U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy
https://www.energycodes.gov/methodology
August 1, 2023

Appendix F:
Methodology for Evaluating Cost-Effectiveness of Commercial Energy Code Changes, R Hart, B Liu
U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy
Pacific Northwest National Laboratory
August 2015

Appendix G:
Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes, ZT Taylor, VV Mendon, N Fernandez
U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy
Pacific Northwest National Laboratory
August 2015

Appendix H:
Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code, Matthew Tyler
U.S. Department of Energy, Pacific Northwest National Laboratory
December 12, 2022

Appendix I:

Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code, Vrushali Mendon, Rob Salcido, and YuLong Xie
U.S. Department of Energy, Pacific Northwest National Laboratory
December 12, 2023

APPENDIX A

2024 NC Energy Code Summary – Commercial: Selected Differences Between Existing 2018 NC Energy Code and Proposed 2024 NC Energy Code

Prepared by the North Carolina Department of Insurance

N.C. Department of Insurance
Office of State Fire Marshal
325 N. Salisbury Street
Raleigh, N.C. 27603

September 5, 2022

2024 NC ENERGY CODE SUMMARY - COMMERCIAL

Selected differences between existing 2018 NC Energy Code and Proposed 2024 NC Energy Code

SEPTEMBER 5, 2022

NORTH CAROLINA DEPARTMENT OF INSURANCE
325 N. Salisbury St

Contents

Disclaimer

This is a brief overview of what seem to be the major differences between the 2018 NC Energy Code, and the proposed 2024 NC Energy Code. It is not a substitute for the entire document. All requirements of the 2024 NC Energy Code are subject to the BCC approval process, and as such are "proposed" and not finalized.

The Commercial portion of the Energy Code has much more requirements in the Mechanical, lighting, and power systems categories than the Residential, simply because there are so many different scenarios that could occur with these systems and they are more power intensive in large commercial systems compared to residential settings. In past code cycles, NC has traditionally eliminated many of the more detailed allowances and requirements pertaining to more complex lighting system control, building automation control, and commissioning of said systems. The proposed 2024 Energy Code retains the language for these items.

Key Items of Proposed 2024 NC Energy Code (Commercial)

- **Definitions**
- **Building Envelope**
- **Mechanical**
- **Service Water Heating**
- **Electrical Power and Lighting Systems**
- **Additional Efficiency Package Options**
- **Total Building Performance**
- **System Commissioning**
- **Existing Buildings**

Definitions

Process energy

The 2018 NC Energy Code had a definition for process energy, and then the scoping requirement exempted process energy from the energy code requirements. The 2024 Code does not exempt process energy. Realistically, there is little that is specifically covered that is not already covered implicitly with high-efficiency motors or in items that are simply beyond the scope of what is covered by the NC Code. Practically however, data centers are quite common, and they are now considered process energy, and would not be exempt. Similarly, refrigeration systems, such as walk-in coolers and refrigeration for food was exempt.

Building Envelope

Compliance Paths - Many available paths to comply

Similar to the 2018 NC Energy Code, there are several different paths to demonstrate compliance, and within each path there are several sub-pathways. Although the values have changed within these various paths, there are no notable new paths introduced, or paths dropped from the 2018 NC Energy Code. However, subject to the size of a building, any compliance path would be required to demonstrate compliance with an added Energy Utilization Index criteria.

Energy Utilization Index

This proposed path by the NC Energy ad hoc committee (it was not part of the 2021 IECC) was deleted after review and input from PNNL.

2024 NC Energy Code Compliance paths

The permit holder can demonstrate compliance via the IECC language, or via the ASHRAE 90.1 language. Within each major path, there are sub-pathways that allow flexibility. At one time, perhaps in the 2012 NC Energy Code, there were substantial differences in the building envelope stringencies of the IECC energy code and the ASHRAE 90.1 standard, but those differences have diminished considerably since then, even in the 2018 code cycle there were little differences in the building envelope, and the ASHRAE 90.1 standard tends to be more control-intensive than the IECC model code language, but that difference too is being diminished.

- **C401.2.1 International Energy Conservation Code.** Commercial buildings shall comply with one of the following:
  - Prescriptive compliance (will include ResCheck for the envelope portion)
  - Total Building Performance
- **C401.2.2 ASHRAE 90.1.** Commercial buildings shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1 (with ResCheck for the Envelope option allowed)

The proposed 2024 Code has similar compliance paths as the 2018 NC Energy code. The paths are outlined slightly differently so that they are supposedly clearer to follow, but there are no major changes in this section.

Additional requirement

The commercial code has had this requirement since the 2012 Energy Code, and it is included again for the 2024 Code.

Climate Zones

- Before we look at the proposed insulation levels, I need to note the Climate Zones are changing – Due to increasing Cooling Degree Days, decreasing Heating Degree Days, and changing the criteria for classification

In and of itself, this is a pretty significant change for NC, as it switches the requirements of 58 out of the 100 NC Counties. See maps below.

Figure 1: 2018 NC Climate Zones

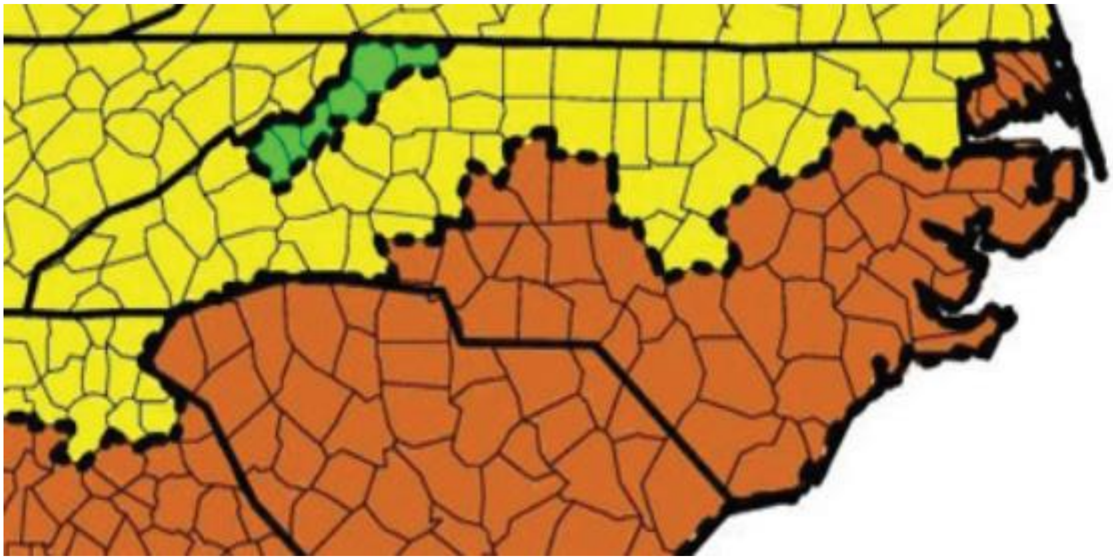

Figure 2: 2024 NC Climate Zones

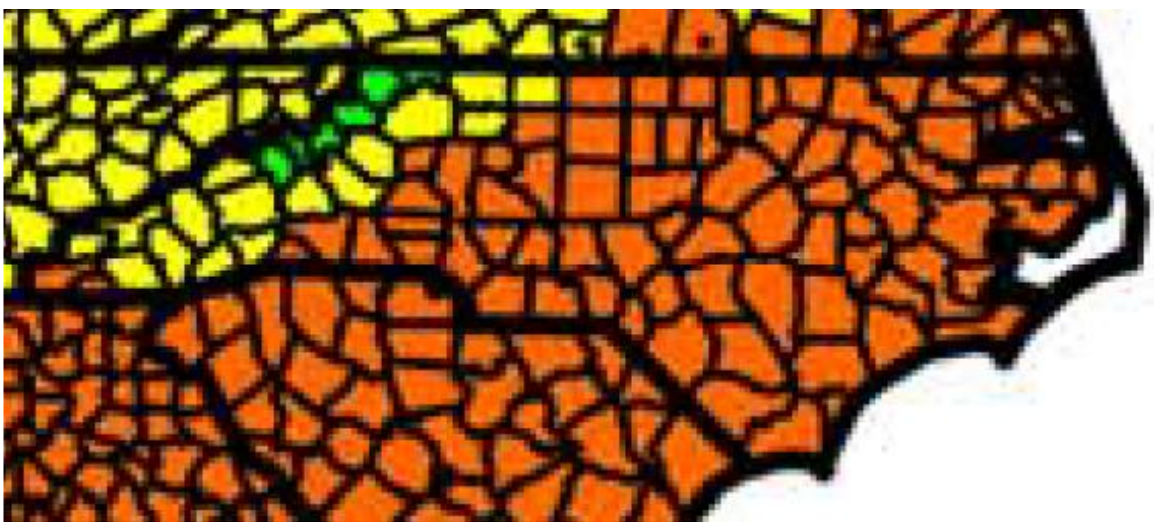

Figure 3: Summary of changes to NC Counties by zone

	2018 NC ECC		2024 NC ECC	
Zone 5	6	6%	5	5%
Zone 4	44	44%	16	16%
Zone 3	50	50%	79	79%

	100	100%	100	100%

In looking at the following thermal envelope categories, bear in mind the proposed changes to the climate zones for 58 of the NC counties. NC is closer to the climate of South Carolina and Alabama than it is to Virginia.

Key Items of Proposed 2024 NC Energy Code – Thermal envelope prescriptive requirements

The commercial thermal envelope requirements would be largely the same as the 2018 NC Energy Code, largely because the Commercial Code adopted large increase in the past, and so the incremental changes are smaller. Several of the walls are slightly more stringent, but several of the changes are just providing more prescriptive options.

Figure 4: Existing (2018 NC Energy code) thermal envelope requirements

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, R-VALUE METHOD[f]

CLIMATE ZONE	3		4		5	
	All other	Group R	All other	Group R	All other	Group R
Roofs						
Insulation entirely above roof deck	R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci
Metal buildings[a, b]	R-10 + R-19 FC	R-10 + R-19 FC	R-19 + R-11 LS; R-25 + R-8 LS	R-19 + R-11 LS; R-25 + R-8 LS	R-19 + R-11 LS; R-25 + R-8 LS	R-19 + R-11 LS; R-25 + R-8 LS
Attic and other – wood framing[c]	R-38	R-38	R-42	R-42	R-42	R-42
Attic and other – steel framing[c]	R-38	R-38	R-49	R-49	R-49	R-49
Walls, above grade						
Mass	R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci	R-11.4ci	R-15ci
Metal building[b]	R-0 + R-9.8ci	R-0 + R-13ci	R-0 + R-15.8ci	R-0 + R-19ci	R-0 + R-19ci	R-0 + R-19ci
Metal framed	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-10ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci
Walls, below grade						
Below-grade wall[c]	R-7.5ci	R-7.5ci	R-7.5ci	R-10ci	R-7.5ci	R-10ci
Floors						
Mass	R-12.5ci	R-12.5ci	R-14.6ci	R-16.7ci	R-14.6ci	R-16.7ci
Joist/Framing	R-30[d]	R-30[d]	R-38	R-38	R-38	R-38
Slab-on-grade floors[c]						
Unheated slabs	NR	R-10 for 24″	R-15 for 24″	R-15 for 24″	R-15 for 24″	R-20 for 24″
Heated slabs	R-15 for 24″	R-15 for 24″	R-20 for 24″	R-20 for 48″	R-20 for 48″	R-20 for 48″
Opaque doors						
Swinging	U-0.70	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50
Nonswinging	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50

Figure 5: Proposed (2024 NC Energy code) thermal envelope requirements

TABLE R402.1.3

INSULATION MINIMUM *R*-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE					3		4 ~~EXCEPT MARINE~~		5 ~~AND MARINE 4~~							
					All other	Group R	All other	Group R	All other	Group R						
Roofs																
Insulation entirely above roof deck					R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci						
Metal buildings[b]					R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS						
Attic and other					R-38	R-38	R-49	R-49	R-49	R-49						
Walls, above grade																
Mass[f]					R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci	R-11.4ci	~~R-13.3ci~~ R-15ci						
Metal building					R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci						
Metal framed					R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-10ci	R-13 + R-10ci						
Wood framed and other					R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R20 + R3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci						
Walls, below grade																
Below-grade wall[d]					~~NR~~ R-7.5ci	~~NR~~ R-7.5ci	R-7.5ci	R-10ci	R-7.5ci	R-10ci						
Floors																
Mass[e]					~~R-10ci~~ R-12.5ci	~~R-10ci~~ R-12.5ci	R-14.6ci	R-16.7ci	R-14.6ci	R-16.7ci						
Joist/framing					R-30[e]	R-30[e]	~~R-30~~ R-38	~~R-30~~ R-38	~~R-30~~ R-38	~~R-30~~ R-38						
Slab-on-grade floors																
Unheated slabs					NR	R-10 for 24″ below	R-15 for 24″ below	R-15 for 24″ below	R-15 for 24″ below	R-20 for 24″ below						
Heated slabs[g]					R-10 for 24″ below+ R-5 full slab	R-10 for 24″ below+ R-5 full slab	R-15 for 24″ below+ R-5 full slab	R-15 for 24″ below+ R-5 full slab	R-15 for 36″ below+ R-5 full slab	R-15 for 36″ below+ R-5 full slab						

Envelope Leakage

For the 2024 NC Energy Code, the Envelope Leakage Rate must be measured for commercial buildings. This was not a requirement in the 2018 NC Code. It is also required to be 3rd-party testing. This requirement is true for both the IECC path and the ASHRAE 90.1 path, although there are some differences in the allowed leakage rate.

There were mandatory building envelope sealing requirements since the 2012 code and even earlier, but there were no requirements to demonstrate the actual performance of the envelope.

> **2024 NC Language** - C402.5.2 Air Leakage Compliance. …The maximum air leakage rate is 0.35 cfm/SF of the building thermal envelope area measured at a pressure differential of 0.30 inches of water gage…
>
> NC added a table for different test pressures, to accommodate more test equipment that may be commonly used.
>
> NC substantially reached forward into the proposed 2024 IECC code for more mature language than is in the 2021 IECC language. Therefore, there are substantial formatting differences being proposed for the 2024 NC Energy Code as opposed to the 2021 IECC stock language for the air leakage testing. The 2021 IECC was the first time the model code had testing language in it for commercial buildings, and the ad hoc committee felt some of the 2024 IECC language had more of the bugs worked out of it.

Other envelope Items

- C402.1.2 Rooms containing fuel-burning appliances.

  Rooms containing open combustion air ducts (ducts communication to the exterior) shall be outside the building thermal envelope, isolated from the remainder of the main thermal envelope. This does not apply to direct vent appliances, fireplaces with combustion air ducts installed, or appliances not requiring combustion air ducts/grilles.

  NC did not adopt this code item in the 2018 NC Energy Code from the 2015 IECC. A typical example for this would be a boiler room where the combustion air louvers are in the wall. This code section requires the designer to gerrymander the thermal envelope around the boiler room, so that the combustion air louvers, which may be open many hours of the year, do not defeat the purpose of the thermal envelope.

Mechanical

C403.2.3 Fault detection and diagnostics.

The 2024 NC Code would require buildings greater than 20,000 SF to have a Fault Detection and Diagnostics system, or have the building controls perform this function, to identify and report faults to the HVAC control system.

Equipment Efficiencies

The tables of equipment efficiencies have been updated to reflect national standards. NC has traditionally used the tables as presented, and 2024 is no exception.

Kitchen exhaust systems

The 2018 NC Energy Code deleted the requirements for certain larger kitchen exhaust systems, the 2024 Code has included the design requirements. The design requirements appear to be what would be standard design, but the inclusion is noted.

Hotel Guestrooms

The 2018 NC code largely deleted the requirements for the HVAC control for guestrooms. The 2024 Code has retained the requirements.

Refrigeration systems

The 2018 NC code defined these systems as process energy, and exempted any requirements. The 2024 Code does not exempt them, and includes the minimum efficiency standards for this equipment.

Excerpt of 2018 NC Energy code-

C403.2.8 Kitchen exhaust systems. Deleted.

Ductwork

- Present requirements are essentially the same as the proposed requirements. The commercial code is a little different than the Residential Code in that there is no semi-conditioned space in the Commercial Code, so technically when ductwork is within the building thermal envelope, there is not a minimum insulation R-value specified. It is good design to include some, but there is not a minimum code requirement.
- Proposed requirements include R-6 for supply and return inside the building but outside the thermal envelope, and R-8 for ductwork outside the building for zones 3 and 4, and R-12 in Zone 5.

Pipe Insulation

The 2024 NC code is not significantly different from the 2018, with the exception of smaller piping. NC has, since 2012, required 1.5-inch insulation on smaller refrigerant lines outside the thermal envelope, where ASHRAE required 1-inch, so NC was more restrictive, and this sometimes would lead to confusion for national distribution companies.

The proposed chart requires more knowledge of the process (temperature of fluid) than the existing chart, but the insulation values are comparable to or less for most applications that are routinely encountered.

Figure 6: 2018 NC Piping Insulation Chart

TABLE C403.2.10
MINIMUM PIPING INSULATION THICKNESS[a, b]

FLUID	NOMINAL PIPE DIAMETER	
	≤ 1.5″	> 1.5″
Steam	$1^1/_2$	3
Hot water	$1^1/_2$	2
Chilled water, brine or refrigerant	$1^1/_2$	$1^1/_2$

Figure 7: 2024 NC Piping Insulation Chart

TABLE C403.12.3
MINIMUM PIPE INSULATION THICKNESS (in inches)[a, c]

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu × in./(h × ft² × °F)[b]	Mean Rating Temperature, °F	< 1	1 to < $1^1/_2$	$1^1/_2$ to < 4	4 to < 8	> 8
> 350	0.32–0.34	250	4.5	5.0	5.0	5.0	5.0
251–350	0.29–0.32	200	3.0	4.0	4.5	4.5	4.5
201–250	0.27–0.30	150	2.5	2.5	2.5	3.0	3.0
141–200	0.25–0.29	125	1.5	1.5	2.0	2.0	2.0
105–140	0.21–0.28	100	1.0	1.0	1.5	1.5	1.5
40–60	0.21–0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20–0.26	50	0.5	1.0	1.0	1.0	1.5

Plumbing

The 2018 Energy Code has no guidance/requirements pertaining to how long the piping systems can be, the primary difference with eh 2024 Code is it incentivizes more compact piping systems to minimize extensive lengths. The insulation requirements are similar to present requirements.

Electrical:

Lighting controls

The present 2018 NC Energy Code deleted any requirements for daylight-responsive controls.

C405.2.3 Daylight-responsive controls. Deleted.
C405.2.3.1 Daylight-responsive control function.
Deleted.
C405.2.3.2 Sidelight daylight zone. Deleted.

C405.2.3.3 Toplight daylight zone. Deleted.

The 2024 NC Energy code has requirements for daylit zones with the following thresholds:

** **C405.2.4 Daylight-responsive controls.** *Daylight-responsive controls* complying with Section C405.2.4.1 shall be provided to control the general lighting within *daylight zones* in the following spaces:

1. Spaces with a total of more than **150 watts** of *general lighting* within primary sidelit daylight zones complying with Section C405.2.4.2.
2. Spaces with a total of more than **300 watts** of *general lighting* within sidelit daylight zones complying with Section C405.2.4.2.
3. Spaces with a total of more than **150 watts** of *general lighting* within toplit daylight zones complying with Section C405.2.4.3.

Lighting wattage allowances

The lighting allowance values have been substantially updated to reflect the much greater prevalence of LED fixtures as the "norm" in new commercial construction. The lighting power allowances are reduced in most case, with some exceptions. These values do not affect light levels, the light levels are by the design professional based on lighting design standards, typically IESNA, but the lighting watts required to provide those light levels are indicated in these tables with commercially available light fixtures.

Figure 8: 2018 NC Energy Code allowed watts - partial table

TABLE C405.4.2(1)
INTERIOR LIGHTING POWER ALLOWANCES:
BUILDING AREA METHOD

BUILDING AREA TYPE	LPD (w/ft^2)
Automotive facility	0.80
Convention center	1.01
Courthouse	1.01
Dining: bar lounge/leisure	1.01
Dining: cafeteria/fast food	0.9
Dining: family	0.95
Dormitory	0.57
Exercise center	0.84
Fire station	0.67
Gymnasium	0.94
Health care clinic	0.90
Hospital	1.05
Hotel/Motel	0.87
Library	1.19
Manufacturing facility	1.17
Motion picture theater	0.76
Multifamily	0.51
Museum	1.02
Office	0.82

Figure 9: 2024 Energy Code wattage allowances - partial table

BUILDING AREA TYPE	LPD (watts/ft²)
Automotive facility	0.75
Convention center	0.64
Courthouse	0.79
Dining: bar lounge/leisure	0.80
Dining: cafeteria/fast food	0.76
Dining: family	0.71
Dormitory[a, b]	0.53
Exercise center	0.72
Fire station[a]	0.56
Gymnasium	0.76
Health care clinic	0.81
Hospital[a]	0.96
Hotel/Motel[a, b]	0.56
Library	0.83
Manufacturing facility	0.82
Motion picture theater	0.44
Multiple-family[c]	0.45
Museum	0.55
Office	0.64

Outlet boxes in thermal envelope

- Although the following line item is located in the Building Thermal Envelope/Air sealing requirement in the code, it is listed here because the electrical contractor would likely be the party responsible for its implementation.
- C402.5.1.2.2.1 **Air-sealed boxes.** Where air-sealed boxes are installed, they shall be marked in accordance with NEMA OS 4. Air-sealed boxes shall be installed in accordance with the manufacturer's instructions.
- Presently, there is not a requirement for NEMA OS 4 boxes.

Transformers, Electrical Motors, Elevators and escalators

Similar requirements from 2018 NC Energy Code, mostly reflective of current national standards or guidelines.

Voltage drop

The 2018 NC Energy Code does not impose a maximum voltage drop on customer-owned wiring. The 2024 Code would limit it to 5%.

C405.10 Voltage drop. The total *voltage drop* across the combination of customer-owned service conductors, feeder conductors and branch circuit conductors shall not exceed 5 percent.

Automatic Receptacle Controls

The 2018 NC energy Code did not have requirements for receptacle control under the prescriptive provisions, but for designers that opted for the ASHRAE 90.1-2013 standard, there was a requirement for receptacle control, and it was implemented a number of times in North Carolina per phone calls to the office. Sometimes, they did not realize the requirement until they got into plan review, and it was picked up by a code official or by another design professional. So, it is not an entirely new requirement.

End-use metering

Similar to the automatic receptacle controls, there was not a requirement in the prescriptive code for end-use metering, unless the permit holder opted for the ASHRAE 90.1 compliance path, and then there were requirements for end-use metering. Therefore, this section also is not entirely new to NC.

2024 NC Language - C405.12.1 Electrical energy metering. For all electrical energy supplied to the building and its associated site, including but not limited to site lighting, parking, recreational facilities and other areas that serve the building and its occupants, meters or other measurement devices shall be provided to collect energy consumption data for each end-use category required by Section C405.12.2.

Energy Monitoring, metering, separation of loads

The energy monitoring and separation of loads by end-use were not requirements in the 2018 NC Energy Code.

2024 NC Energy Code - C405.12 Energy monitoring. New buildings with a gross *conditioned floor area* of ~~25,000~~ 20,000 square feet (2322 m^2) or larger shall be equipped to measure, monitor, record and report energy consumption data in compliance with Sections C405.12.1 through C405.12.5.

> **Exception:** R-2 occupancies and individual tenant spaces are not required to comply with this section provided that the space has its own utility services and meters and has less than 5,000 square feet (464.5 m^2) of *conditioned floor area*.

2024 NC Energy Code - C405.12.1 Electrical energy metering. For all electrical energy supplied to the building and its associated site, including but not limited to site lighting, parking, recreational facilities and other areas that serve the building and its occupants, meters or other measurement devices shall be provided to collect energy consumption data for each end-use category required by Section C405.12.2.

2024 NC Energy Code - C405.12.2 End-use metering categories. Meters or other *approved* measurement devices shall be provided to collect energy use data for each end-use category indicated in Table C405.12.2. Where multiple meters are used to measure any end-use category, the data acquisition system shall total all of the energy used by that category. Not more than 5 percent of the measured load for each of the end-use categories indicated in Table C405.12.2 shall be permitted to be from a load that is not within that category

Additional Efficiency Options

This category has been required on the commercial side of the energy code since 2012, and the items have been updated for 2024.

Also, the Total Building Performance section is updated to reflect the impact of this requirement, that is why the proposed building has to be no more than 85% the use of the base-code building, as the 15% is representative of what the additional efficiency requirement provides to the base building.

Total Building Performance

This section has been updated and clarified as to what is mandatory and what is flexible for demonstration of compliance.

Commissioning and Functional testing

This section has been updated to reflect the model code suggestions for the IECC 2021. NC has had some commissioning requirements since 2012, but in general condensed and eliminated most of the functional testing requirements.

Existing Buildings

The 2018 NC Energy Code has several key differences with the 2024 Energy code. Those will be discussed in their respective categories which follow.

Additions (C502.2)

The 2018 NC Code required additions to comply with the new code, however it did not classify the change in space conditioning from unconditioned to conditioned as an "addition" The 2024 NC Energy code classifies that as an addition, and requires the thermal envelope to be brought up to the present (2024) requirements, or allows the Simulated Building performance method to be used such that it can result in no more than 110% of the annual energy use as the prescriptive path.

The 2018 Code allowed upgrades to an unconditioned space that costs less than $10,000 to not have any energy code compliance requirements. This was a common code path to add air conditioning to previously unconditioned warehouses converted into conditioned spaces.

Alterations

The 2018 Code and the 2024 code have largely the same requirements and exceptions, the key difference being the conversion of unconditioned space to conditioned space. The 2018 NC Code considered that to be an alteration, but the 2024 Code considers that to be an addition (additional conditioned square footage) and does not have a dollar threshold to exclude an upgrade.

Repairs

The 2018 NC Code largely followed the generic language shown below in C504.1.

SECTION C504
REPAIRS

C504.1 General. *Repair* of the building systems shall not make the building less conforming than it was before the *repair* was undertaken. Work on nondamaged components necessary for the required *repair* of damaged components shall be considered part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter.

Where a building was constructed to comply with ANSI/ASHRAE/IESNA 90.1, repairs shall comply with the standard and need not comply with Sections C402, C403, C404 and C405.

The 2024 language is as shown next:

C504.1 General. *Buildings* and structures, and parts thereof, shall be repaired in compliance with Section C501.3 and this section. Work on nondamaged components that is necessary for the required *repair* of damaged components shall be considered to be part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter. Routine maintenance required by Section C501.3, ordinary *repairs* exempt from *permit* and abatement of wear due to normal service conditions shall not be subject to the requirements for *repairs* in this section.

Where a building was constructed to comply with ANSI/ASHRAE/IESNA 90.1, repairs shall comply with the standard and need not comply with Sections C402, C403, C404 and C405.

C504.2 Application. For the purposes of this code, the following shall be considered to be repairs:

1. Glass-only replacements in an existing sash and frame.
2. *Roof repairs*.
3. Air barriers shall not be required for *roof repair* where the repairs to the building do not include *alterations*, renovations or *repairs* to the remainder of the building envelope.
4. Replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided that an existing vestibule that separates a conditioned space from the exterior shall not be removed.
5. *Repairs* where only the bulb, the ballast or both within the existing luminaires in a space are replaced, provided that the replacement does not increase the installed interior lighting power.

Change of Occupancy or Use

The 2018 NC language was straight forward, and restricted upgrades to new work

R505.1 General. New work performed in spaces undergoing a change in occupancy shall comply with the requirements of this code. Unaltered portions of the existing building or building supply system shall not be required to comply with this code.

The 2024 language is different in that it is less clear as to what "shall comply with this code" means, but in the past that has been interpreted as meaning sections or assemblies that are altered. A change of use or occupancy does not necessarily mean any assemblies are modified. Unmodified assemblies require no upgrades.

However, the 2024 language clearly identifies spaces going from unconditioned to conditioned require to be in compliance with R502, which is the same as for additions, therefore they need to be brought up to current requirements (2024).

C505.1 General. Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code. Where the use in a space changes from one use in Table C405.3.2(1) or C405.3.2(2) to another use in Table C405.3.2(1) or C405.3.2(2), the installed lighting wattage shall comply with Section C405.3. Where the space undergoing a change in occupancy or use is in a building with a fenestration area that exceeds the limitations of Section C402.4.1, the space is exempt from Section C402.4.1 provided that there is not an increase in fenestration area.

Exceptions:

1. Where the component performance alternative in Section C402.1.5 is used to comply with this section, the proposed UA shall not be greater than 110 percent of the target UA.
2. Where the total building performance option in Section C407 is used to comply with this section, the annual energy cost of the proposed design shall not be greater than 110 percent of the annual energy cost otherwise permitted by Section ~~C407.3~~. C407.2.

End of Commercial

APPENDIX B

2024 NC Energy Code Summary - Residential: Selected Differences Between Existing 2018 NC Energy Code and Proposed 2024 NC Energy Code

Prepared by the North Carolina Department of Insurance

N.C. Department of Insurance
Office of State Fire Marshal
325 N. Salisbury Street
Raleigh, N.C. 27603

September 2, 2022

2024 NC ENERGY CODE SUMMARY - RESIDENTIAL

Selected differences between existing 2018 NC Energy Code and Proposed 2024 NC Energy Code

SEPTEMBER 2, 2022

NORTH CAROLINA DEPARTMENT OF INSURANCE
325 N. Salisbury St

Contents

Disclaimer

This is a brief overview of what seem to be the major differences between the 2018 NC Energy Code, and the proposed 2024 NC Energy Code. It is not a substitute for the entire document. All requirements of the 2024 NC Energy Code are subject to BCC approval process, and as such are "proposed" and not finalized.

Key Items of Proposed 2024 NC Energy Code (Residential)

- **Thermal Envelope**
- **Electrical**
- **Mechanical**
- **Plumbing**

Compliance Paths - Many available paths to comply

Similar to the 2018 NC Energy Code, there are several different paths to demonstrate compliance, and within each path there are several sub-methods. Although the values have changed within these various paths, there are no notable new paths introduced, or paths dropped from the 2018 NC Energy Code.

2024 NC Energy Code Compliance paths

- **R401.2.1 Prescriptive Compliance Option.**
- **R401.2.2 Total Building Performance Option.**
- **R401.2.3 Energy Rating Index Option.**
- **R401.2.6 REScheck Option**. North Carolina approved version of REScheck shall be permitted to demonstrate compliance with this code. Envelope requirements may not be traded off against the use of high efficiency heating or cooling equipment. No tradeoff calculations are needed for required termite inspection and treatment gaps.

Additional requirement

This would be the first code cycle where this item, **Additional energy efficiency**, is a requirement in the Residential Section. It has been a requirement in the Commercial section in the 2012 and 2018 Code cycle, but will be new to NC for the Residential section.

- **R401.2.5 Additional energy efficiency**. This section establishes additional requirements applicable to all compliance approaches to achieve additional energy efficiency. The permit holder is required to select one of the available options in Section R408 to comply. Slightly different requirements for the performance path and the ERI path.

Options include:

R408.2.1 Enhance envelope performance option

R408.2.2 More efficient HVAC equipment performance option

R408.2.3 Reduced energy use in service water heating option

R408.2.4 More efficient duct thermal distribution option

R408.2.5 Improved air sealing and efficient ventilation system option

There may be an adjustment period as users get used to reading and implementing this requirement.

Climate Zones

- Before we look at the proposed insulation levels, I need to note the Climate Zones are changing – Due to increasing Cooling Degree Days, decreasing Heating Degree Days, and changing the criteria for classification

In and of itself, this is a pretty significant change for NC, as it switches the requirements of 58 out of the 100 NC Counties. See maps below.

Figure 1: 2018 NC Climate Zones

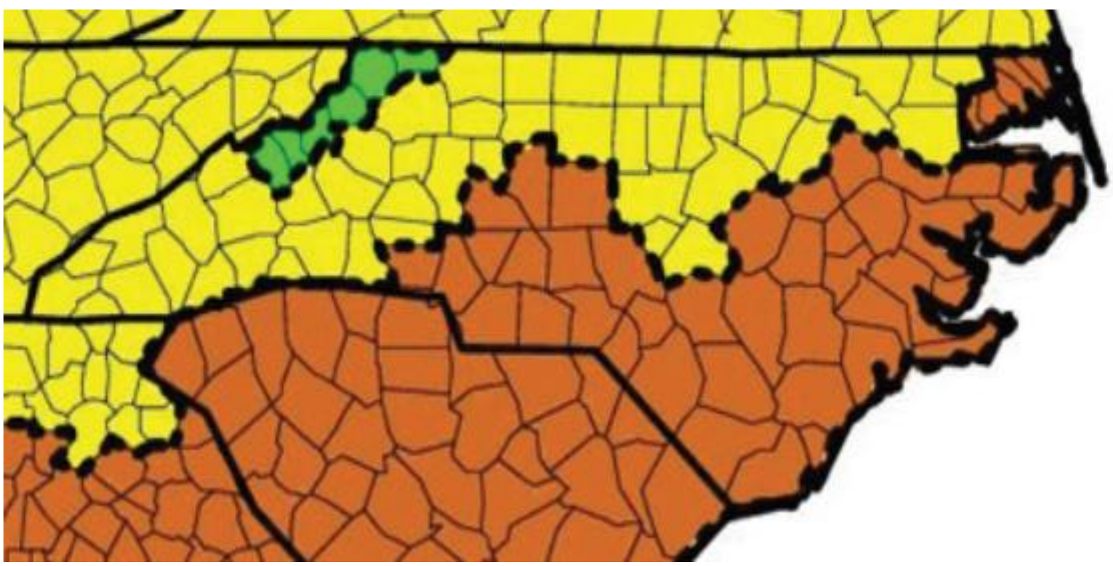

Figure 2: 2024 NC Climate Zones

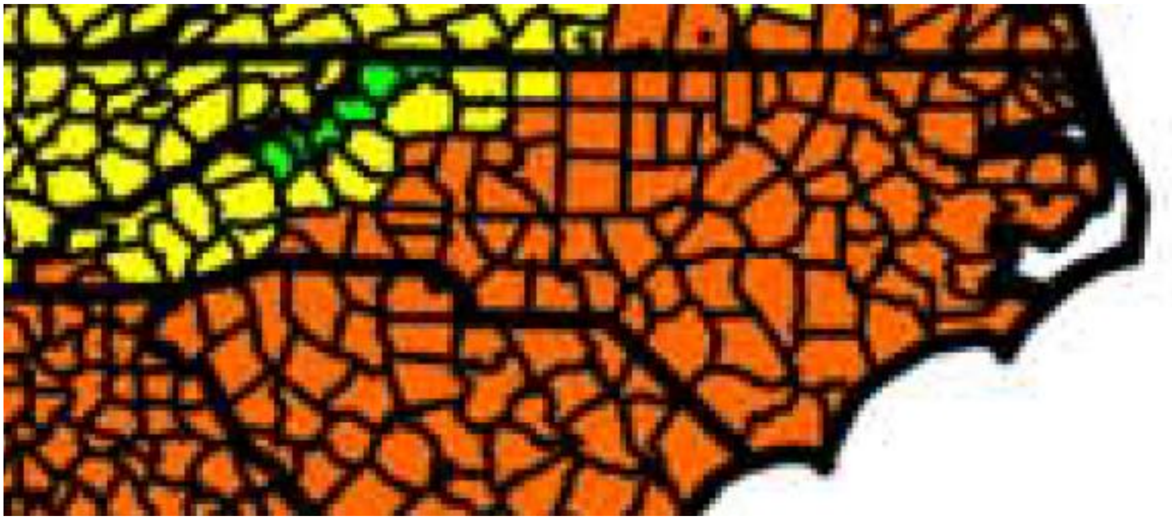

Figure 3: Summary of changes to NC Counties by zone

	2018 NC ECC		2024 NC ECC	
Zone 5	6	6%	5	5%
Zone 4	44	44%	16	16%
Zone 3	50	50%	79	79%
	100	100%	100	100%

In looking at the following thermal envelope categories, bear in mind the proposed changes to the climate zones for the majority of NC counties. NC is closer to the climate of South Carolina and Alabama than it is to Virginia.

Key Items of Proposed 2024 NC Energy Code – Thermal envelope prescriptive requirements

The thermal envelope requirements would be increasing, with the majority of the increase in the walls. The walls have several options to comply. The permit holder would have several choices of how to build the walls, but if they chose to use fibrous insulation, it would require 2x6 exterior walls. If they chose to use the options with more continuous insulation, 2x4 exterior walls can be used to meet the requirements.

Figure 4: Existing (2018 NC Energy code) thermal envelope requirements

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b,i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, k]	CEILING *R*-VALUE[m]	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c,o] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
3	0.35	0.55	0.30	38 or 30ci[l]	15 or 13+2.5[h]	5/13 or 5/10ci	19	5/13[f]	0	5/13
4	0.35	0.55	0.30	38 or 30ci[l]	15 or 13+2.5[h]	5/13 or 5/10ci	19	10 /15	10	10/15
5	0.35	0.55	NR	38 or 30ci[l]	19[n] or 13+5[h] or 15+3[h]	13/17 or 13/12.5ci	30[g]	10/15	10	10/19

Figure 5: Proposed (2024 NC Energy code) thermal envelope requirements

TABLE R402.1.3
INSULATION MINIMUM *R*-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE[i]	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c,g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c,g] WALL *R*-VALUE
3	.30	0.55	0.25	49	20 or 13 + 5ci or 0 + 15	8/13	19	5ci or 13[f]	10ci, 2 ft	5ci or 13[f]
4	.30	0.55	0.40	60	20 + 5 or 13 + 10ci or 0 + 15	8/13	19	10ci or 13	10ci, 4 ft	10ci or 13
5	0.30[i]	0.55	0.40	60	20 + 5 or 13 + 10ci or 0 + 15	13/17	30	15ci or 19 or 13 + 5ci	10ci, 4 ft	15ci or 19 or 13 + 5ci

Envelope Leakage

For the 2024 NC Energy Code, the Envelope Leakage Rate must be measured, there is no visual option like there was in the 2012 and 2018 Energy Code. It is not a mandatory 3[rd]-party testing.

The maximum leakage rate in the 2018 NC Energy Code, when using the measured option, is 5.0 ACH50

The maximum leakage rate in the 2024 NC Energy Code, when suing the prescriptive envelope path, is 3.0 ACH50.

- There is also a maximum allowed leakage rate for any compliance path other than the prescriptive path of 4.0 ACH50.

Other envelope Items

- R402.4.4 Rooms containing fuel-burning appliances.

Rooms containing open combustion air ducts (ducts communication to the exterior) shall be outside the building thermal envelope, isolated from the remainder of the main thermal envelope. This does not apply to direct vent appliances, fireplaces with combustion air ducts installed, or appliances not requiring combustion air ducts/grilles.

NC did not adopt this code item in the 2018 NC Energy Code from the 2015 IECC.

Mechanical

Ductwork

- There are prescriptive paragraphs added to account for ductwork buried in attic insulation. The 2018 NC Code does not prohibit this, it was just not spelled out in detail how to account for it.
- The 2024 language is very prescriptive.
- Ductwork insulation
- Present requirements include R-8 for supply and return outside the thermal envelope, and R-4.2 for ductwork in semi-conditioned space, and no required insulation for ductwork located in conditioned spaces.

The proposed 2014 NC code eliminates the semi-conditioned category, ductwork will either be in conditioned space or not.

Ductwork located outside conditioned space is required to be R-8 for ducts 3 inches diameter and larger, and R-6 for ductwork smaller 3 inches in diameter.

Duct tightness testing

The duct tightness testing requirements for the 2018 NC energy Code are 5 CFM25/100SF conditioned floor area, with no requirements for testing ductwork located within the thermal envelope/air barrier.

The 2024 NC Energy code requirements would require 4 CFM25/100SF conditioned floor area, for ductwork located outside the thermal envelope/air barrier, and no more than 8 CFM25/100SF conditioned floor area for ductwork located within the thermal envelope/air barrier.

Building cavities cannot be used as ducts or plenums. Presently, (2018 code) they can still be used as return air plenums.

Plumbing

Service water heating requires R-3 insulation, which is the same as present, but more line-items are included to clarify where it is required:

1. Piping $^3/_4$ inch (19.1 mm) and larger in nominal diameter located inside the *conditioned space*.
2. Piping serving more than one dwelling unit.
3. Piping located outside the *conditioned space*.
4. Piping from the water heater to a distribution manifold.
5. Piping located under a floor slab.

6. Buried piping.
7. Supply and return piping in circulation and recirculation systems other than cold water pipe return demand recirculation systems.

Electrical:

- ELECTRICAL POWER AND LIGHTING SYSTEMS
    - Present 2018 NC Code requires not less than 75% of the lamps be high efficacy
    - Proposed 2024 NC Code requires all light fixtures contain high efficacy light sources.
    - R404.1 Lighting equipment. All permanently installed lighting fixtures, excluding kitchen appliance lighting fixtures, shall contain only *high-efficacy* lighting sources.

Lighting controls

The present 2018 NC Energy Code does not have any specific requirements for control of lighting.

The 2024 NC Energy code has requirements for dimmers or other controls for permanently installed lighting fixtures.

R404.2 Interior lighting controls. Permanently installed lighting fixtures shall be controlled with either a dimmer, an occupant sensor control or other control that is installed or built into the fixture.

Exception: Lighting controls shall not be required for the following:

1. Bathrooms.
2. Hallways.
3. Exterior lighting fixtures.
4. Lighting designed for safety or security.

Outlet boxes in thermal envelope

- Although the following line item is located in the Building Thermal Envelope/Air sealing requirement in the code, it is listed here because the electrical contractor would likely be the party responsible for its implementation.
- R402.4.6 Electrical and communication outlet boxes (air-sealed boxes). Electrical and communication outlet boxes installed in the building thermal envelope shall be sealed to limit air leakage between conditioned and unconditioned spaces. Electrical and communication outlet boxes shall be tested in accordance with NEMA OS 4…

Presently, there is not a requirement for NEMA OS 4 boxes in the NC Code.

Simulated Performance Alternative

This section has been updated and clarified as to what is mandatory and what is flexible for demonstration of compliance. A mandatory air tightness testing is required, and can be no more than 3.0 ACH50, which is the same as the prescriptive path. It can be less, but must be demonstrated by testing.

Service water heating can be given credit for compactness of design, meaning the less overall piping the better to minimize heat losses.

Energy Rating Index Compliance Alternative (ERI)

This section has been updated and clarified which sections of the prescriptive code are required for compliance, rather than having "mandatory" by the categories, it is within the method.

Has a section to include on-site renewable power generation.

Similar to the 2018 NC Energy Code, there are backstops for the thermal envelope. It was rewritten to require hose to be no more than 1.15 times the UA of the values allowed in the 2021 IECC. In other words, no more than 15% more heat transfer allowed than the prescriptive code.

If there are on-site renewable energy sources, the thermal envelope is allowed to be not less than the values allowed in the 2015 IECC.

Figure 6: 2024 NC Energy Code ERI values

TABLE R406.5
MAXIMUM ENERGY RATING INDEX

CLIMATE ZONE	ENERGY RATING INDEX
3	51
4	54
5	55

Figure 7: 2018 NC Energy Code ERI values

TABLE R406.4.1
MAXIMUM ENERGY RATING INDEX
(without calculation of on-site renewable energy)

CLIMATE ZONE	Jan 1, 2019– Dec 31, 2022	Jan 1, 2023 and forward
3	65	61
4	67	63
5	67	63

Existing Buildings

The 2018 NC Energy Code has several key differences with the 2024 Energy code. Those will be discussed in their respective categories which follow.

Additions

The 2018 NC Code required additions to comply with the new code, however it did not classify the change in space conditioning from unconditioned to conditioned as an "addition" The 2024 NC Energy code classifies that as an addition, and requires the thermal envelope to be brought up to the present (2024) requirements, or allows the Simulated Building performance method to be used it can result in no more than 110% of the annual energy use as the prescriptive path.

The 2018 Code allowed upgrades to an unconditioned space that costs less than $10,000 to not have any energy code compliance requirements. This was a common code path to add air conditioning to sunrooms, garages, glamping structures, workshops, garages, etc.

Alterations

The 2018 Code and the 2024 code have largely the same requirements and exceptions, the key difference being the conversion of unconditioned space to conditioned space. The 2018 NC Code considered that to be an alteration, but the 2024 Code considers that to be an addition (additional conditioned square footage) and does not have a dollar threshold to exclude an upgrade.

Repairs

The 2018 NC Code largely followed the generic language shown below in R504.1.

R504.1 General. Repair of the building systems shall not make the building less conforming than it was before the repair was undertaken. Work on nondamaged components necessary for the required *repair* of damaged components shall be considered part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter.

The 2024 NC Code has similar language and does not appear to be substantially different.

R504.1 General. *Buildings*, structures and parts thereof shall be repaired in compliance with Section R501.3 and this section. Work on nondamaged components necessary for the required *repair* of damaged components shall be considered to be part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter. Routine maintenance required by Section R501.3, ordinary repairs exempt from *permit*, and abatement of wear due to normal service conditions shall not be subject to the requirements for *repairs* in this section.

R504.2 Application. For the purposes of this code, the following shall be considered to be *repairs*:

1. Glass-only replacements in an existing sash and frame.
2. Roof *repairs*.
3. *Repairs* where only the bulb, ballast or both within the existing luminaires in a space are replaced provided that the replacement does not increase the installed interior lighting power.

Change of Occupancy or Use

The 2018 NC language was straight forward, and restricted upgrades to new work

R505.1 General. New work performed in spaces undergoing a change in occupancy shall comply with the requirements of this code. Unaltered portions of the existing building or building supply system shall not be required to comply with this code.

The 2024 language is different in that is less clear as to what "shall comply with this code" means, but in the past that has been interpreted as meaning sections or assemblies that are altered. A change of use or occupancy does not necessarily mean any assemblies are modified. Unmodified assemblies require no upgrades.

However, the 2024 language clearly identifies spaces going from unconditioned to conditioned require to be in compliance with R502, which is the same as for additions, therefore be brought up to current requirements (2024)

R505.1 General. Any space that is converted to a dwelling unit or portion thereof from another use or occupancy shall comply with this code.

> **Exception:** Where the simulated performance option in Section R405 is used to comply with this section, the annual energy cost of the *proposed design* is permitted to be 110 percent of the annual energy cost allowed by Section R405.2.
>
> **R505.1.1 Unconditioned space.** Any unconditioned or low-energy space that is altered to become a *conditioned space* shall comply with Section R502.

End of Residential

APPENDIX C

Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code

Prepared by Matthew Tyler

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Pacific Northwest National Laboratory
902 Batelle Boulevard
Richland, WA 99354

March 22, 2023

MEMORANDUM

Date:	**3/22/2023**		
To:	**North Carolina Building Code Council**	Information Release #	**PNNL-SA-180329**
From:	**Matthew Tyler**		
Subject:	**Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code**		

Moving to the proposed 2024 North Carolina Energy Conservation Code from the 2018 North Carolina Energy Conservation Code is expected to be cost-effective for North Carolina. This assessment of cost-effectiveness is based on expected changes in construction cost relative to energy cost savings. The analysis is based on six building prototypes[1] and three of the 16 climate zones in the United States.

Climate zones are defined in ASHRAE Standard 169, with the hottest being climate zone 0 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating moist or humid, B indicating dry, and C indicating marine. Most of North Carolina is in climate zone 3A, the Blue Ridge Mountains are in climate zone 4A, and a few counties in the northwest corner are in climate zone 5A.

The analysis included the following six building prototypes: small office, large office, standalone retail, primary school, small hotel, and mid-rise apartment.

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes. Net LCC savings is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The costs include initial equipment and construction costs, maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective, which is the case here.

Two LCC scenarios[2] are analyzed with the inputs shown in Table 1 and the differences are outlined here:

- Scenario 1: represents publicly-owned buildings, considers initial costs, energy costs, maintenance costs, and replacement costs without borrowing or taxes. These LCC results per square foot are shown in Table 2 by building type and climate zone.

[1] https://www.energycodes.gov/prototype-building-models#Commercial
[2] https://www.energycodes.gov/methodology

- Scenario 2: represents privately-owned buildings, considers initial costs, energy costs, maintenance costs, replacement costs, borrowing costs (financing of the incremental first costs), and tax impacts (such as mortgage interest and depreciation deductions using corporate tax rates). These LCC results per square foot are shown in Table 3 by building type and climate zone.

The energy prices used in the analysis are:

- Electricity price: $0.0877/kWh
- Natural gas price: $0.8800/therm

These prices are the state average commercial energy costs. This is a weighted average by monthly retail sales of electricity and natural gas for commercial buildings in North Carolina. The prices and sales data are from the United States Energy Information Administration (EIA) *Electricity Power Monthly* and *Natural Gas Monthly.*[3,4]

Table 4 below shows the economic impact of upgrading to the 2024 Energy Conservation Code by building type in terms of the annual energy cost savings in dollars per square foot. Table 5 shows the additional construction cost per square foot required by the additional energy code requirements.

The added construction cost is negative for some building types, which represents a reduction in first costs and a savings that is included in the net LCC savings. This is due to the following:

- Fewer light fixtures are required when the allowed lighting power is reduced. Also changes from fluorescent to LED technology results in reduced lighting costs in many cases and longer lamp lives, requiring fewer lamp replacements.
- Smaller heating, ventilating, and air-conditioning (HVAC) equipment sizes can result from the lowering of heating and cooling loads due to other efficiency measures, such as better envelope. For example, the 2024 Energy Conservation Code has more stringent envelope and fenestration U-factors. This results in smaller equipment and distribution systems, resulting in a negative first cost.

The state averages by building type and climate zone shown in Table 2 through Table 5 are weighted averages based on weightings shown in Table 6. These weighting factors are based on the floor area of new construction and major renovations for the six analyzed building prototypes.

Again, when net LCC is positive, the updated code edition is considered cost-effective, which is the case for all analyzed building types in Scenarios 1 and 2.

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[3] https://www.eia.gov/electricity/monthly/
[4] https://www.eia.gov/naturalgas/monthly/

Table 1. Economic Analysis Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period – Years	30	30
Nominal Discount Rate	8.98%	8.98%
Real Discount Rate	7.00%	7.00%
Inflation	1.85%	1.85%
Electricity Price, per kWh	$0.0877	$0.0877
Natural Gas Price, per therm	$0.8800	$0.8800
Energy Price Escalation, uniform present value factors	Electric 19.17, Gas 23.45	Electric 19.17, Gas 23.45
Loan Interest Rate	NA	5.25%
Federal Corporate Tax Rate	NA	21.00%
State Corporate Tax Rate	NA	2.50%

Table 2. Net LCC Savings, Scenario 1 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$3.78	$5.06	$6.32	$6.17	$11.76	$6.70	$6.16
4A	$4.13	$5.57	$5.54	$6.49	$11.54	$5.93	$6.00
5A	$3.59	$6.04	$5.73	$4.83	$11.15	$2.77	$5.18
State Average	$3.80	$5.06	$6.24	$6.18	$11.73	$6.64	**$6.15**

Table 3. Net LCC Savings, Scenario 2 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$3.95	$4.44	$5.83	$5.11	$12.06	$6.44	$5.76
4A	$4.22	$4.75	$5.07	$5.50	$11.83	$5.89	$5.70
5A	$3.85	$5.16	$5.22	$4.50	$11.43	$2.63	$4.85
State Average	$3.97	$4.44	$5.75	$5.13	$12.02	$6.40	**$5.75**

Table 4. Annual Energy Cost Savings ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.176	$0.180	$0.242	$0.170	$0.240	$0.267	$0.227
4A	$0.184	$0.180	$0.204	$0.191	$0.227	$0.263	$0.220
5A	$0.181	$0.197	$0.215	$0.208	$0.231	$0.080	$0.189
State Average	$0.177	$0.180	$0.238	$0.172	$0.238	$0.266	**$0.226**

Table 5. Incremental Construction Cost ($/ft²)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.342	($1.275)	($0.993)	($2.137)	$0.603	($0.695)	($0.878)
4A	$0.183	($1.669)	($0.957)	($1.999)	$0.610	($0.255)	($0.651)
5A	$0.539	($1.805)	($1.037)	($0.670)	$0.572	($0.468)	($0.719)
State Average	$0.333	($1.276)	($0.991)	($2.117)	$0.604	($0.670)	**($0.863)**

Table 6. Construction Weights by Building Type

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	10.0%	11.1%	24.3%	11.9%	2.6%	33.2%	93.1%
4A	0.7%	0.0%	2.3%	0.8%	0.4%	2.0%	6.2%
5A	0.0%	0.0%	0.4%	0.1%	0.0%	0.1%	0.7%
State Average	10.7%	11.1%	27.1%	12.8%	3.0%	35.3%	100.0%

APPENDIX D

Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code

Prepared by Vrushali Mendon, Rob Salcido, and YuLong Xie

U.S. Department of Energy
Pacific Northwest National Laboratory
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March 24, 2023

MEMORANDUM

Date:	**3/24/2023**		
To:	**Bridget Herring, North Carolina Building Code Council**	Information Release #	**PNNL-180509 Rev-1**
From:	**Vrushali Mendon, Rob Salcido, and YuLong Xie**		
Subject:	**Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code**		

The State of North Carolina is in the process of updating their current residential energy code, the 2018 North Carolina Energy Conservation Code (NCECC) which is an amended version of the 2015 International Energy Conservation Code (IECC), to the 2024 NCECC, which is an amended version of the 2021 IECC. The Building Code Council of North Carolina requested an analysis on the energy, environmental, and economic impacts of the proposed code. To assess these impacts, PNNL analyzed the cost-effectiveness of adopting the 2024 NCECC compared to the 2018 NCECC.

Moving to the 2024 NCECC is cost-effective for both single-family and low-rise multifamily residential buildings when compared to the 2018 NCECC in North Carolina. The new code will provide energy cost savings of 18.7%. This equates to $399 of annual utility bill savings for the average North Carolina household as detailed in Table 1. Adopting the 2024 NCECC will also result in societal benefits such as cost savings and reduced greenhouse gas emissions. During the first year alone, North Carolina residents could expect to save over $15,372,000in energy costs and reduce CO_2 emissions by 130,700 metric tons, equivalent to the annual CO_2 emissions of nearly 29,000 cars on the road. Adopting the 2024 NCECC in North Carolina is expected to result in homes that are energy efficient, more affordable to own and operate, and based on newer industry standards for health, comfort, and resilience.

Table 1. Individual Consumer Impact[1]

Metric	Compared to the 2018 NCECC
Life-cycle cost savings of the 2024 NCECC	$2,319
Net annual consumer cash flow in year 1 of the 2024 NCECC [2]	$144
Annual (year 0) energy cost savings of the 2024 NCECC ($)[3]	$399
Annual energy cost savings of the 2024 NCECC (%)[4]	18.7%

Table 2. Societal Benefits

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	15,372,000	5,331,440,000
CO_2 emission reduction, Metric tons	130,700	65,815,000
CH_4 emissions reductions, Metric tons	9.4	4,700
N_2O emissions reductions, Metric tons	1.310	660
NOx emissions reductions, Metric tons	78.5	39,500
SOx emissions reductions, Metric tons	50.3	25,300

Table 3. Statewide Jobs Impact

Statewide Impact	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	755	22,500
Jobs Created Construction Related Activities	1,270	37,900
Total Jobs Created	2,025	60,400

Methodology

DOE's cost-effectiveness methodology evaluates 32 residential prototypes comprising two building types, four foundation types, and four HVAC types. The entire set is simulated with TMY3 weather data representing climate zone 3A, 3AWH, 4A and 5A in this analysis.

Construction cost differences between the 2024 NCECC and the 2018 NCECC were taken directly from DOE/PNNL reports on the cost-effectiveness of new code editions. National cost

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[1] A weighted average is calculated across building configurations and climate zones.
[2] The annual cash flow is defined as the net difference between annual energy savings and annual cash outlays (mortgage payments, etc.), including all tax effects but excluding up-front costs (mortgage down payment, loan fees, etc.). First-year net cash flow is reported; subsequent years' cash flow will differ due to the effects of inflation and fuel price escalation, changing income tax effects as the mortgage interest payments decline, etc.
[3] Annual energy savings is reported at time zero, before any inflation or price escalations are considered.
[4] Annual energy savings is reported as a percentage of whole building energy use.

estimates were adjusted by a North Carolina-specific construction cost multiplier[5] and appropriate Consumer Price Index (CPI) multipliers[6] to bring costs into 2022 dollars.

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes. LCC is the calculation of the present value of costs over a 30-year period including initial equipment and construction costs, energy savings, maintenance and replacement costs, and residual value of components at the end of the 30-year period. When the LCC of the updated code (e.g., the 2024 NCECC) is lower than that of the previous code (the 2018 NCECC), the updated code is considered cost-effective.

The energy savings from the simulation analysis are converted to energy cost savings using fuel prices found in Table 3. Fuel prices are escalated over the analysis period based on an escalation factor of 1.6% for all fuel types.

Table 3. Fuel Prices used in the Analysis

Electricity ($/kWh)	**Gas ($/Therm)**	**Fuel Oil ($/MBtu)**
0.116	1.253	2.422

The financial and economic parameters used in calculating the LCC and annual consumer cash flow are based on the latest DOE cost-effectiveness methodology.[7] The real discount rate is assumed to be 7.0% as requested by the State of North Carolina. The parameters are summarized in Table 4 for reference.

[5] https://www.energycodes.gov/sites/default/files/2021-11/Location_Factors_Report.pdf
[6] https://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/
[7] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Table 4. Economic Parameters Used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	5%
Loan fees	0.6% of mortgage amount
Loan term	30 years
Down payment	10% of home value
Real discount rate[8]	7.0%
Inflation rate	1.6%
Marginal federal income tax	15%
Marginal state income tax	5.25%
Property tax	1.1%

Consumer Impacts

Moving to the 2024 NCECC is cost-effective for households living in single-family and low-rise multifamily units in North Carolina. Based on a 30-year life-cycle cost analysis, the average consumer can expect to save nearly $4,347 and see a positive cashflow in 3 years.

Table 5 through Table 7 display typical cost-effectiveness metrics analyzed in DOE national and state energy code analyses. These metrics include climate zone specific life-cycle cost savings, consumer cash flow timeframe,[9] and annual energy cost savings. Tables 8 and 9 show the climate zone specific incremental construction costs when updating to the 2018 IECC based on the single-family and multifamily prototypes used in this analysis.

[8] Assuming a rate of inflation of 1.6%, this works out to a nominal discount rate of 8.71% using this conversion: $(1 + R\text{nominal}) = (1 + R\text{real}) \times (1 + R\text{inflation})$

[9] Consumer Cash Flow: Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)

Table 5. Life-Cycle Cost Savings of the 2024 NCECC compared to the 2018 NCECC

Climate Zone	Life-Cycle Cost Savings ($)
3A	2,063
3AWH	1,858
4A	4,530
5A	3,256

Table 6. Consumer Cash Flow from Compliance with the 2024 NCECC compared to the 2018 NCECC

	Cost/Benefit	3A	3AWH	4A	5A
A	Incremental down payment and other first costs	$429	$429	$421	$534
B	Annual energy savings (year one) [10]	$395	$381	$545	$523
C	Annual mortgage increase	$236	$236	$231	$294
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$31	$31	$30	$38
E = [B-(C+D)]	Net annual cash flow savings (year one)	$129	$114	$283	$191
F = [A/E]	Years to positive savings, including up-front cost impacts	4	4	2	3

[10] Annual energy savings as reported at year 1, after considering inflation and price escalations.

Table 7. Simple Payback Period for the 2024 NCECC Compared to the 2018 NCECC

Climate Zone	Simple Payback (Years)
3A	11
3AWH	11
4A	8
5A	10

Table 8. Total Single-Family Construction Cost Increase for the 2024 NCECC Compared to the 2018 NCECC

Single-family Prototype House			
Climate Zone	**Crawlspace**	**Slab**	**Unheated Basement**
3A	$4,763	$5,194	$4,763
3AWH	$4,763	$5,194	$4,763
4A	$4,755	$5,186	$4,755
5A	$6,057	$6,487	$6,057

Table 9. Multifamily Construction Cost Increase for the 2024 NCECC Compared to the 2018 NCECC per Dwelling Unit[11]

Multifamily Prototype Apartment/Condo			
Climate Zone	**Crawlspace**	**Slab**	**Unheated Basement**
3A	$1,803	$1,867	$1,803
3AWH	$1,803	$1,867	$1,803
4A	$1,552	$1,616	$1,552
5A	$2,029	$2,092	$2,029

[11] In the multifamily prototype model, the heated basement is added to the building, and not to the individual apartments. The incremental cost associated with heated basements is divided among all apartments equally.

For a more detailed description of the approach PNNL uses to evaluate residential energy code cost-effectiveness, including building prototypes, energy and economic assumptions, and other considerations, please review the latest DOE Residential Cost-Effectiveness Methodology.[12]

[12] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

APPENDIX E

Methodology

https://www.energycodes.gov/methodology
(cited by March 22, 2023 *Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code*, at footnote 2)

U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Accessed August 1, 2023

Methodology

The U.S. Department of Energy (DOE) evaluates published model codes and standards to help states and local jurisdictions better understand the impacts of updating commercial and residential building energy codes and standards. DOE has established methodologies for evaluating the energy and economic performance of model energy codes and standards, as well as proposed changes. This method serves to ensure DOE proposals are both energy efficient and cost-effective.

The DOE methodology contains two primary assessments:

1. Energy savings
2. Cost-effectiveness

Energy and economic calculations are performed through a comparison of baseline and improved buildings for both energy savings and cost effectiveness. Depending on the complexity of the proposal being analyzed, analysis or modeling of changes between representative building types is performed to find savings. Incremental costs for the improvements is developed using engineering cost estimates of a typical upgrade. National or climate zone energy savings are typically reported. In considering cost-effectiveness, longer term energy savings are balanced against incremental initial costs through a Life-Cycle Cost perspective.

ENERGY SAVINGS

COMMERCIAL

Energy savings is determined by comparing two cases, one for the baseline and one for the proposed or comparison case. Energy use for each case can be simulated with the DOE EnergyPlus™ software for 16 prototype buildings (https://www.energycodes.gov/energycodes/prod/docroot/prototype-building-models) that cover 80% of the commercial building floor area in the United States for new construction, including both commercial buildings and mid- to high-rise residential buildings. These prototype buildings were created by researchers at the Pacific Northwest National Laboratory (PNNL). The DOE EnergyPlus software covers almost all aspects of commercial envelopes; heating, ventilation, and air conditioning; water heating; lighting systems; plug and process loads. As necessary, this analysis may also include post-processing of EnergyPlus prototype results, temperature bin analysis, engineering analysis of individual affected components, or other accepted approaches appropriate to the particular cases.

RESIDENTIAL

Energy consumption is modeled using the DOE EnergyPlus™ software for both single-family and multifamily buildings based on an established suite of residential prototypes (https://www.energycodes.gov/prototype-building-models):

Table 1. Single-Family Prototype Assumptions

Parameter	Assumption
Conditioned floor area	2,376 ft^2 (plus 1,188 ft^2 of conditioned basement, where applicable)
Footprint and height	30-ft-by-40 ft, two-story, 8.5-ft-high ceilings
Area above unconditioned space	1,188 ft^2
Area below roof/ceilings	1,188 ft^2
Perimeter length	140 ft
Gross exterior wall area	2,380 ft^2
Window area (relative to conditioned floor area)	Fifteen percent equally distributed to the four cardinal directions (or as required to evaluate glazing-specific code changes)
Door area	42 ft^2

Parameter	Assumption
Internal gains	86,761 Btu/day
Heating systems	Natural gas furnace, heat pump, electric furnace, or oil-fired furnace
Cooling system	Central electric air conditioning
Water heating	Same as fuel used for space heating, or as required to evaluate domestic hot water-specific code changes

Table 2. Multifamily Prototype Assumptions

Parameter	Assumption
Conditioned floor area	1,200 ft^2 per unit, or 23,400 ft^2 total (plus 1,200 ft^2 of conditioned basement on ground-floor units, where applicable)
Footprint and height	Each unit is 40 ft wide by 30 ft deep, with 8.5-ft-high ceilings. The building footprint is 120 ft by 65 ft.
Area above unconditioned space	1,200 ft^2 on ground-floor units
Wall area adjacent to unconditioned space	None
Area below roof/ceilings	1,200 ft^2 on top-floor units
Perimeter length	370 ft (total for the building), 10 ft of which borders the open breezeway
Gross wall area	5,100 ft^2 per story, 2,040 ft^2 of which faces the open breezeway (15,300 ft^2 total)
Window area (relative to gross wall area)	Twenty-three percent of gross exterior wall area, excluding walls facing the interior breezeway (or as required to evaluate glazing-specific code changes)
Door area	21 ft^2 per unit (378 ft^2 total)

Parameter	Assumption
Internal gains	54,668 Btu/day per unit (984,024 Btu/day total)
Heating systems	Natural gas furnace, heat pump, electric furnace, or centralized oil-fired boiler
Cooling system	Central electric air conditioning
Water heating	Same as fuel used for space heating, or as required to evaluate domestic hot water-specific code changes

The DOE analysis covers almost all aspects of residential buildings, including envelope; heating, ventilation, and air conditioning; water heating; and lighting systems. As part of its analysis, the Department examines variations across these systems, which results in the evaluation of a significant number of unique scenarios representative of U.S. climate and building types.

COST-EFFECTIVENESS

COMMERCIAL

The DOE methodology accounts for the benefits of energy-efficient building construction over a multi-year analysis period, balancing initial costs against longer term energy savings. DOE evaluates energy codes and code proposals based on life-cycle cost analysis over a multi-year study period, accounting for energy savings, incremental investment for energy efficiency measures, and other economic impacts. The value of future savings and costs are discounted to a present value, with improvements deemed cost effective when the net savings (savings minus cost) is positive. Because there is a variation in the economic criteria of different commercial building owners, up to three scenarios may be used:

1. **Scenario 1:** (also referred to as the Publicly-Owned Method): Life cycle cost analysis method representing government or public ownership

(without borrowing or taxes). This scenario uses economic inputs that have been established for Federal projects.

2. **Scenario 2:** (also referred to as the Privately-Owned Method): Life cycle cost analysis method representing private or business ownership (includes loan and tax impacts). This scenario uses typical commercial economic inputs, with initial costs being financed, and considers tax impacts for savings, interest and depreciation.
3. **Scenario 3:** (also referred to as the ASHRAE 90.1 committee Scalar Method): Represents a private ownership point of view, and uses economic inputs established by the 90.1 ASHRAE Standing Standard Project Committee.

Life-cycle cost is the method DOE uses to assess the cost-effectiveness of commercial energy codes. Maintenance costs and interim equipment replacements are considered along with residual value at the end of the analysis period. DOE also includes a calculation of simple payback, or the number of years required for energy cost savings to exceed the incremental first costs of a new code or code change proposals. Simple payback is not used as a measure of cost effectiveness as it does not account for the time value of money, the value of energy cost savings that occur after payback is achieved, or any maintenance or replacement costs that occur after the initial investment. The commercial sector economic factors currently used in life cycle cost analysis for the three scenarios are shown below. Specific parameters are selected at the time an individual analysis is conducted, and will be documented, as appropriate, in the published report.

Table 3. Summary of Current Economic Parameter Estimates

Parameter	Scenario 1 (Publicly-Owned Method)	Scenario 2 (Privately-Owned Method)	Scenario 3 (ASHRAE 90.1-2019 Scalar Method)
Period of Analysis	Measure life, up to 30 years	Measure life, up to 30 years	Measure life, up to 40 years

Parameter	Scenario 1 (Publicly-Owned Method)	Scenario 2 (Privately-Owned Method)	Scenario 3 (ASHRAE 90.1-2019 Scalar Method)
Energy Prices	Latest national or local (depending on purpose of analysis) annual average prices based on current DOE EIA data*	Latest national or local (depending on purpose of analysis) annual average prices based on current DOE EIA data*	$0.1063/kWh $0.98/therm blend**
Energy Escalation Rates	Price escalation rates taken from 2019 NIST Handbook 135 Supplement	Price escalation rates taken from 2019 NIST Handbook 135 Supplement	NIST year-by-year rates (same as scenario 1) plus inflation of 2.73% (heating) and 2.07% (cooling)
Loan Term	N/A	Measure life, up to 30 years	Measure life, up to 40 years
Loan Interest Rate	N/A	5.25%	5.00%
Nominal Discount Rate	N/A	5.25% (same as loan rate)	8.5%
Real Discount Rate	3.00%	3.34%	6.31%
Inflation Rate	N/A	1.85% annual	2.06% annual
Property Tax Rate	N/A	N/A	N/A
Federal Income Tax Rate	N/A	21.0%	0%***

Parameter	Scenario 1 (Publicly-Owned Method)	Scenario 2 (Privately-Owned Method)	Scenario 3 (ASHRAE 90.1-2019 Scalar Method)
State Income Tax Rate	N/A	State values vary; highest marginal corporate rate used	0%***

*Average EIA prices from EIA. State prices from EIA are used for individual state analysis. National analysis of Standard 90.1 may use the Scenario 3 prices established by ASHRAE.

**The ASHRAE Scalar Method identifies a fossil fuel rate that is primarily applied to heating energy use. For this reason, the fossil fuel rate is a blended heating rate and includes proportional (relative to national heating fuel use) costs for natural gas, propane, heating oil, and electric heat. Heating energy use in the prototypes for fossil fuel equipment is calculated in therms based on natural gas equipment, but in practice, natural gas equipment may be operated on propane, or boilers that are modeled as natural gas may use oil in some regions.

***Income tax rates are 0% for Scenario 3 because the current discount rate is based on pre-tax rate of return.

RESIDENTIAL

The DOE methodology accounts for the benefits of energy-efficient home construction over the life of a typical mortgage, balancing initial costs against longer term energy savings. DOE evaluates residential energy codes based on three measures of cost-effectiveness:

1. *Life-Cycle Cost**: Full accounting over a 30-year period of the cost savings, considering energy savings, the initial investment financed through increased mortgage costs, tax impacts, and residual values of energy efficiency measures.
2. *Cash Flow*: Net annual cost outlay (difference between annual energy cost savings and increased annual costs for mortgage payments, etc.).

3. *Simple Payback*: Number of years required for energy cost savings to exceed the incremental first costs of a new code.

**Life-cycle cost is the primary measure by which DOE assesses the cost-effectiveness of residential energy codes.*

Table 4. Summary of Current Economic Parameter Estimates

Parameter	Current Estimate
Mortgage Interest Rate	5%
Loan Term	30 years
Down Payment Rate	10% of home price
Points and Loan Fees	0.6% (non-deductible)
Discount Rate	5% (equal to Mortgage Interest Rate)
Period of Analysis	30 years
Property Tax Rate	1.1% of home price/value
Income Tax Rate	15% federal, state values vary
Home Price Escalation Rate	Equal to Inflation Rate
Inflation Rate	1.6% annual
Energy Prices and Escalation Rates	Latest national average prices based on current Energy Information Administration data and projections; price escalation rates taken from latest Annual Energy Outlook.

LEARN MORE...

ENERGY AND ECONOMIC ANALYSIS (/ENERGY-AND-ECONOMIC-ANALYSIS)

APPENDIX F

Methodology for Evaluating Cost-Effectiveness of Commercial Energy Code Changes

Prepared by R Hart, B Liu

U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy
Pacific Northwest National Laboratory
902 Batelle Boulevard
Richland, WA 99354

August 2015

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Methodology for Evaluating Cost-Effectiveness of Commercial Energy Code Changes

R. Hart, B. Liu

August 2015

Prepared by Pacific Northwest National Laboratory

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Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes

R Hart
B Liu

August 2015

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

Prepared by
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Summary

This document lays out the U.S. Department of Energy's (DOE's) methodology for evaluating the cost-effectiveness of energy code and standard[1] proposals and editions. The evaluation is applied to new provisions or editions of ANSI/ASHRAE/IES[2] Standard 90.1 and the International Energy Conservation Code. The methodology follows standard life-cycle cost (LCC) economic analysis procedures. Cost-effectiveness evaluation requires three steps: 1) evaluating the energy and energy cost savings of code changes, 2) evaluating the incremental and replacement costs related to the changes, and 3) determining the cost-effectiveness of energy code changes based on those costs and savings over time.

Cost-effectiveness can be evaluated for an individual code change proposal or an entire edition-to-edition upgrade of an energy code. Multiple parties are interested in building energy codes, and they have different economic viewpoints. To account for this, and the fact that the ASHRAE Standing Standard Project Committee (SSPC) 90.1 has established an economic analysis procedure, three scenarios have been established for the cost-effectiveness methodology:

1. **Scenario 1** (also referred to as the *Publicly-Owned Method*): LCC analysis method representing government or public ownership (without borrowing or taxes).
2. **Scenario 2** (also referred to as the *Privately-Owned Method*): LCC analysis method representing private or business ownership (includes loan and tax impacts).
3. **Scenario 3** (also referred to as the *ASHRAE 90.1 Scalar Method*): Represents a pre-tax private investment point of view, and uses economic inputs established by the ASHRAE SSPC 90.1.

In evaluating code change proposals and assessing new editions of commercial building energy codes, DOE intends to calculate multiple metrics selected from the following:

- Life-cycle cost net savings (a.k.a., net present value (NPV) of savings)
- Savings-to-investment ratio (SIR)
- The ASHRAE 90.1 scalar ratio
- Simple payback period

NPV of savings based on LCC is the primary metric DOE intends to use to evaluate whether a particular code change is cost-effective. Any code change that results in an NPV of savings greater than to zero (i.e., monetary benefits exceed costs) will be considered cost-effective. The payback period, scalar ratio, and SIR analyses provide additional information DOE believes is helpful to other participants in code change processes and to states and jurisdictions considering adoption of a new code.

Economic parameters are chosen to represent the economic impact of a typical commercial building ownership or tenant situation. DOE's approach is to consult appropriate sources of publicly available information to establish assumptions for each financial, economic, and energy price parameter, following

[1] Throughout this document, when referring to energy codes, energy standards are included, as they become adopted into code, and are evaluated for their impact as an adopted code.
[2] ANSI – American National Standards Institute; ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers; IES – Illuminating Engineering Society; IESNA – Illuminating Engineering Society of North America (IESNA rather than IES was identified with Standard 90.1 prior to 90.1-2010)

the guidelines established in this methodology. DOE intends to update parameters for future analyses to account for changing economic conditions, and document the source of each parameter in the specific analysis.

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Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
DEER	Database for Energy Efficient Resources
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
FEMP	Federal Energy Management Program
HVAC	heating, ventilating, and air-conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
LCC	life-cycle cost
MEP	mechanical, electrical, and plumbing
MHC	McGraw-Hill Construction
NIST	National Institute of Standards and Technology
NPV	net present value
PNNL	Pacific Northwest National Laboratory
PPI	Producer Price Index
SIR	savings-to-investment ratio
SSPC	Standing Standard Project Committee

Contents

Tables

1.0 Introduction

The U.S. Department of Energy (DOE)[1] has developed and established a methodology for evaluating the energy and economic performance of commercial energy codes. This methodology serves two primary purposes. First, as DOE participates in the codes and standards development processes, DOE will use the methodology described herein, where appropriate, to ensure that DOE's proposals are both energy efficient and cost-effective. Second, when a new edition of ANSI/ASHRAE/IES[2] Standard 90.1 is published, DOE will evaluate the new standards and codes[3] as a whole to estimate expected energy savings and assess cost-effectiveness, which will help inform states and local jurisdictions interested in adopting the new codes. DOE may also evaluate the cost-effectiveness of new editions of the International Energy Conservation Code (IECC). DOE's measure of cost-effectiveness balances longer-term energy savings against increases to initial costs through a life-cycle cost (LCC) perspective.

1.1 Need for Cost-effectiveness Analysis

Section 307 of the Energy Conservation and Production Act, as amended, directs DOE to support voluntary building energy codes by providing "assistance in determining the cost-effectiveness and the technical feasibility of the energy efficiency measures included in such standards and codes" (42 U.S.C. 6836(a)(3)) and by periodically reviewing the technical and economic basis of the voluntary building energy codes and seeking adoption of all technologically feasible and economically justified energy efficiency measures and otherwise participating in any industry process for review and modification of such codes (42 U.S.C. 6836(b)(2) and (3)).

The methodology described here supports DOE in fulfilling its charge to evaluate energy codes and energy code proposals. Where evaluation of the cost-effectiveness of codes is required, DOE intends to follow the procedures and use the parameters presented here. In some cases, DOE may rely on extant cost-effectiveness studies directly addressing the building elements involved in a proposed change, if such can be identified. When evaluating code changes proposed by entities other than DOE,[4] DOE may rely on energy savings estimates, cost estimates, or cost-effectiveness analyses provided by the proponent(s) or others if DOE deems the estimates and calculations credible.

[1] Throughout this document, DOE is identified as the primary actor in developing and applying the discussed cost-effectiveness methodology. In this activity, DOE has and will use outside resources, including the work of other parties, such as the National Laboratories, to achieve its goal of evaluating cost-effectiveness of code proposals. DOE engages in this activity through the Buildings Technology Office, and uses resources from other divisions in DOE, including the Federal Energy Management Program (FEMP) and the Energy Information Administration (EIA).

[2] ANSI – American National Standards Institute; ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers; IES – Illuminating Engineering Society; IESNA – Illuminating Engineering Society of North America (IESNA rather than IES was identified with Standard 90.1 prior to 90.1-2010)

[3] Throughout this document, when referring to energy codes, energy standards are included, as they become adopted into code, and are evaluated for their impact as an adopted code.

[4] All code change proposals for ASHRAE Standard 90.1 are publicly available and are published by ASHRAE as addenda for public review so that public comments can be considered by the committee in a consensus process that follows ANSI procedures. The consensus process determines whether the code changes are approved for addition to the next published edition of Standard 90.1.

Incremental first cost or cost-effectiveness information is requested by code development bodies for proposals to energy codes. For example, the International Code Council (ICC) Code Development Procedures (ICC 2014) require the following:

> 3.3.5.6 Cost Impact: The proponent shall indicate one of the following regarding the cost impact of the code change proposal: 1) the code change proposal will increase the cost of construction; or 2) the code change proposal will not increase the cost of construction. The proponent shall submit information which substantiates either assertion. This information will be considered by the code development committee and will be included in the bibliography of the published code change proposal. Any proposal submitted which does not include the requisite cost information shall be considered incomplete and shall not be processed.

The ASHRAE 90.1 Standing Standard Project Committee (SSPC) discusses cost-effectiveness analysis related to the ANSI consensus process on pages 1 and 4 of its recent work plan:[5]

> The main goal and primary responsibility is to publish a consensus standard in mandatory language: That sets practical, technically feasible, and **cost effective** minimum energy efficiency requirements for commercial buildings, except for low-rise residential buildings, on a consistent time schedule. *[Emphasis added]*
>
> …Thus, neither ASHRAE nor ANSI has an overt requirement for economic analysis, nor for any other analysis for that matter, except that the SSPC must reach "consensus" before a new standard will be approved by ANSI.
>
> That said, the Committee has often used economic analysis in its decision-making process and it continues to believe that economics play an important role in establishing the requirements for a minimum national building energy efficiency standard. Sometimes the Committee may desire a rigorous and detailed level of economic analysis, while at other times intuitive professional judgment as to the economic impact of a proposed new measure—*without rigorous analysis*—may be sufficient.

Thus, ICC requires cost, but not cost-effectiveness information, although such analysis often helps to advance a proposal that increases the cost of construction. ASHRAE SSPC 90.1 sees benefit in cost-effectiveness analysis, although it is not always seen as necessary in the consensus process. In both cases, cost-effectiveness, where used during the code development process, is applied to individual code change proposals and not codes as a whole. Many states[6] require or encourage cost-effectiveness analysis of the energy code in adoption proceedings to demonstrate that overall the code has financial benefit to the group of building users as a whole.

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[5] Work plan presented and approved at ASHRAE SSPC 90.1 meeting in June 2014, Seattle, New York State Energy Conservation Construction Code Act WA.

[6] As an example, section 11-101 of the *New York State Energy Conservation Construction Code Act* requires "such code mandate that economically reasonable energy conservation techniques be used" and cost-effectiveness analysis of energy codes is used in their adoption process. Available at: http://public.leginfo.state.ny.us/LAWSSEAF.cgi?QUERYTYPE=LAWS+&QUERYDATA=$$ENG11-101$$@TXENG011-101+&LIST=LAW+&BROWSER=BROWSER+&TOKEN=01053978+&TARGET=VIEW.

1.2 Evaluating Cost-effectiveness

Evaluating cost-effectiveness requires three primary steps: 1) evaluating the energy and energy cost savings of code changes, 2) evaluating the incremental and replacement costs related to the changes, and 3) determining the cost-effectiveness of energy code changes based on those costs and savings over time. The DOE methodology estimates the energy impact by simulating the effects of the code change(s) on typical new commercial buildings, assuming both old and new code provisions are implemented fully and correctly. The methodology does not estimate rates of code adoption or compliance. Cost-effectiveness is defined primarily in terms of LCC evaluation, although the DOE methodology includes several metrics intended to assist states considering adoption of new codes.

DOE intends to use the methodology described in this document to address DOE's legislative direction related to building energy codes. DOE also intends to use this methodology to inform its participation in the update processes of ASHRAE Standard 90.1 and the IECC, both in developing code-change proposals and in assessing the proposals of others when necessary. DOE further intends to use this methodology in comparing the cost-effectiveness of new code editions to prior editions or existing state energy efficiency codes.

The focus of this document is commercial buildings, which DOE defines in a manner consistent with both Standard 90.1 and the IECC—buildings except one- and two-family dwellings, townhouses, and low-rise (three stories or less above grade) multifamily residential buildings.

This document is arranged into four primary parts covering the following:

1. Estimating the Energy and Energy Cost Savings of Code Changes—by simulating changes to representative building types. DOE defines commercial prototype buildings, establishes typical construction and operating assumptions, and identifies climate locations to be used in estimating impacts in all climate zones and all states. The building prototypes cover a range of the most typical commercial buildings and include a variety of building system types (e.g., heating and cooling equipment) to facilitate appropriate accounting for the energy use of different commercial occupancies.
2. Estimating the Incremental Cost of Code Changes—by comparing the first cost of baseline buildings to the first cost of buildings with the code implemented. Incremental replacement and maintenance costs are also accounted for. A combination of methods is used to arrive at a national incremental cost, and then adjustment factors are applied to arrive at incremental costs appropriate for states.
3. Estimating the Cost-effectiveness of Code Changes—by comparing energy cost savings to increases in the first cost of the buildings. The methodology defines four metrics—net present value (NPV) of savings, savings-to-investment ratio (SIR), scalar ratio, and simple payback period—that may be calculated. It also establishes sources for the economic parameters to be used in estimating those metrics and identifies sources of energy-efficiency measure costs.
4. Aggregating Energy and Economic Results—across building types and climate locations. The methodology establishes sources for weighting factors to be used in aggregating location- and building-type-specific results to state, national, climate zone, or other domain results.

2.0 Estimating the Energy and Energy Cost Savings of Code Changes

The first step in assessing the impact of a code change or a new code is estimating the energy and energy cost savings of the associated changes. DOE will usually employ computer simulation analysis to estimate the energy impact of a code change. (Situations in which other analytical approaches might be preferred are discussed later.) Where credible energy savings estimates are not available, DOE intends to conduct analysis using an appropriate building energy estimation tool. In most cases, DOE intends to use the EnergyPlus™ (EnergyPlus 2011) software as the primary tool for its analyses. If necessary to more accurately capture the relevant impacts of a particular code change, DOE may supplement EnergyPlus with other software tools, research studies, or performance databases. Such code changes will be addressed case by case.

Code changes affecting a particular climate zone will be simulated in a weather location representative of that zone. Where a code change affects multiple climate zones, DOE intends to produce an aggregate (national or state) energy impact estimate based on simulation results from weather locations representative of each zone, weighted to account for estimated new commercial construction by zone and the fraction of specific building types that will be affected by the code change. Code changes affecting a particular climate zone will be simulated in representative weather locations. DOE's methodology includes weighting factors based on recent new building construction data to allow the individual location results to be aggregated to climate-zone and national averages as needed. These methodologies, weighting factors, and aggregation approaches are described in Section 5.0.

2.1 Building Energy Use Simulation

The energy performance of most energy-efficiency measures in the scope of building energy codes can be estimated by computer simulation. In estimating the energy performance of pre- and post-revision codes, two building cases will be analyzed: 1) a building that complies with the pre-revision code and 2) an otherwise identical building that complies with the revised code under analysis. These two building cases will be simulated in a variety of locations to estimate the overall (national average) energy impact of the new code or code proposal. The inputs used in those simulations are discussed in the following sections.

2.1.1 Energy Simulation Tool

DOE intends to use a whole building simulation tool to calculate annual energy consumption for relevant end uses. For most situations, the EnergyPlus software, developed by DOE, will be the tool of choice. EnergyPlus provides for detailed time-step (hourly or shorter time steps are typical) simulation of a building's energy consumption throughout a full year, based on typical weather data for a given location. It covers most aspects of building systems impacting energy use in commercial buildings: envelopes; heating, ventilating, and air-conditioning (HVAC) equipment and systems; water heating equipment and systems; lighting systems; and plug and process loads. Depending on how building energy codes evolve, it may be necessary to identify additional tools to estimate the impacts of some changes. For example, inputs to EnergyPlus are often established with survey data, separate engineering calculations, or ancillary analysis programs, as some systems are not directly covered within EnergyPlus (e.g., elevator operation, swimming pools, and two-dimensional heat transfer through assemblies of building materials).

DOE recognizes there are other tools that can produce credible energy estimates. DOE intends to use EnergyPlus as its primary tool because it includes advanced simulation capabilities, is under active development, is recognized as one of the leading simulation tools, and has the potential to include capabilities either unavailable or less sophisticated in other accepted simulation tools. EnergyPlus has capabilities for detailed simulation of complex HVAC systems, advanced capabilities for simulating interaction between primary and secondary HVAC systems, and the potential for analyzing detailed control strategies.

2.1.2 Building Prototypes

Separate simulations are typically conducted for multiple commercial building prototypes. The prototypes used in the simulations are intended to represent a cross section of common commercial building types covering 80% of new commercial construction. DOE developed 16 prototype building models, which were reviewed extensively by building industry experts on ASHRAE SSPC 90.1 during development and assessment of multiple editions of ASHRAE Standard 90.1. These prototype models, their detailed characteristics, and their development are published on DOE's Building Energy Codes Program (BECP) web site.[1] A detailed description of the prototypes can also be found in a technical report published by Pacific Northwest National Laboratory (PNNL), *Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010* (Thornton et al. 2011). The prototype models are further described in detail in the quantitative determination of the energy savings of Standard 20.1-2013 (Halverson et al. 2014). Table 2.1 shows the general characteristics DOE intends to use in analyzing the prototypes. Note that any of the prototype characteristics may be modified if a code change impacts it or such modification adds accuracy to the energy savings estimate for particular code changes.

DOE may select a subset of these prototype buildings and simulate them in representative climate locations for the cost-effectiveness analysis to represent most of the energy and cost impacts of the code changes in a particular code or proposal analysis. This approach is based on the fact that not all code requirements will apply to a set of standardized prototypes. The overall savings of a code edition will be well characterized if the preponderance of code measures and climate zones are directly modeled. The selection approach is discussed further in Section 5.1.

[1] See www.energycodes.gov/development/commercial/90.1_models.

Table 2.1. Commercial Prototype Building Basic Characteristics

Building Prototype	Floor Area (ft^2)	Number of Floors	Aspect Ratio	Window-to-Wall Ratio (WWR)	Floor-to-Floor Height (ft)
Small Office	5,500	1	1.5	15%	10
Medium Office	53,630	3	1.5	33%	13
Large Office	498,640	12*	1.5	40%	13
Standalone Retail	24,690	1	1.28	7%	20
Strip Mall	22,500	1	4	11%	17
Primary School	73,970	1	N/A	35%	13
Secondary School	210,910	2	N/A	33%	13
Outpatient Healthcare	40,950	3	N/A	20%	10
Hospital	241,410	5*	1.33	16%	14
Small Hotel	43,210	4	3	11%	9, 11‡
Large Hotel	122,120	6*	5.1, 3.8**	27%	10, 13‡
Warehouse	52,050	1	2.2	0.71%†	28
Quick-Service Restaurant	2,500	1	1	14%	10
Full-Service Restaurant	5,500	1	1	18%	10
Mid-Rise Apartment	33,740	4	2.75	15%	10
High-Rise Apartment	84,360	10	2.75	15%	10

* These buildings also include a basement, which is not included in the number of floors.
** The large hotel basement aspect ratio is 3.8:1; all other floors have an aspect ratio of 5.1:1.
† For the warehouse, 0.71% is the overall WWR. The warehouse area has no windows; the WWR for the small office in the warehouse is 12%.
‡ The second number is the height of the first floor only.

2.1.3 Default Inputs

Input values for building components that do not differ between the two subject codes will be set to either 1) match a shared code requirement if one exists, 2) match standard reference design specifications from the code's performance path if the component has such specifications, or 3) match best estimates of typical practice otherwise. Examples of these items are 1) wall insulation R-values that are the same in both code editions, 2) the heating system type required for performance analysis, and 3) typical internal equipment (plug) loads based on surveys or load calculation handbooks, respectively. Because such component inputs are used in both pre- and post-revision simulations, their specific values are considered neutral and are of secondary importance, so it is important only that they be reasonably typical of the construction types being evaluated.

2.1.4 Provisions Requiring Special Consideration

Some building components or energy conservation measures do not lend themselves to straightforward pre- and post-change simulation of energy consumption. For example, the use of hourly simulation is of dubious value in assessing the energy impact of service water heat piping insulation. Rather than including an exact piping heat loss model in the building simulation, typical expected losses may be separately calculated and entered as loads into the simulation model.

Another situation requiring special consideration involves analysis of new or innovative equipment that cannot be implemented directly in the energy simulation software. One example is a heat recovery device for service water heating that uses heat rejected from the chiller. Analysis of such a proposal can be effectively performed by analyzing the load outputs from EnergyPlus in a separate tabular analysis using standard engineering formulas for the impact of heat recovery on the energy use of the building. Another example of post processing is analysis of water-side economizers for Addendum *du* to ASHRAE Standard 90.1-2013 using hourly data extracted from EnergyPlus models (Hart et al. 2014a).

2.2 Weather Locations

Simulations (and other analyses as appropriate) will usually be conducted in one representative weather location per selected climate zone in the code, including a separate location for each moisture regime.[2] Table 2.2 shows the climate locations typically used for a national savings analysis, each of which is represented by a Typical Meteorological Year (TMY3)[3] weather data file. The locations shown in Table 2.2 for analysis through Standard 90.1-2013 were selected to be reasonably representative of their respective climate zones by Briggs et al. (2003). ASHRAE SSPC 90.1 has recently updated the representative cities to adopt changes made in ASHRAE Standard 169-2013, *Climatic Data for Building Design Standards*, and to provide a better match for actual average climate in each climate zone. DOE may use these updated representative locations (also shown in Table 2.2) for analysis starting with Standard 90.1-2016 and the 2018 IECC. There are several approaches for climate zone selection:

- For a national level energy saving analysis, up to 16 climate locations are used, selected from those shown in Table 2.2.
- For a national level cost-effectiveness analysis, DOE may select a subset of the climate zones to represent most of the energy and cost impacts of the code changes in a particular code or proposal analysis. The selection approach is discussed further in Section 5.1.
- For a state level code cost-effectiveness analysis, alternate cities located in each climate zone for the state are selected. A TMY3 weather station with robust data is selected within the state where possible, or adjacent to the state being analyzed if better data is in the adjacent city.
- For measures or code changes that impact primarily building envelope or are not impacted by humidity conditions, the cities representing the thermal climate zones may be used, with the results applying to the climate zones that share the same thermal climate zone numbers, regardless of moisture regime.

[2] Moisture regimes reflect the average humidity in a climate zone. As seen in Table 2.2, moisture regime A represents higher humidity (moist) than B (dry), while marine (C) zones have some moisture, but also have more moderate temperature ranges.
[3] See http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/ .

- Some analyses are conducted only for the adjoining climate zones where requirements are proposed to change. For example, increased exterior duct insulation in climate zone 5 and colder only requires an analysis in thermal climate zones 4 and 5 where the analysis shows the extra insulation is not cost-effective in climate zone 4, but is cost-effective in climate zone 5. Because a logical argument can be made that colder climate zones will result in more heat loss, the extra insulation can be presumed to be cost-effective in climate zones 6 through 8.

Table 2.2. Climate Locations Used in Energy Simulations

Climate Zone*	Moisture Regime	Representative Locations for 90.1 National Analyses			
		Analysis Before and Including 90.1-2013 and 2015 IECC		Analysis Starting with 90.1-2016 and 2018 IECC	
		City, State	Thermal Climate Zone	City, State	Thermal Climate Zone
1A	Moist	Miami, FL	1	Honolulu, HI	1
2A	Moist	Houston, TX	2	Tampa, FL	2
2B	Dry	Phoenix, AZ	N/A	Tucson, AZ	N/A
3A	Moist	Memphis, TN	N/A	Atlanta, GA	3
3B	Dry	El Paso, TX	3	El Paso, TX	N/A
3C	Marine	San Francisco, CA	N/A	San Diego, CA	N/A
4A	Moist	Baltimore, MD	N/A	New York, NY	4
4B	Dry	Albuquerque, NM	4	Albuquerque, NM	N/A
4C	Marine	Salem, OR	N/A	Seattle, WA	N/A
5A	Moist	Chicago, IL	5	Buffalo, NY	5
5B	Dry	Boise, ID	N/A	Denver, CO	N/A
5C	Marine	n/a	N/A	Port Angeles, WA	N/A
6A	Moist	Burlington, VT	6	Rochester, MN	6
6B	Dry	Helena, MT	N/A	Great Falls, MT	N/A
7	N/A	Duluth, MN	7	International Falls, MN	7
8	N/A	Fairbanks, AK	8	Fairbanks, AK	8

* Climate zones outside the United States are not shown.

2.3 Energy Cost Savings

Annual energy costs are a necessary part of the cost-effectiveness analysis. They are based on the energy consumption multiplied by average energy prices. For the national Standard 90.1 analysis, DOE will use the same energy prices as approved by ASHRAE SSPC 90.1 for standard development—energy prices that were based on DOE Energy Information Administration (EIA) data. Using the same prices that were used for development of a particular edition of Standard 90.1 provides a consistent approach and applies a similar cost-effectiveness threshold to the entire standard that was used for individual proposals as the standard was developed. The ASHRAE 90.1 Scalar Method identifies a fossil fuel rate[4] that is primarily applied to heating energy use, with some application to service water heating. DOE may apply this mixed fuel approach to state cost-effectiveness analysis.

[4] The ASHRAE 90.1 Scalar Method fossil fuel rate is a blended heating rate and includes proportional costs for natural gas, propane, heating oil, and electric heat relative to national heating fuel use share. Heating energy use in the prototypes for fossil fuel equipment is calculated in therms based on natural gas equipment, but in practice, similar equipment may be operated on propane, or boilers that are modeled as natural gas may use oil in some regions.

In any event, prices used for cost-effectiveness energy analyses are derived from the DOE EIA data (EIA 2012, 2014). DOE intends to use the most recently available national or state annual average commercial energy prices from the EIA. Annual average prices are used to avoid selecting a short-term price that is subject to seasonal fluctuations. If energy prices from the most recent year(s) are unusually high or low, DOE may use a longer-term average of energy prices, such as the average from the past 3 years and projections for the next 2 years.[5] For individual state analysis, DOE intends to use state annual average commercial energy prices from EIA. The energy prices used in a specific analysis along with their source will be declared and documented in that analysis.

[5] EIA energy projections are available from either the *Short-Term Energy Outlook* or *Annual Energy Outlook*

3.0 Estimating the Incremental Costs of Code Changes

The second step in assessing the cost-effectiveness of a proposed code change or a newly revised code is estimating the first cost of the changed provision(s). The *first cost* of a code change refers to the marginal cost of implementing one or more changed code provisions. For DOE's analyses, first cost refers to the retail cost (the total cost to a building developer) prior to amortizing the cost over multiple years through financing, and includes the full price paid by the building developer, including materials, sales taxes, labor, overhead, and profit. First cost excludes maintenance and other ongoing costs associated with the new code provision(s). Where regular maintenance costs are expected to be significantly different as a result of code requirements, they are estimated and converted to an annual maintenance cost, then accounted for separately on an annualized basis in the LCC calculation. There are also replacement costs estimated when individual component life is shorter than the economic study period.

DOE recognizes that estimating the first cost of a code change can be challenging, and will attempt to identify credible cost estimates from multiple sources when possible. Judgment is often required to determine an appropriate cost for energy code analysis when multiple credible sources of construction cost data yield a range of first costs. Cost data will be obtained from existing sources, including cost estimating publications such as RS Means cost estimating handbooks[1]; industry sources (often through web sites); and other resources including journal articles, research, and case studies. DOE may also subcontract with engineering or architectural professionals to provide specialized expertise and complete cost estimates for energy efficiency measures or representative building systems. DOE will use all of these resources to determine the most appropriate construction cost parameters based on factors including the applicability and thoroughness of the data source.

3.1 Cost Estimating Approach

The first step in developing the incremental cost estimates is to define the items to be estimated, such as specific pieces of equipment and their installation. The second step begins by defining the types of costs to be collected. Cost estimates cover incremental costs for material, labor, construction equipment, commissioning, maintenance, and overhead and profit. These costs are estimated both for initial construction and for replacing equipment or components at the end of their useful life during the study period. The third step is to compile the unit and assembly costs needed for the cost estimates. These costs are derived from multiple sources:

- Cost estimating consulting firms; mechanical, electrical, and plumbing (MEP) consulting engineering firms; or specialized consultants (such as daylighting) may be retained to develop general cost estimates applicable to code changes in the prototypes.
- Cost estimates for new work and later replacements are developed to approximate what a general contractor typically submits to the developer or owner and include subcontractor and contractor costs and markups.

[1] RS Means cost estimating handbooks are available at www.rsmeans.com/.

- Maintenance costs are intended to reflect what a maintenance firm would charge. Once initial costs are developed, a technical review is often conducted by members of the ASHRAE SSPC 90.1 and PNNL internal sources.

3.2 Sources of Cost Estimates

Table 3.1 describes typical sources of cost estimates by category. This table is an example based on the national cost-effectiveness analysis of Standard 90.1-2013 (Hart et al. 2014b), and is typical of sources of costs that will be used in completing cost-effectiveness analyses of codes and efficiency standards for commercial buildings. In this example, RS Means refers to any of the appropriate RS Means cost estimating handbooks.

Table 3.1. Example Sources of Cost Estimates by Cost Category

Cost Category	Typical Sources
HVAC Motors included in this category	Cost estimator and PNNL staff used quotes from suppliers and manufacturers, online sources, and their own experience.*
HVAC Ductwork, piping, selected controls items	MEP consulting engineers provided ductwork and plumbing costs based on one-line diagrams they created as well as the model outputs, including system airflows, capacity, and other factors, and provided detailed costs by duct and piping components using RS Means 2012. The MEP consulting engineers also provided costs for several control items.*
HVAC Selected items	PNNL used internal expertise and experience supplemented with online sources.*
Lighting Interior lighting power allowance and occupancy sensors	PNNL staff with input from ASHRAE 90.1 Lighting Subcommittee. Product catalogs were used for consistency with some other online sources where needed.
Lighting Daylighting	PNNL staff and daylighting consulting firm.
Envelope Opaque insulation and fenestration	Costs dataset developed by professional cost estimator.*
Commissioning	Cost estimator, RS Means 2014, MEP consulting engineers, and PNNL staff expertise.
Labor	RS Means 2014 and the MEP consulting engineers for commissioning rate.
Replacement life	Lighting equipment including lamps and ballasts from product catalogs. Mechanical from ASHRAE 90.1 Mechanical Subcommittee protocol for cost analysis.
Maintenance	Originator of the other costs for the affected items, or PNNL staff expertise.

* Where detailed costs were developed in 2012, they were updated to 2014 using inflation factors developed from RS Means handbooks, as discussed in Section 3.4.

3.2.1 Approach to Cost Data Collection

For code changes that impact many system or construction assembly elements of a building, DOE consults multiple national construction cost estimation publications published by RS Means, which provide a wide variety of construction cost data. This is appropriate for many code changes that impact the construction of commercial buildings (e.g., increasing insulation thickness on piping) where the efficiency change can be tied to incremental changes in material thickness or items clearly identified in the estimating guides. RS Means cost handbooks do not always identify the efficiency levels of products and may not have both standard and high-efficiency options. They do not, for example, have detailed costs on improved duct sealing or building envelope sealing, and the costs for fenestration products (windows, doors, and skylights) are focused on aesthetic features rather than energy efficiency characteristics such as solar heat gain coefficient or low-e coatings.

When a code change impacts only the materials used in a building, without impacting labor, cost data can often be obtained from national suppliers. These sources can have the advantage of providing recent costs, and the costs can be localized if a state or local analysis is needed. However, these sources often do not provide all the specific energy efficiency measure improvements that are typically needed for code improvement analyses.

As needed, DOE conducts literature searches of specialized building science research publications that assess the costs of new or esoteric efficiency measures that are not covered in other data sources. Examples include energy efficiency case studies, surveys of demonstration projects, utility or regional energy economic potential savings studies, and journal articles.

3.2.2 Economies of Scale and Market Transformation Effects

Construction costs often show substantial differences between regions, sometimes based primarily on local preferences and the associated economies of scale. Because new code changes may require building construction with new and potentially unfamiliar techniques in some locations, initial local cost estimates may overstate the long-term costs of implementing the change. For example, economizer fault diagnostics or LED parking lot lighting may be reasonably priced in California, where the technology has been required by code for a period of time. In southeastern states, the price for the same technology may be high, due to contractor unfamiliarity. Similar issues may arise where manufacturers produce large quantities of a product that just meet a current energy code requirement, giving that product a relatively low price in the market. Should the code requirement increase, it is likely that manufacturers will increase production of a new conforming product, lowering its price relative to the current premium for what is now a high efficiency product.

DOE intends to evaluate new code changes case by case to determine whether it is appropriate to adjust current costs for anticipated market transformation after a new code takes effect. DOE intends to evaluate specific new or proposed code provisions to determine whether and how prices might be expected to follow an experience curve with the passage of time. It is noted that site-built construction may involve several types of efficiency improvements. The real cost of code changes requiring new technologies may drop in the future as manufacturers learn to produce them more efficiently. The long-term cost of code changes that involve new techniques may likewise drop as contractors learn to implement them in the field more efficiently and with less labor. Finally, code changes that simply require more of a currently used technology or technique may have relatively stable real costs, with prices generally following inflation over time.

3.2.3 Addressing Code Changes with Multiple Approaches to Compliance

One challenge of estimating the costs of energy code changes is selecting an appropriate characterization of new code requirements. A requirement for lower fan horsepower, for example, might be met with a more efficient fan, high surface area filters, better belts, a premium efficiency motor, more but smaller fan units, larger ductwork, or some combination of these options. Each approach will have different costs and may be subject to differing constraints depending on the situation. Some approaches, for example, may be inappropriate in some building types, but not others. Some approaches may open the possibility for new and less expensive construction approaches. Overall, DOE intends to apply two principles in reviewing options in the code:

- A single option will be selected for analysis that is expected to be the least-cost method of compliance that is considered to represent typical construction.
- If a requirement includes multiple options, and one analyzed option that is widely applicable is found to be cost-effective, the requirement will be deemed cost-effective. It is not necessary to demonstrate the cost-effectiveness of all options. This is because there is a cost-effective path through the code, and if a higher cost option is chosen, that is the developer or designer's choice.

It is difficult for DOE to anticipate either the types of code changes that will emerge in future building energy codes or the manner in which developers will choose to meet the new requirements; however, DOE intends to evaluate changes case by case and seek the least-cost way to achieve compliance unless that approach is deemed inappropriate in a large percentage of situations. For code changes that touch on techniques with which there is recent research experience (e.g., through DOE's Federal Energy Management Program (FEMP)[2] and Building Technologies Office[3]), DOE will consult the relevant publications or researchers for advice on appropriate construction assumptions.

DOE anticipates that some new code provisions may have significantly different first costs depending on unrelated aesthetic choices or exceptions and flexibility options in the code. For example, a requirement for window shading could be met with interior blinds, electrochromatic windows, static exterior shading devices, or an active tracking exterior shading system. In addition, optional trade-offs may be included in the code that guarantee minimum energy performance but are not necessarily evaluated for cost-effectiveness. For example, a maximum window-to-wall ratio may be established as a baseline, but a predetermined trade-off may allow the building design to exceed that ratio if an energy recovery device or other energy saving options are included. Because the additional windows and energy saving options are optional, it is not necessary to establish the cost-effectiveness of the alternative design combination.

Finally, some new code provisions may come with no specific construction changes at all, but rather be expressed purely as a performance requirement. It is also conceivable that a code could be expressed simply as energy use intensity, where the requirement is a limit on energy use per square foot of conditioned floor area. DOE intends to evaluate any such code changes case by case and will conduct literature research or new analyses to determine the reasonable set of construction changes that could be expected to emerge in response to such new requirements. Again, DOE intends to focus on the least-cost approach deemed to be reasonable, cost-effective, and meet the code requirement.

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[2] See http://energy.gov/eere/femp/articles/technologies.
[3] See http://energy.gov/eere/buildings/improving-energy-efficiency-commercial-buildings.

3.3 Cost Parameters

Several general parameters are typically applied to all of the cost estimates. These items include new construction material and labor cost adjustments, a replacement labor hour adjustment, replacement material and labor cost adjustments, and a project cost adjustment. The cost adjustments were developed by PNNL during the cost-effectiveness analysis of Standard 90.1-2010 and were based on cost-estimating guides and practices of cost-estimating consultants for that study (Thornton et al. 2013). DOE intends to use these parameters for future estimates—unless there are changes noted in the industry—and they are described in Table 3.2.

Table 3.2. Cost Estimate Adjustment Parameters

Cost Items	Value*	Description**
New construction labor cost adjustment	52.6%	Labor costs used are base wages with fringe benefits. Added to this is 19%: 16% for payroll, taxes, and insurance including worker's compensation, Federal Insurance Contributions Act, unemployment compensation, and contractor's liability, and 3% for small tools. The labor cost plus 19% is multiplied by 25%: 15% for home office overhead, and 10% for profit. A contingency of 2.56% is added as an allowance to cover wage increases resulting from new labor agreements.
New construction material cost adjustment	15.0% to 26.5%	Material costs are adjusted for a waste allowance set at 10% in most cases for building envelope materials. For other materials such as HVAC equipment, 0% waste is the basis. The material costs plus any waste allowance are multiplied by the sum of 10% profit on materials, and sales taxes. An average value for sales taxes of 5% is applied.
Replacement - additional labor allowance	65.0%	Added labor hours for replacement to cover demolition, protection, logistics, cleanup, and lost productivity relative to new construction. Added prior to calculating replacement labor cost adjustment.
Replacement labor cost adjustment	62.3%	The replacement labor cost adjustment is used instead of the new construction labor cost adjustment for replacement costs. The adjustment is the same except for subcontractor (home office) overhead, which is 23% instead of 15% to support small repair and replacement jobs.
Replacement material cost adjustment	26.5% to 38.0%	The replacement material cost adjustment is used instead of the new construction material cost adjustment for replacement costs. The adjustment is for purchase of smaller lots and replacement parts. 10% is added and then is adjusted for profit and sales taxes.
Project cost adjustment	28.8%	The combined labor, material, and any incremental commissioning or construction costs are added together and adjusted for subcontractor general conditions and for general contractor overhead and profit. Subcontractor general conditions add 12% and include project management, job-site expenses, equipment rental, and other items. A general contractor markup of 10% and a 5% contingency are added to the subcontractor subtotal as an alternative to calculating detailed general contractor costs (RS Means 2014).

* Values shown and used are rounded to first decimal place.
** Values provided by the cost estimator except where noted.

For national cost-effectiveness studies, costs are not adjusted for climate locations. The climate location results are intended to represent an entire climate subzone even though climate data for a particular city is used for simulation purposes. Costs will vary significantly between a range of urban, suburban, and rural areas within the selected climate locations, which typically cross multiple states. For state-level cost-effectiveness analysis, costs are adjusted for specific cities based on city cost index adjustments from RS Means or other sources.

3.4 Cost Updating for Inflation

Cost estimates are typically developed for current national average prices. Labor costs are based on estimated hours and current crew labor rates from RS Means. In some cases, cost estimates completed for a prior code cycle are still applicable, and are adjusted for inflation rather than creating a new cost estimate or obtaining current unit prices throughout the cost estimate. Where cost estimates are updated, inflation factors specific to the equipment are used. These inflation factors are developed for each specific equipment or insulation type by comparing RS Means from the time of the estimate with the current RS Means.

3.5 Cost Estimate Spreadsheet Workbook

To provide a transparent view of the costs used in the analysis, a cost estimate spreadsheet will typically be prepared in conjunction with the cost-effectiveness report. The intent of such a cost estimate is to show the basis for costs used in the analysis, although in some cases detailed information obtained from individual manufacturers will be averaged and only the average value will be included in the documentation. For some individual proposals, a spreadsheet may not be necessary, as the costs may be cited from other documents or sources. As one example, the cost estimate spreadsheet for the analysis of Standard 90.1-2013 (Hart et al. 2014b) was organized in the following sections:

1. Introduction
2. HVAC cost estimates
3. Lighting cost estimates
    a. Interior lighting power density
    b. Interior lighting occupancy related controls
    c. Daylighting controls
4. Envelope, power, and other cost estimates
5. Cost estimate summaries and cost-effectiveness analysis results

DOE may also provide a calculating tool that allows cost adjustments to be entered, especially for state analysis. This allows local evaluation of particular cost or other economic impacts to be adjusted in evaluating codes for use by states in the adoption process. For DOE's assessment of cost-effectiveness, the researched input values for economic and cost parameters will continue to be used.

4.0 Estimating the Cost-effectiveness of Code Changes

The last step in assessing the cost-effectiveness of a proposed code change or a newly revised code is calculating the corresponding economic impacts of the changed provision(s). These impacts are measured under different economic scenarios with several economic metrics.

4.1 Cost-effectiveness Analysis

The intent of the DOE cost-effectiveness methodology is to determine whether code changes are economically justified from the perspective of a public policy that balances increased building costs against energy savings over time. The DOE methodology accounts for the benefits of energy-efficient building construction to building owners and tenants that accrue over 30 years. To accommodate multiple economic views, the LCC analysis is applied to multiple scenario methods: Publicly-Owned Method, Privately-Owned Method, and ASHRAE 90.1 Scalar Method. The scenarios, methodologies, and input parameters are described in this section.

Cost-effectiveness is analyzed using the incremental cost information presented in Section 3.0 and the energy cost information presented in Section 2.0. Multiple economic metrics are available, as discussed further in Section 4.2. Several of these may be presented in a particular analysis, and they are selected from the following:

- Life-cycle cost net savings (a.k.a., NPV of savings)
- Savings-to-investment ratio
- The ASHRAE 90.1 scalar ratio
- Simple payback period

4.1.1 Economic Scenarios

Commercial building developers and owners have different perspectives, depending primarily on whether the ownership is public or private. The building owner has a different view of the economic impact of energy purchases as a landlord than as an owner who occupies the building. In tenant situations, the energy operating costs may be paid by the tenant directly to utilities or indirectly via the building owner through a net lease. In the latter situation, the costs for energy efficiency may be paid by a building owner who does not receive energy benefits through reduced bills; however, these incremental costs can be considered to be passed through to the tenant in the lease rates. In every case, someone will pay the energy bill for the building—having savings if it is a more efficient building—and someone will pay the added cost of a more efficient building. While local rental market conditions may result in higher or lower lease rates relative to the incremental cost of efficiency improvements, a complete economic model of such variability would be quite difficult to implement. To provide a straightforward and economic equivalent analysis, the cost-effectiveness analysis will be from the point of view of a building owner who receives the benefits of energy savings. This approach puts the analysis of the costs and savings of all energy saving measures on a common footing for analysis.

DOE evaluates energy codes and code proposals based on LCC analysis over a multi-year study period, accounting for energy savings, incremental investment for energy efficiency measures, and other economic impacts. The value of future savings and costs are discounted to a present value, with improvements deemed cost-effective when the NPV of savings (present value of savings minus present value of costs) is positive. Because the economic criteria of different commercial building owners vary, up to three scenarios may be used for cost-effective analysis:

- **Scenario 1** (also referred to as the ***Publicly-Owned Method***): LCC analysis method representing government or public ownership (without borrowing or taxes). This scenario uses a real dollar methodology and economic inputs that have been established for federal projects under FEMP as amended by the Energy Independence and Security Act of 2007 (EISA).
- **Scenario 2** (also referred to as the ***Privately-Owned Method***): LCC analysis method representing private or business ownership (includes loan and tax impacts). This scenario uses typical commercial economic inputs, with initial costs being financed, and considers tax impacts for savings, interest, and depreciation. The general methodology is identical to that used under Scenario 1, except that it is a nominal dollar analysis with the addition of consideration for income and property taxes, financing, and a private sector discount rate.
- **Scenario 3** (also referred to as the ASHRAE 90.1 ***Scalar Method*** (McBride 1995)): Represents a pre-tax private investment point of view, and uses economic inputs established by the ASHRAE SSPC 90.1. The ASHRAE 90.1 Scalar Method uses standard life-cycle costing techniques in a similar manner to Scenarios 1 and 2, although the parameters and methodology used in the analysis are established by ASHRAE SSPC 90.1.

It is important to understand that, except for the minor adjustments noted here, DOE uses methods and parameters established by others for Scenarios 1 and 3. Scenario 1 parameters are established by federal statute (42 U.S.C. 8254). Scenario 3 parameters are established by ASHRAE SSPC 90.1 for each edition of Standard 90.1. The method and parameters used for Scenario 2 are established by DOE, although the method and parameters are developed and selected to be consistent with Scenario 1 except where typical private investment criteria support different parameters.

When selecting scenarios for a particular cost-effectiveness analysis, DOE notes that Scenarios 2 and 3 both reflect a private-ownership view. As a result, each analysis typically includes Scenario 1 to reflect a public-ownership view and the private-ownership view is reflected by either Scenario 2 or 3. For a national analysis, the ASHRAE Scalar Method (McBride 1995) is used for the private-ownership view, as this was the method applied to individual proposals in development of the standard. The ASHRAE energy prices are typically used for the national analysis, again for consistency with the individual proposal analyses. For individual state analysis, DOE typically uses local state energy prices, and cost-effectiveness is determined based on LCC using Scenario 1 and Scenario 2 economic parameters. Scenario 2 is used as the Private-Ownership Method for state analysis, since the method and parameter selection can be maintained on a consistent basis by DOE. Scenario 2 also more closely matches Scenario 1 and the cost-effectiveness method used for residential codes than does Scenario 3.

4.1.2 Cost-effectiveness Methodology

The primary basis of cost-effectiveness assessment is an LCC analysis. The LCC analysis perspective compares the present value of incremental costs, replacement costs, and maintenance and energy cost savings for each prototype building and climate location. The degree of borrowing and the impact of taxes vary considerably for different building projects, creating many possible cost scenarios. These varying costs are not included in the Scenario 1 Publicly-Owned Method LCC analysis, but are included with the Privately-Owned Method Scenario 2 analysis and the Scenario 3 SSPC 90.1 Scalar Method.

The LCC analysis approach is based on the LCC analysis method used by FEMP,[1] a method required for federal projects and used by other organizations in both the public and private sectors (NIST 1995). The LCC analysis method consists of identifying costs (and revenues, if any) and the year in which they occur, and determining their value in present dollars (known as the net present value). This method uses fundamental engineering economics relationships about the time value of money. For example, money in hand today is normally worth more than money received tomorrow, which is why people pay interest on a loan and earn interest on savings. Future costs are discounted to the present based on a discount rate. The discount rate may reflect what interest rate can be earned on other conventional investments with similar risk, or in some cases, the interest rate at which money can be borrowed for projects with the same level of risk.

4.1.2.1 Discounted Value

The following calculation method can be used to account for the present value of costs or revenues:

$$\text{Present Value} = \text{Future Value} / (1+ i)^n$$

i is the discount rate (or interest rate in some analyses)

n is the number of years in the future the cost occurs

The present value of any cost that occurs at the beginning of year 1 of an analysis period is equal to that initial cost. For this analysis, initial construction costs occur at the beginning of year 1, and all subsequent costs occur at the end of the future year identified.

4.1.2.2 Study Period

The LCC analysis depends on the number of years into the future that costs and revenues are considered, known as the *study period*. While the FEMP method allows a 40-year[2] study period (42 U.S.C. 8254(a)(1)), the DOE code analysis method uses 30 years for Scenarios 1 and 2 and 40 years for Scenario 3. Thirty years is the same study period used for the cost-effectiveness analysis of the residential energy code, conducted by DOE and PNNL (DOE 2012), and is the same period used in previous cost-effectiveness evaluations of Standard 90.1 (Thornton et al. 2013; Hart et al. 2014a). National Institute of Standards and Technology (NIST)-provided energy escalation and discount rates are also limited to 30 years. The 30-year study period is also widely used for LCC analysis in government and industry, and the Office of Management and Budget long-term study period is set at 30 years. The study period is also a balance between capturing the impact of future replacement costs, inflation, and energy escalation; the higher the uncertainty of these costs, the further into the future they are considered.

[1] See 10 CFR part 436, subpart A, "Methodology and Procedures for Life Cycle Cost Analyses," Jan. 1, 2004.
[2] Section 441 of EISA amended the FEMP cost-effective methodology to increase the maximum study period from 25 to 40 years (42 U.S.C. 8254(a)(1)).

4.1.2.3 Residual Value

When the length of the study period does not exactly match the measure life, the residual value of equipment beyond the period of analysis is accounted for. The FEMP LCC analysis method includes a simplified approach for determining the residual value. The residual value is the proportion of the initial cost equal to the remaining years of service divided by the initial cost. For example, the residual value of a wall assembly in year 30 is (40-30)/40 or 25% of the initial cost. The residual values applied in year 30 are discounted from year 30 to a present value and included as a reduction in the total present value of cost. Three cases need to be considered for residual value:

- Where the measure life matches the study period, or an even multiple of the life matches the study period, there is no residual value. For example, electronic controls with a 15-year life in a 30-year study period include a replacement cost at year 15, and that replacement has no further value at year 30, so the residual value is zero.
- Where the useful life of equipment or materials extends beyond the study period, there is a residual value. For code measures analyzed, the longest useful life defined is 40 years for all envelope cost items, such as wall assemblies, as recommended by the SSPC 90.1 Envelope Subcommittee. Forty years is longer than the 30-year study period used in Scenario 1 and 2 LCC analyses. A residual value of the unused life of a cost item is calculated at the last year of the study period for components with longer lives than the study period. So, for example, a measure with a 40-year life in a 30-year study period would have a residual value of 25% of its first cost.
- Where the replacement life does not fit neatly into the study period (e.g., a chiller with a 23-year useful life), the residual value is not a salvage value, but rather a measure of the available additional years of service not yet used for the replacement. To use the chiller example with a 30-year study period, at 30 years there is a 16-year (23+23-30) residual life remaining. So the residual value would be (46-30)/23, or 69.5% of the replacement cost, discounted from year 30 to present value.

4.2 Economic Metrics

In evaluating code change proposals and assessing new editions of commercial building energy codes, DOE intends to calculate multiple metrics selected from the following:

- Life-cycle cost net savings (a.k.a., NPV of savings)
- Savings-to-investment ratio
- The SSPC 90.1 scalar ratio
- Simple payback period

Life-cycle cost net savings is the primary metric DOE intends to use to evaluate whether a particular code change is cost-effective. Any code change that results in an LCC net savings greater than or equal to zero (i.e., monetary benefits exceed costs) will be considered cost-effective. The payback period and SIR analyses provide additional information DOE believes is helpful to other participants in code change processes and to states and jurisdictions considering adoption of new codes. These metrics are discussed further below.

4.2.1 Life-Cycle Cost Net Savings

Life-cycle cost net savings is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified period. Sometimes referred to as *net present value* analysis or *engineering economics*, LCC analysis is a well-known approach to assessing cost-effectiveness. Because the key feature of LCC analysis is the summing of costs and benefits over multiple years, it requires that cash flows in different years be adjusted to a common year for comparison. This is done with a *discount rate* that accounts for the time value of money. Like most LCC implementations, DOE's method sums cash flows in year-zero dollars, which allows the use of standard discounting formulas. Cash flows adjusted to year zero are termed *present values*. The procedure used for discounting is taken directly from the FEMP cost-effective methodology for federal buildings[3] as described in *NIST Handbook 135* (Fuller and Petersen 1995). In actual practice, these procedures have been implemented in a spreadsheet format to produce identical results, rather than using the manual worksheets included in NIST Handbook 135 or the FEMP Building Life Cycle Cost computer program.[4] Formulas shown in Table 4.4 are taken from or adapted directly from formulas in NIST Handbook 135. Where situations are not covered by the FEMP cost-effective methodology, DOE will apply concepts from two ASTM International standard practices, E917 (ASTM 2010a) and E1074 (ASTM 2010b), or as outlined in the *ASHRAE HVAC Applications Handbook* (ASHRAE 2011). The resultant procedure is both straightforward and comprehensive and is in accord with the methodology recommended and used by NIST.[5]

Present values can be calculated in either nominal or real terms. In a nominal analysis, all compounding rates (discount rate, mortgage rate, energy escalation rate, etc.) include the effect of inflation, while in a real analysis inflation is removed from those rates. The two approaches are algebraically and economically equivalent, and for commercial analysis DOE intends to use a real analysis for Scenario 1. In Scenario 2, nominal discounting is applied for constant future cash flows such as loan payments and related tax deductions, while a private sector real discount rate is applied to account for inflation on items such as maintenance and replacement costs, property taxes, and energy savings.[6] This approach is equivalent to a nominal analysis. Scenario 3 is a nominal analysis from a private-ownership viewpoint.

LCC is defined formally as the present value of all costs and benefits summed over the period of analysis. For Scenarios 1 and 2, DOE will typically use NPV of savings as the commercial test metric, which is one of three equivalent ways to quantify LCC:

- Calculate the LCC of both options, including all costs (first, maintenance, replacement, and energy), independently and compare them. In this case, the lower LCC would be the preferable alternative, and the case representing the new code would need a lower LCC than the old code case to be considered cost-effective.
- Calculate the present value of the incremental costs and subtract the present value of the incremental benefits. The result is the LCC of the change, expressed as a cost. In this case, the net cost should be negative to justify the change.

[3] See 10 CFR part 436, subpart A, "Methodology and Procedures for Life Cycle Cost Analyses," Jan. 1, 2004.
[4] See http://www1.eere.energy.gov/femp/information/download_blcc.html.
[5] For a detailed discussion of LCC and related economic evaluation procedures specifically aimed at private sector analyses, see Ruegg and Petersen 1987.
[6] Using a real discount rate to discount uninflated future values is equivalent to using a nominal discount rate to discount inflated future values.

- Calculate the present value of the incremental benefits and subtract the present value of the incremental costs. The result is the LCC net savings or the NPV of savings, also referred to as the NPV of savings. In this case, the NPV of savings should be positive or zero to justify the change. Since a positive result represents a cost-effective outcome, this metric is preferred, and its calculation is shown in Eq. (1).

$$NPV\ of\ savings = PV(Incremental\ Benefits) - PV\ (Incremental\ Costs) \quad (1)$$

In LCC analysis, a future cash flow (positive or negative) is brought into the present by assuming a discount rate (D). The discount rate is an annually compounding rate[7] by which future cash flows are discounted in value. It represents the minimum rate of return demanded of the investment in energy-saving measures. It is sometimes referred to as an alternative investment rate.

4.2.2 Savings-to-Investment Ratio

An additional metric that may be used in Scenarios 1 and 2 is SIR, a ratio of benefits to costs, as shown in Eq. (2). The SIR of a code change must be greater than 1.0 for the change to be considered cost-effective, unless costs are negative and the code change is obviously cost effective.,

$$SIR = \frac{PV(Benefits)}{PV\ (Costs)} \quad (2)$$

The calculation of SIR is further defined in the regulations for the FEMP cost-effective methodology for federal buildings.[1] The SIR has the advantage of allowing comparison between two alternative items reviewed for cost-effectiveness. When a threshold of "SIR greater than 1.0" is used, the assessment of cost-effectiveness is the same as it is for the NPV of savings metric.

4.2.3 Scalar Ratio

The scalar ratio is used specifically for Scenario 3, the ASHRAE SSPC 90.1 Scalar Method. Using this approach, the payback is calculated as the sum of the first costs and present value of the replacement costs, divided by the difference of the energy cost savings and incremental maintenance cost. The result is compared to the scalar ratio limit that is dependent on the life of a measure. A code change is considered cost-effective if the payback is less than the limit. For the analysis of 90.1-2016 with a 40-year study period, the scalar ratio limit is 21.4 for heating or fossil fuel savings, 18.2 for cooling or electric savings, or a weighted limit for mixed savings. Unlike the simple payback period, this is a true cost-effectiveness method, because the scalar ratio threshold has been developed similar to a discounted payback using cost-effectiveness methods.

4.2.4 Simple Payback Period

The simple payback period is a straightforward metric that includes only the costs and benefits directly related to the implementation of the energy-saving measures associated with a code change. It

[7] The analysis can be done for other periods of time (e.g., monthly), but for simplicity DOE uses annual periods for the subject analyses.

represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in energy prices, tax effects, measure replacements, resale values, etc. The payback period *P*, which has units of *years*, is defined as the marginal cost of compliance with a new code (*C*, the "first costs" above and beyond the baseline code), divided by the annual marginal benefit from compliance (ES_0, the energy cost savings in year 0, less M_a, annual maintenance cost increases), as shown in Eq. (3).

$$P = \frac{C}{ES_0 - M_a} \tag{3}$$

The simple payback period is a metric useful for its simplicity and ubiquity. Because it focuses on the two primary characterizations of a code change—cost and energy performance—it allows an assessment of cost-effectiveness that is easy to compare with other investment options and requires a minimum of input data. The simple payback period is used in many contexts, and may be desired by state agencies considering the adoption of new energy codes; hence, DOE will calculate the payback period when it assesses the cost-effectiveness of code changes. However, because payback period ignores many of the longer-term factors in the economic performance of an energy efficiency investment, DOE does not intend to use the payback period as a primary indicator of cost-effectiveness for its own decision-making purposes.

This method does not take into account any costs or savings after the year in which payback is reached, does not consider the time value of money, and does not take into account any replacement costs, even those that occur prior to the year in which simple payback is reached. The method also does not have a defined threshold for determining whether an alternative's payback is cost-effective. Decision makers generally set their own threshold for a maximum allowed payback. The simple payback perspective is reported for information purposes only, not as a basis for concluding that a particular code, standard, or proposal is cost-effective.

4.2.5 Economic Metric Summary

To provide a better understanding of the relationship of the various economic metrics, the metrics are summarized in Table 4.1. Each metric is named, with its abbreviation, and the applicable scenarios and cost-effective thresholds are provided.

Table 4.1. Economic Metrics

Metric	Abbreviation*	Used in Scenarios	Cost-effectiveness Threshold
Life-Cycle Cost Net Savings (a.k.a. Net Present Value of Savings)	NPV	1,2	≥0
Savings-to-Investment Ratio	SIR	1,2	≥1.0
Simple Payback	SPP	1,2,3	Does not measure cost-effectiveness
Scalar Ratio**	N/A	3	≤ 21.4 for 40-year life heating ≤ 18.2 for 40-year life cooling

* NPV = net present value of savings; SPP is simple payback period.

**The scalar ratio is tested against a limit set by the measure life, fuel type, and economic parameters used for each edition of Standard 90.1. The values shown are for 90.1-2016. Heating is a blended fossil fuel rate, and cooling is for electric measures.

4.3 Economic Parameters and Other Inputs

Calculating the metrics described above requires defining various economic parameters. Table 4.2 shows the primary parameters of interest and how they apply to the four metrics. There is also some variation of requirement depending on the economic scenario.

Table 4.2. Economic Parameters Required for Cost-effectiveness Metrics

Parameter	Parameter Needed for Metric			
	Scenario 1 LCC & SIR	**Scenario 2 LCC & SIR**	**Scenario 3 Scalar Ratio**	**Simple Payback Period**
First costs, including sales tax on materials	Yes	Yes	Yes	Yes
Energy savings	Yes	Yes	Yes	Yes
Energy prices	Yes	Yes	Yes	Yes
Energy price escalation rates	Yes	Yes	Yes	No
Period of analysis	Yes	Yes	Yes	No
Replacement costs and residual value	Yes	Yes	Yes	No
Discount rate (real and nominal)	Real	Nominal	Nominal	No
Loan parameters (rate and term)	No	Yes	Yes	No
Inflation rate	No	Yes	Yes	No
Tax rates, federal and state income tax	No	Yes	Yes*	No
Tax rate, property tax	No	Yes	No	No

* Income tax rates are not required for Scalar Ratio analysis of Standard 90.1-2016 proposals, as the discount rate is pre-tax.

These parameters are chosen to represent the economic impact of a typical commercial building ownership or tenant situation. DOE intends to consult appropriate sources of information to establish assumptions for each financial, economic, and energy price assumption. Whenever possible, economic assumptions will be taken from the published sources discussed below. DOE notes that most values vary across time, location, markets, institutions, circumstances, and individuals. Where multiple sources for any parameter are identified, DOE will prefer recent values from sources DOE deems best documented and most reliable.

DOE intends to update parameters for future analyses to account for changing economic conditions. The current parameters for use in analyzing proposals for Standard 90.1-2016 and the 2018 IECC are included in Appendix A. In some cases, state-level analysis of the completed edition of a code may use different economic parameters than were used for individual proposals, as individual proposals are typically analyzed at a national level, and several years earlier than the final evaluation of a code edition. The parameters used and their sources will be documented in each particular analysis. Parameters for this methodology have been published at the BECP web site[8] starting with analysis for 2015 IECC in mid-2012.

[8] See http://www.energycodes.gov/development/commercial/methodology.

Table 4.3. Economic Parameters and Their Symbols

Parameter	Symbol
Period of Analysis	L
Energy Prices	N/A
Energy Escalation Rates	N/A
Loan Term	M_L
Loan Interest Rate	I
Nominal Discount Rate	D_n
Real Discount Rate	D_r
Inflation Rate	R_{INF}
Property Tax Rate	R_P
Income Tax Rate, federal	R_{TF}
Income Tax Rate, state	R_{TS}

4.3.1 Scenario 1: Publicly-Owned Method Parameters

The LCC analysis requires assumptions about what the value of money today is relative to money in the future, and about how values of the cost items will change over time, such as the cost of energy and HVAC equipment. These values are determined by the analyst depending on the purpose of the analysis. In the case of the FEMP LCC analysis method, NIST periodically publishes an update of economic factors (Rushing et al. 2013).

The DOE nominal discount rate is based on long-term Treasury bond rates averaged over the 12 months prior to publication of the NIST report. The nominal rate is converted to a real rate to correspond with the constant-dollar analysis approach for this analysis. The method for calculating the real discount rate from the nominal discount rate uses the projected rate of general inflation published in the most recent *Report of the President's Economic Advisors, Analytical Perspectives* (referenced in the NIST 2013 and 2011 annual supplements without citation). The mandated procedure would result in a discount rate for 2011 and 2013 lower than the 3.0% floor prescribed in 10 CFR 436. Thus, the 3.0% floor is used as the real discount rate for FEMP analyses in 2011 and 2013. The implied long-term average rate of inflation was calculated as -0.5 %[9] (Rushing et al. 2013).

4.3.2 Scenario 2: Privately-Owned Method Parameters

For Scenario 2, there are seven primary cash flows that are relevant to LCC analysis of energy code changes, summarized in Table 4.4. The total cost of the code changes (C) is not directly included in the analysis; rather, the incremental cost (C) is accounted for as loan payments assumed to occur over the 30-year (or other) study period. Replacement costs (C_r) for items that have shorter lives than the study period are often calculated at a higher cost than the initial installation to account for more difficulty in installation during replacement rather than new construction. The replacement costs are also incremental costs, reflecting cost increases or reductions required due to the new code. The replacement is made and the same efficiency and savings are estimated to continue. Where a measure or replacement does not have a life equal to or evenly divisible by the study period, there is a residual value, incurred at the end of the analysis period. The residual value is the cost of the code changes, multiplied by the fraction of the lifetime (i.e., value) of the code changes or replacements remaining at the end of the study period. This is

[9] The negative implied long-term inflation rate is not a prediction of deflation, but a result of the 3.0% floor on the discount rate, when the actual discount rate was lower. The negative inflation rate is not required in real analysis.

a simplified treatment of residual value, similar to straight-line depreciation, but is meant to encapsulate an average of the remaining lifetime of all components. The replacement and residual costs are discounted using a real discount rate to account for inflation, which is equivalent to inflating the costs, then discounting them with a nominal rate. Annual maintenance costs (M_a) are also accounted for. Property tax occurs every year, starting on year 1, is the property tax rate (R_P) multiplied by C, and is discounted with a real rate, which again is equivalent to property values increasing at the rate of inflation and then being discounted at a nominal rate. This assumes that the tax assessment of the building increases by exactly the same amount as the code-related cost increase, and that the tax assessment increases in step with inflation. The cost of property tax is the net of a federal tax (R_{TF}) deduction benefit.

Energy savings occur every year, starting at year 1, and are equal to the calculated energy cost savings at year 0 (ES_0), adjusted by the real escalation rates required to be used in the FEMP cost-effective methodology. These escalation rates exclude inflation, so the escalated energy savings are discounted to present value using a real discount rate (D_r), which again is equivalent to applying a combination of inflation and escalation to energy costs, to estimate their nominal future value, and then discounting with a nominal discount rate (D_n). Discount and escalation rates for the FEMP cost-effective methodology are established annually by NIST and published in the *NIST Handbook 135 Supplement* (Rushing et al. 2013). Loan payments occur every year of the study period, are constant payments, and are calculated as an annual payment, as calculated using the standard equation shown in Table 4.4.

Table 4.4. Present Value Cost and Benefit Components for Scenario 2

Cost Item	Equation for Present Value	Discount Rate	Cost or Benefit
First Cost*	C	N/A	N/A
Loan Payments	$C\left(\frac{i(1+i)^{M_L}}{(1+i)^{M_L}-1}\right)\left(\frac{(1+D_n)^{M_L}-1}{D_n(1+D_n)^{M_L}}\right)$	Nominal	Cost
Replacement Costs and Residual Value	$\sum_{Y=1}^{L}\frac{C_r}{(1+D_r)^Y}$	Real	Cost
Maintenance Costs	$M_a\left(\frac{(1+D_r)^L-1}{D_r(1+D_r)^L}\right)$	Real	Cost
Property Tax Net of Fed Income Tax Benefit	$C(R_P)\left(\frac{(1+D_r)^L-1}{D_r(1+D_r)^L}\right)(1-R_{TF})$	Real	Cost
Energy Savings Net of Income Tax Penalty	(1- R_{TC}) (Annual Energy Savings Escalated with NIST rates that change over time, and then discounted with real discount rate D_r to be equivalent to applying inflation and then using a nominal discount rate D_n)	Real, escalated	Benefit
Interest Tax Deduction**	$(1-R_{TC})\sum_{Y=1}^{M_L}\frac{LI_Y}{(1+D_r)^Y}$	Nominal	Benefit
Depreciation Tax Deduction	$\frac{C}{39}\left(\frac{(1+D_n)^{39}-1}{D_n(1+D_n)^{39}}\right)R_{TC}$	Nominal	Benefit

Note: Symbols for variables are listed in Table 4.3 and discussed in Section 4.3.4.
* First cost (*C*) is not directly used in the Scenario 2 LCC or SIR. As previously discussed, Scenario 2 uses a financed approach, and the present value of the loan payments is treated as a cost in the LCC or SIR.
** Loan interest paid in a given year (LI_Y) is simply the mortgage interest rate multiplied by the loan balance. The loan balance is calculated as the present value in year *Y* of the remaining stream of loan payments, discounted at the mortgage interest rate.

For Scenario 2, tax deductions for loan interest payments begin in year 1 and continue through the end of the 30-year analysis period. A depreciation tax benefit is calculated based on a 39-year straight-line depreciation applicable to commercial buildings (IRS 2012a). This depreciation benefit is calculated for the full 39 years that it is available for current and future property owners. While the depreciation extends beyond the study period, calculating this value for the full 39-year straight-line depreciation term is considered the most straightforward approach to capturing the residual value of this benefit, as these deductions will continue beyond the study period with a high level of certainty. The income tax deductions are calculated at the combined effective state and federal income tax rate (R_{TC}) multiplied by the sum of loan interest payments and depreciation taken each year. The combined (R_{TC}) effective state (R_{TS}) and federal (R_{TF}) income tax rate is based on state taxes being deductible from federal taxes, as shown in Eq. (4).

$$R_{TC} = R_{TF} + R_{TS}\,(1- R_{TF}) \tag{4}$$

4.3.3 Scenario 3: ASHRAE 90.1 Scalar Method Parameters

The SSPC 90.1 does not consider cost-effectiveness of the entire set of changes for an update to the whole Standard 90.1. However, cost-effectiveness is often considered when evaluating a specific addendum to Standard 90.1. The Scalar Method was developed by SSPC 90.1 to evaluate the cost-effectiveness of proposed changes (McBride 1995). The Scalar Method is an alternative LCC approach for individual energy efficiency changes with a defined useful life, taking into account first costs, annual energy cost savings, annual maintenance, taxes, inflation, energy escalation, and financing impacts. The Scalar Method allows a discounted payback threshold (scalar ratio limit) to be calculated based on the measure life. Because this method is designed to be used with a single measure with one value for useful life, it does not account for replacement costs. A measure is considered cost-effective if the simple payback (scalar ratio) is less than the scalar limit.

As an example, Table 4.5 shows the economic parameters used in the 90.1 Scalar Method for the Standard 90.1-2016 analysis. These parameters were adopted by the SSPC 90.1.

Table 4.5. Scalar Method Economic Parameters and Scalar Ratio Limit

Input Economic Variables	**Heating**	**Cooling**
Economic Life – Years	40	
Down Payment – $	$0.00	
Energy Escalation Rate – %*	NIST year-by-year rates + 2.38% inflation	
Nominal Discount Rate – %	9.34%	
Loan Interest Rate – %	7.0%	
Federal Tax Rate – %**	0%	
State Tax Rate – %**	0%	
Heating – Fossil Fuel† Price, $/therm	$1.000	
Cooling – Electricity Price, $/kWh		$0.1013
Scalar Ratio Limit	**21.4**	**18.2**

* The NIST escalation rates are from the NIST 2013 supplement (Rushing et al. 2013). The real escalation rates are combined with an inflation rate for this nominal analysis.

** Tax rates are zero for 90.1-2016 because a nominal discount rate based on before-tax investments was selected.

† The ASHRAE Scalar Method identifies a fossil fuel rate that is primarily applied to heating energy use. For this reason, the fossil fuel rate is a blended heating rate and includes proportional (relative to national heating fuel use) costs for natural gas, propane, heating oil, and electric heat. Heating energy use in the prototypes for fossil fuel equipment is calculated in therms based on natural gas equipment, but in practice, natural gas equipment may be operated on propane, or boilers that are modeled as natural gas may use oil in some regions.

DOE extends the Scalar Method to allow for the evaluation of multiple measures with different useful lives. This extended method takes into account the replacement of different components in the total package of Standard 90.1changes, allowing the NPV of the replacement costs to be calculated over 40 years. The SSPC 90.1 Envelope Subcommittee uses a 40-year replacement life for envelope components, and the useful lives of all other cost components in the cost estimate are less than that. For example, an item with a 20-year life would be replaced once during the study period. The residual value of any items with useful lives that do not fit evenly within the 40-year period is calculated using the method described in Section 4.1.2.3. Using this approach, the simple payback is calculated as the sum of the first costs and present value of the replacement costs, divided by the difference of the energy cost savings and incremental maintenance cost.

To determine cost-effectiveness, the result is compared to the scalar ratio limit for the 40-year period, 21.4 for heating or fossil fuels or 18.2 for electric or cooling, as shown in Table 4.5. For measures or evaluations that have a mixture of electric and fossil fuel savings, the separate scalar ratio limits are weighted by the proportion of each type of cost savings. The scalar ratio limit represents the simple payback for a 40-year life measure that would have a positive LCC using the other economic parameters shown. The packages of changes for each combination of prototype and climate location are considered cost-effective if the corresponding scalar ratio is less than the scalar ratio limit. The parameters shown in Table 4.5 are based on consensus of the SSPC 90.1.

4.3.4 Detailed Discussion of Economic Parameters

The meaning and source of each economic input parameter is discussed below. Where there are variations in the meaning or source for the different scenarios, these are discussed as well.

4.3.4.1 Economic Study Period (*L*)

DOE's economic analysis is intended to examine the costs and benefits impacting all the owners or tenants who use a commercial building and pay for energy use either directly or through a net lease. Because energy efficiency features may last longer than the average length of ownership or tenancy, a longer analysis period than the initial ownership period or tenancy is used. Assuming a single owner keeps the property throughout the analysis period accounts for long-term energy benefits without requiring complex accounting for resale values at property turnover. Commercial buildings will typically last 50 years or more. However, some energy efficiency measures may not last as long as the building does. Although 30 years is less than the life of the building, some efficiency measures, equipment in particular, may require replacement during that timeframe. As discussed earlier, when energy-saving equipment costs are analyzed, replacement costs will be included at the life of the equipment. The replacement costs are then discounted to present value as part of the cost. The impact of the selection of a study period is significantly moderated by the effect of the discount rate in reducing the value of costs and benefits far into the future.

DOE's methodology for Scenarios 1 and 2 is intended to assess cost-effectiveness based on a 30-year period of analysis or study period. The FEMP cost-effective methodology for federal buildings was amended by EISA to allow a study period of up to 40 years (42 U.S.C. 8254(a)(1)), while the DOE cost-effectiveness method for commercial building codes uses 30 years. The 30-year study period is used in the methodology for consistency with DOE's residential code cost-effectiveness analysis, and is also widely used for LCC analysis in government and industry. The study period is also a balance between capturing the impact of future replacement costs, inflation, and energy escalation and limiting uncertainty; the further into the future these costs are projected, the greater their uncertainty. The perspective of a single 30-year owner allows consideration of economic impacts on building owners or tenants, either single or multiple in succession, as well as consideration of long-term energy savings. While the full study period of 30 years is appropriate when analyzing the impact of an entire code, when individual measures are analyzed, a shorter study period equal to the measure life may be used. In this situation, the measure life will be determined based on measure life references. The primary reference is the *ASHRAE*

HVAC Applications Handbook (ASHRAE 2011, p. 37.3), and secondary resources include the Database for Energy Efficient Resources (DEER),[10] utility program guidelines (GDS 2007; KEMA 2009; Skumatz 2012), or Appendix J to the *Oregon State Energy Efficient Design Guidelines* (ODOE 2011).

Note that the parameters and methodology for Scenario 3, the ASHRAE 90.1 Scalar Method, are developed by the ASHRAE SSPC 90.1. A 40-year maximum study period is established by the SSPC for that method. For Scenario 3, a 40-year study period will be used, with the cost of interim replacements of shorter-lived equipment or measures added during the study period. This is a departure from the way the ASHRAE 90.1 Scalar Method is applied in the SSPC 90.1, and is necessary because typically DOE analyzes the entire code that contains multiple measures with different lives, while in the typical analysis for the ASHRAE SSPC 90.1, a single measure with a fixed life is analyzed. The 40-year life is the maximum used in SSPC analysis, typically for envelope measures.

4.3.4.2 First Cost (*C*)

As discussed earlier, the first cost represents the incremental cost of code-related energy features to a building owner. It represents the full (retail) cost of such features, including materials, sales tax[11] on materials, labor, and contractor overhead and profit, but excludes any future costs such as for maintenance.

4.3.4.3 Loan Interest Rate (*i*)

Commercial real estate is highly leveraged, with less than 20% of funding from private investors (National Association of Realtors 2013). Accordingly, for the analysis of the economic benefits to the commercial building owners and tenants for improved energy efficiency, DOE intends to assume that buildings are purchased or refinanced using a loan. For simplification, no down payment is assumed in Scenarios 2 and 3. Scenario 1 does not evaluate loan impact.

For Scenario 2, DOE intends to use recent commercial loan rates in cost/benefit analyses, and will consult multiple online sources[12] to determine a representative rate for each analysis. Recently, DOE used a commercial loan rate of 6% for cost/benefit analyses of ASHRAE Standard 90.1 (Hart et al. 2013).

An alternative approach is to evaluate historical commercial loan rates and identify a real rate that approximates a long-term average, then use that rate in a real analysis or combine it with a recent (and anticipated future) inflation rate in a nominal analysis. DOE intends to use the former approach on the theory that recent rates are a better indicator of near-term future rates that will be in effect when a new code goes into effect. For Scenario 3, the loan rate is established by the ASHRAE 90.1 committee.

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[10] The DEER is a California Energy Commission and California Public Utilities Commission sponsored database designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life all with one data source. See www.energy.ca.gov/deer/.

[11] Sales tax from online sources: http://taxfoundation.org/article/state-and-local-sales-tax-rates-2011-2013

[12] See www.realtyrates.com/commercial-mortgage-rates.html; www.commercialloandirect.com/commercial-rates.php.

4.3.4.4 Loan Term (M_L)

For the analysis of cost-effectiveness, the loan term will be set equal to the study period. While a typical commercial loan may be shorter, it is quite common for commercial buildings to be resold to a buyer who will take out a new loan or to be refinanced during their ownership period. While these are separate serial loans, the economic effect is similar to a single, longer-term loan.

4.3.4.5 Discount Rate (D)

The purpose of the discount rate is to reflect the time value of money. Because DOE's economic perspective is that of a building owner, that time value is determined primarily by the investor's best alternative investment at similar risk to the energy features being considered.

The discount rate is chosen to represent the desired perspective of the economic analysis, for Scenario 1, a public building owner, for Scenario 2, a private building owner or developer in a post-tax context, and for Scenario 3, a private building owner or developer in a pre-tax context.

For Scenario 1, DOE intends to use the real discount rate (D_r) established annually in the *NIST Handbook 135 Supplement* for the FEMP analysis. For Scenario 2, DOE intends to set the nominal discount rate (D_n) to be equivalent to the commercial loan interest rate (i). Because commercial lending is a viable source of funds for real estate investors, the associated loan rate is a reasonable estimate of an investor's alternative post-tax investment rate of return or discount rate. That real estate investors borrow money at that rate demonstrates that their implicit discount rate must be at least that high. As previously discussed, a real discount rate (D_r) is also used in Scenario 2 for discounting items that experience inflation. The selection of that rate is discussed below under Inflation Rate and the type of discount rate used for different cash flows is shown in Table 4.4.

For Scenario 3, the nominal discount rate (D_n) is established by the ASHRAE SSPC 90.1. As a point of comparison for the current parameters in Appendix A, the 9.34% nominal discount rate in Scenario 3 is based on industry surveys of commercial real estate investors expected rate of return **before taxes**. While the 6.0% nominal discount rate for Scenario 2 appears lower, this is an **after-tax** discount rate, and if adjusted for a combined national and average state corporate income tax rate of 38.1%, the effective **pre-tax** discount rate for Scenario 2 would be 9.7%.

4.3.4.6 Property Tax Rate (R_P)

Property taxes vary widely within and among states. To determine a tax rate for analysis, DOE intends to use the average U.S. property tax rates (Lincoln Institute of Land Policy 2013) and weight them by rural and urban population[13] and distribution of building size (EIA 2003) to arrive at a national weighted average. For current national level commercial code analysis, the resulting property tax rate is 2.04%. For state level analyses, state-specific rates will be used.

[13] See https://ask.census.gov/faq.php?id=5000&faqId=5971.

4.3.4.7 Income Tax Rate (R_{TC})

The marginal income tax rate paid by the building owner determines the value of the interest, property tax, and depreciation tax deductions. The combined effective (R_{TC}), state (R_{TS}), and federal (R_{TF}) income tax rates are based on state taxes being deductible from federal taxes, as shown in Eq. (4). DOE intends to account for corporate income tax deductions in the cost/benefit analyses. The federal corporate tax rate currently varies from 15%, transitioning to a 34% flat rate for incomes between $335,000 and $10,000,000 and then increasing to 35% (IRS 2012b, p. 17). DOE's intends to use the flat rate for the next-to-highest tier of corporate income for their corporate income tax rate (R_{TF}) estimate, currently 34%. Should that tax structure change, the approach will be reevaluated. Where state corporate income taxes apply, rates will be taken from state sources or collections of state data such as those provided by the Federation of Tax Administrators.[14]

4.3.4.8 Inflation Rate (R_{INF})

An inflation rate is not needed in the real or constant dollar analysis in Scenario 1, and the inflation rate for Scenario 3 is determined by the ASHRAE SSPC 90.1. The inflation rate R_{INF} is used to determine a real discount rate (D_r) for Scenario 2. This real discount rate is applied to items that are subject to inflation as shown in Table 4.4. A long-term inflation rate appropriate for the study life is necessary. To capture a relatively constant long-term inflation rate over time that is appropriate for the study period, the inflation rate for the past 30 years will be applied to the next 30 years. Estimates of an annual inflation rate will be based on current (CI_C) and past (CI_P) indices from Producer Price Index (PPI) data published by the Bureau of Labor Statistics.[15] The past (CI_P) index is selected 30 years prior to the current (CI_C) index. For the period since June 2004,[16] "final demand construction" PPI data is used, normalized to "finished goods less food and energy" PPI data that is used for earlier periods. The equivalent compound inflation rate (R_{INF}) is calculated from the current (CI_C) and past (CI_P) construction indices as shown in Eq. (5).

$$R_{INF} = \left(\frac{CI_C}{CI_P}\right)^{1/30} - 1 \qquad (5)$$

The real discount rate (D_r) for Scenario 2 is found based on the nominal discount rate (D_n) as shown in Eq. (6).

$$D_r = \left(\frac{1 + D_n}{1 + R_{INF}}\right) - 1 \qquad (6)$$

4.3.4.9 Energy Prices

Energy prices over the length of the period of analysis are needed to determine the energy cost savings from improved energy efficiency. Both current energy prices and energy price escalation rates are needed to establish estimated energy prices in future years.

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[14] Federation of Tax Administrators: www.taxadmin.org.
[15] Bureau of Labor Statistics. See www.bls.gov/.
[16] "Final demand construction" PPI data was initiated in June 2004 and is not available for earlier periods.

DOE will use the most recently available national annual average commercial energy prices from the EIA. Annual average prices are used to avoid selecting a short-term price that is subject to seasonal fluctuations. If energy prices from the most recent year(s) are unusually high or low, DOE may consider using a longer-term average of energy prices, such as the average from the past 3 years and projections for the next 2 years. For individual state analysis, DOE will use state annual average commercial energy prices from EIA.

4.3.4.10 Energy Price Escalation

Energy price escalation accounts for the fact that energy prices generally have increased faster than general inflation. Energy price escalation rates for Scenarios 1 and 2 will be obtained from the most recent projections in the *NIST Handbook 135 Supplement* to account for projected changes in energy prices. Currently, ASHRAE SSPC 90.1 uses the same escalation rates, and they will also be used for Scenario 3. Note that these escalation rates do not include inflation. Inflation is not necessary in Scenario 1, as it is a current dollar or real discount analysis. In Scenario 2, the real discount rate is used rather than the nominal discount rate for energy savings, as the escalation does not include inflation. In the ASHRAE 90.1 Scalar Method, inflation is added to the future energy savings along with the escalation rate above inflation, and then a nominal discount rate is used to arrive at a present value. While each of these procedures appears different, they each arrive at the correct present value of energy savings based on the particular parameters and methods used in the scenario.

5.0 Aggregating Energy and Economic Results

5.1 Weighting Factors: Building Types and Climate Zones

Simulation results for the building types and climate zones will be weighted based on weighting factors shown in Table 5.1 and Table 5.2, respectively. Weighting factors are based on disaggregated construction volume data from McGraw-Hill Construction (MHC) Project Starts Database. The MHC database contains the floor area of new construction in the United States for the years 2003 to 2007.[1] PNNL analyzed this MHC database to develop detailed construction weights by building type, climate zones, and states (Jarnagin and Bandyopadhyay 2010). These weights are used in developing weighted national energy savings estimates. For each analysis, the weights are normalized for the prototypes used in the analysis so weightings total 100%. These weighting factors are based on climate zones used through Standard 90.1-2013 and the 2015 IECC. Revisions that change the climate zones or switch to a new climate basis will require an update of the weighting factors or the development of a custom procedure to capture the impacts on national or state commercial energy efficiency.

[1] The 2003 to 2007 period represents a good time for commercial construction. Later data encountered a recession when commercial construction was curtailed. The database is used simply to represent characteristic weightings as a percentage of building types and locations, and is expected to be a valid predictor of commercial construction for the foreseeable future.

Table 5.1. National Weighting factors by Prototype

Prototype	Total Floor Area ×1,000 ft²	Construction Weights
Small Office	371,009	4.50%
Medium Office	400,091	4.80%
Large Office	220,134	2.70%
Standalone Retail	1,009,246	12.20%
Strip Mall	375,093	4.50%
Primary School	330,418	4.00%
Secondary School	685,508	8.30%
Outpatient Healthcare	289,171	3.50%
Hospital	228,131	2.80%
Small Hotel	113,837	1.40%
Large Hotel	327,562	4.00%
Warehouse	1,105,951	13.40%
Quick Service Restaurant	38,809	0.50%
Full Service Restaurant	43,650	0.50%
Mid-rise Apartment	484,343	5.90%
High-rise Apartment	593,241	7.20%
Covered by Prototypes	6,616,193	80%
No prototype	1,649,785	20%
Total	8,265,977	100%

Table 5.2. Commercial Weighting Factors by Climate Zone

Climate Zone	Thermal Climate Zone	Moisture Regime	Overall Location Weight
1A	1	Moist	3.2%
2A	2	Moist	15.2%
2B		Dry	3.0%
3A	3	Moist	15.0%
3B		Dry	10.1%
3C		Marine	1.6%
4A	4	Moist	19.3%
4B		Dry	0.5%
4C		Marine	3.0%
5A	5	Moist	19.4%
5B		Dry	4.3%
6A	6	Moist	4.2%
6B		Dry	0.6%
7	7	N/A	0.5%
8	8	N/A	0.1%

5.2 Building Prototype Selection

DOE may select a subset of the prototype buildings and simulate them in selected representative climate locations for the cost-effectiveness analysis to represent most of the energy and cost impacts of the code changes in a particular code or proposal analysis.

For example, for the Standard 90.1-2010 and 90.1-2013 national analyses, six of the prototype buildings were selected for cost estimate development in five climate locations, as shown in bold font in Table 5.3. The 6 prototypes selected provide a good representation of the overall code cost effectiveness, without requiring simulation of all 16 prototypes.[2] DOE intends to continue to use these six prototypes unless a code change is identified that is not represented and has a large impact in one of the other prototypes. The resulting cost-effectiveness analysis from the six prototype analysis represents most of the energy and cost impacts of the changes in Standard 90.1. These six prototypes were chosen to represent the energy impact of five of the eight commercial principal building activities. The five represented principal building activities account for 74% of the new construction by floor area covered by the full suite of 16 prototypes.

Table 5.3. Prototype Buildings

Principal Building Activity	Building Prototype	Included in Subset for Cost-Effectiveness Analysis
Office	***Small Office***	**Yes**
	Medium Office	No
	Large Office	**Yes**
Mercantile	***Standalone Retail***	**Yes**
	Strip Mall	No
Education	***Primary School***	**Yes**
	Secondary School	No
Healthcare	Outpatient Healthcare	No
	Hospital	No
Lodging	***Small Hotel***	**Yes**
	Large Hotel	No
Warehouse	Warehouse (non-refrigerated)	No
Food Service	Quick-service Restaurant	No
	Full-service Restaurant	No
Apartment	***Mid-rise Apartment***	**Yes**
	High-rise Apartment	No

5.3 Represented HVAC Equipment Types

To estimate the mix of energy types impacted by codes and the effect of different types of equipment, various water heating, space heating, and cooling equipment is selected for each prototype based on a typical application, with the goal of representing a broad cross section of the many commercial HVAC

[2] An analysis of the 6 prototype presented at the interim SSPC 90.1 meeting on October 19, 2011 showed savings for 90.1-2010 v. 2004 to be within 2.5% of the full set of 16 prototype analysis.

and other systems used in the commercial building sector. The selections were vetted by building experts, including representatives of ASHRAE SSPC 90.1. The heating and cooling source and predominant and additional HVAC system types are shown in Table 5.4.

Table 5.4. HVAC Primary and Secondary Equipment

Building Prototype	Heating	Cooling*	Predominant System*	Additional System*
Small Office	Heat Pump	Unitary DX	Packaged CAV	No
Medium Office	Gas Furnace	Unitary DX	Packaged VAV w/Reheat	No
Large Office	Boiler	Chiller, Cooling Tower	VAV w/Reheat	No
Standalone Retail	Gas Furnace	Unitary DX	Packaged CAV**	No
Strip Mall	Gas Furnace	Unitary DX	Packaged CAV**	No
Primary School	Gas Furnace	Unitary DX	Packaged CAV**	No
Secondary School	Boiler	Air-cooled Chiller	VAV w/Reheat	Packaged CAV
Outpatient Healthcare	Boiler	Unitary DX	Packaged VAV w/Reheat	No
Hospital	Boiler	Chiller, Cooling Tower	VAV w/Reheat	Central CAV
Small Hotel	Electricity	DX	PTAC	No
Large Hotel	Boiler	Air-cooled chiller	Fan-coil Units	VAV w/Reheat
Warehouse	Gas Furnace	Unitary DX	Unit Heater	Packaged CAV
Quick-service Restaurant	Gas Furnace	Unitary DX	Packaged CAV	No
Full-service Restaurant	Gas Furnace	Unitary DX	Packaged CAV**	No
Mid-rise Apartment	Gas	DX	Split DX system	No
High-rise Apartment	Boiler	Fluid Cooler	WSHP	No

* System abbreviations: DX = direct expansion; CAV = constant air volume; VAV = variable air volume; PTAC = packaged terminal air conditioners; WSHP = water source heat pump
** These systems are constant volume in 90.1-2007, and in some cases are VAV in 90.1-2010 and later

5.4 Aggregation across Building Type and Climate Zone

DOE may use one of two approaches to demonstrate overall cost-effectiveness for a code or standard edition as a whole.

- If all the individual building types and climate zones included in the analysis are found to be cost-effective independently, using the metrics and scenarios applied, the overall cost-effectiveness is demonstrated.
- For situations where some building type and climate zone combinations do not meet cost-effective criteria, if the preponderance of individual building type and climate zones included in the analysis are found to be cost-effective independently, using the metrics and scenarios applied, the overall cost-effectiveness is demonstrated even though a minority of the building type and climate zone combinations may not meet some economic criteria. To verify the impact in this case, DOE will aggregate the costs and savings on a national or state level.

5.4.1 National and State-Level Aggregations

When energy code proposals are developed, they are typically shown to be cost-effective for situations and building types where they are likely to be applied. The proposal cost-effectiveness analysis does not usually cover all building types or climate zones. In combination with a sample-based cost-effectiveness analysis, professional judgment of the consensus body is used to determine if a particular proposal is appropriate for addition to the standard or code. Proposals are also evaluated using national average energy prices, and the prices in some states can be lower. This means that for some building types in some climate zones, individual proposals may not be cost-effective. For individual code cycles, it is possible that some building type and climate zone combinations may not meet cost-effectiveness metric criteria, especially when analyzed at the state level with lower energy prices.

Individual results for building types in a climate zone can be aggregated to a national or state domain using weighting factors based on construction floor area for that domain. When a subset of climate zones or building types is selected for analysis, the weighting factors on each axis will be normalized so that the weightings for selected climate zones and building types each total 100%. Individual results are then multiplied by the weighting factors to arrive at an aggregate result.

5.4.2 Demonstration of Aggregate Cost-effectiveness

For situations where some building type and climate zone combinations do not meet cost-effective criteria, the results for all the analyzed combinations will be weighted based on construction data. If the resulting cross-weighted cost-effectiveness metric for the commercial building set as a whole in the state or national domain analyzed meets the cost-effectiveness criteria, DOE will deem that cost-effectiveness has been demonstrated.

5.5 Supplemental Range of Results or Sensitivity Analysis

In some cases it may be desirable to understand the range of results that might occur given variation in some of the parameters. This type of analysis shows the sensitivity of the cost-effectiveness to each parameter and shows the range of possible results. This analysis can be conducted using either a Monte Carlo or discrete probability method.[3] An example of such an analysis is shown in Appendix B. This type of analysis may help demonstrate the cost-effectiveness of a code or standard as a whole in a particular domain when some individual building type and climate zone combinations do not meet cost-effectiveness criteria.

[3] A Monte Carlo analysis uses multiple random values of sensitive variables in an iterative analysis to find the range and distribution of possible outcomes, while a discrete probability method uses selected values that are assigned expected probabilities to determine an expected range of outcomes.

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Appendix A

Current Cost-effectiveness Parameters

A.1 Commercial Cost-effectiveness Parameters

Following the methodology outlined in this document and previously posted on the Building Energy Codes Program web site,[1] the U.S. Department of Energy (DOE) has established the following parameters for analysis of current code proposals as of January 2015. Current economic parameters are posted at the same web site. These parameters are subject to reevaluation for each analysis and may change if deemed appropriate. The parameters used and their source will be documented in each analysis.

Table A.1. Summary of Current Economic Parameter Estimates

Parameter	Symbol	Scenario 1 (Publicly-Owned Method)	Scenario 2 (Privately-Owned Method)	Scenario 3 (ASHRAE 90.1-2016 Scalar Method)
Period of Analysis	L	30 years*	30 years*	40 years*
Energy Prices		Latest national annual average prices based on current DOE Energy Information Administration (EIA) data**		$0.1013/kWh $1.00/therm blend†
Energy Escalation Rates		Price escalation rates taken from 2013 *NIST Handbook 135 Supplement*‡‡	National Institute of Standards and Technology (NIST) year-by-year rates (same as scenario 1)	NIST year-by-year rates (same as scenario 1) plus 2.38% inflation
Loan Term	M_L	N/A	$M_L = L$ (same as period of analysis)	$M_L = L$ (same as period of analysis)
Loan Interest Rate	I	N/A	6.00%	7.00%
Nominal Discount Rate	D_n	N/A	6.00% (same as loan rate)	9.34%
Real Discount Rate	D_r	3.0%	4.06%	5.0%
Inflation Rate	R_{INF}	N/A	1.87% annual	2.38% annual
Property Tax Rate	R_P	N/A	2.04%	N/A
Income Tax Rate, federal	R_{TF}	N/A	34.0%	0%‡
Income Tax Rate, state	R_{TS}	N/A	State values vary; highest marginal corporate rate used	0%‡

* Study period shown is for full code or standard analysis, for individual measures, measure life may be used as the study period.

** Average EIA prices from EIA. State prices from EIA are used for individual state analysis. National analysis of Standard 90.1 may use the Scenario 3 prices established by ASHRAE.

† The ASHRAE Scalar Method identifies a fossil fuel rate that is primarily applied to heating energy use. For this reason, the fossil fuel rate is a blended heating rate and includes proportional (relative to national heating fuel use) costs for natural gas, propane, heating oil, and electric heat. Heating energy use in the prototypes for fossil fuel equipment is calculated in therms based on natural gas equipment, but in practice, natural gas equipment may be operated on propane, or boilers that are modeled as natural gas may use oil in some regions.

‡ Income tax rates are 0% for Scenario 3 because the current discount rate is based on pre-tax rate of return.

‡‡ Price escalation from Rushing et al. 2013.

[1] See http://www.energycodes.gov/development/commercial/methodology.

Appendix B

Supplemental Range of Results Method

Appendix B

Supplemental Range of Results Method

In some cases, it may be desirable to understand the range of results that might occur in a cost-effectiveness analysis, given potential variation in some of the parameters. This type of analysis shows the sensitivity of the cost-effectiveness to each parameter and shows the range of results that can occur. This analysis can be conducted using either a Monte Carlo or discrete probability method. This example uses a discrete probability or decision analysis method. This type of analysis may be helpful in demonstrating cost-effectiveness of a code or standard as a whole in a particular domain when some individual building type and climate zone combinations do not individually meet cost-effectiveness criteria.

B.1 Evaluating Multiple Mixed Cost-effectiveness Results

To demonstrate the Range of Results Method, two discrete probability analyses are conducted. The first shows the impact of variation in energy cost savings and construction costs and the second adds variation in economic parameters. For these examples, preliminary results of the analysis of ASHRAE Standard 90.1-2013 compared to 90.1-2010 are used. Note that this is intended to provide an example of the method, not a finished result. In a finished analysis, more research into each variable and the associated probabilities would be undertaken, and more documentation of that research, the data and expert sources used, and the range of each input parameter would be provided.

When conducting a national analysis, many parameters will vary from region to region and state to state. Variable parameters in the cost-effectiveness analysis include the following:

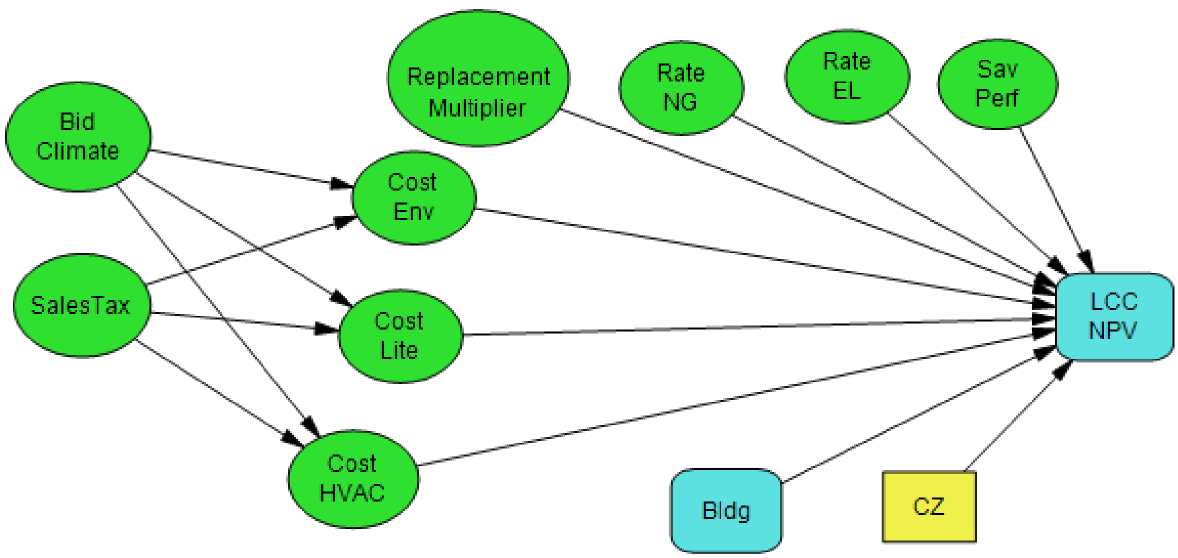
- **Construction costs.** Separate location cost factors for building envelope (walls and windows), lighting, and HVAC can be applied. In addition, sales tax varies from location to location and bid climate affects costs beyond average location multipliers. Replacement costs include a fairly large cost increase multiplier, and variation can be included for that cost as well. A variable reflecting bid climate is also included, as the number of active construction projects can have a large impact on local construction costs.
- **Energy cost savings.** A range of energy prices can be applied, along with multipliers on the escalation factors. In addition, a savings range can be applied, as there will be variation in savings in actual buildings compared with the prototype buildings.
- **Economic parameters.** While economic parameters have been established by federal statute or committee consensus process, there is variability in discount rates for various sectors and in the escalation rates for energy prices that can actually occur.

In a discrete probability analysis, a high, nominal, and low value for each factor is used (sometimes additional discrete states are added). Where a good set of data is available, these values and the probability of their occurrence can be determined fairly precisely, as is the case with occurrence of different state energy prices or sales taxes. In other cases, expert judgment can be applied to arrive at a reasonable range of values that are generally acceptable, and a reasonable set of probabilities can be applied. Even without a complete set of data-based inputs, a valid range of results can be shown, as individual high and low values tend to average out, and probabilities often match a standard distribution. The value of the analysis is not predicting a precise expected value, but is seeing the range of results that occurs with the given inputs and a good estimate for the expected value of the overall group result based on the given range of inputs. The expected value is similar to a weighted average, based on probability.

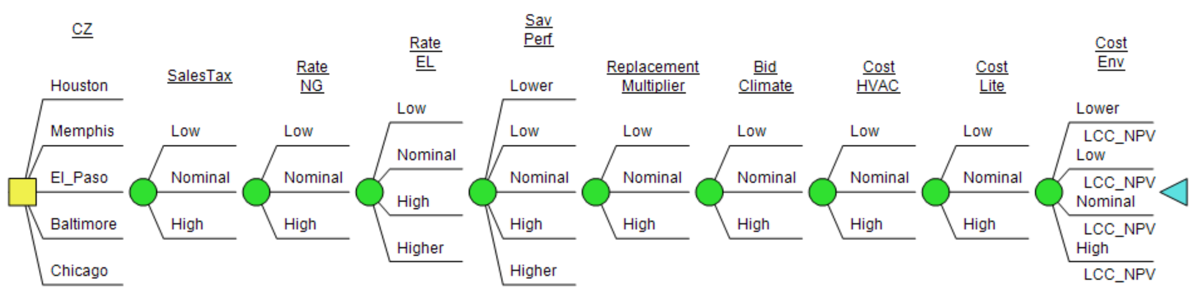
B.2 Example of Variable Costs and Energy Parameters

For this analysis, a weighted average net present value (NPV) savings of the six building types is used in Scenario 1. Variation in energy cost savings and construction cost values are analyzed.

An influence diagram shows the relationship of the parameters in this analysis:

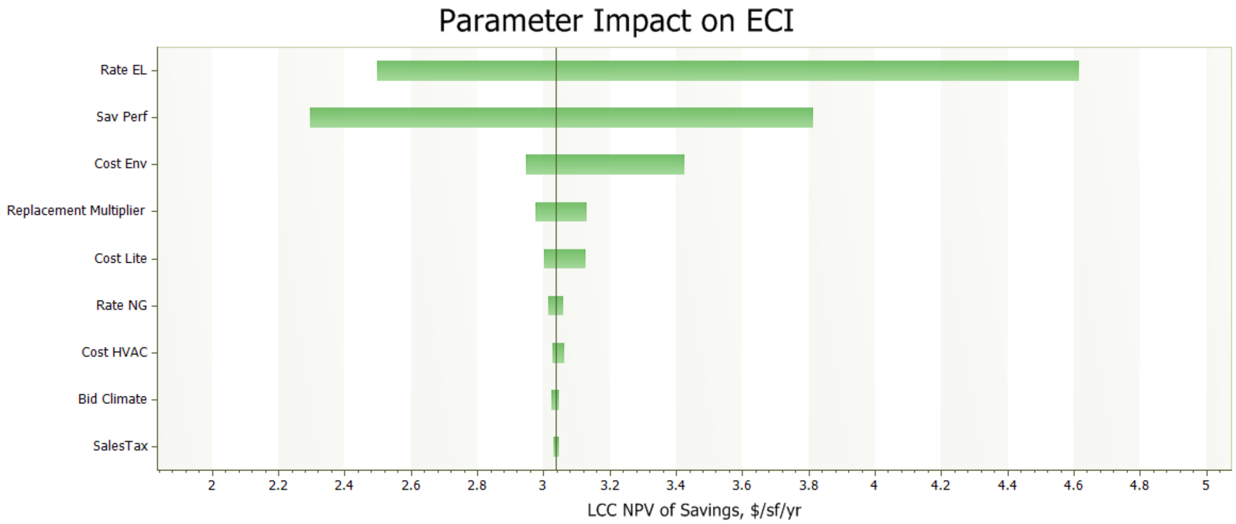


That relationship can also be seen as a decision tree, where the discrete states for each parameter are shown:

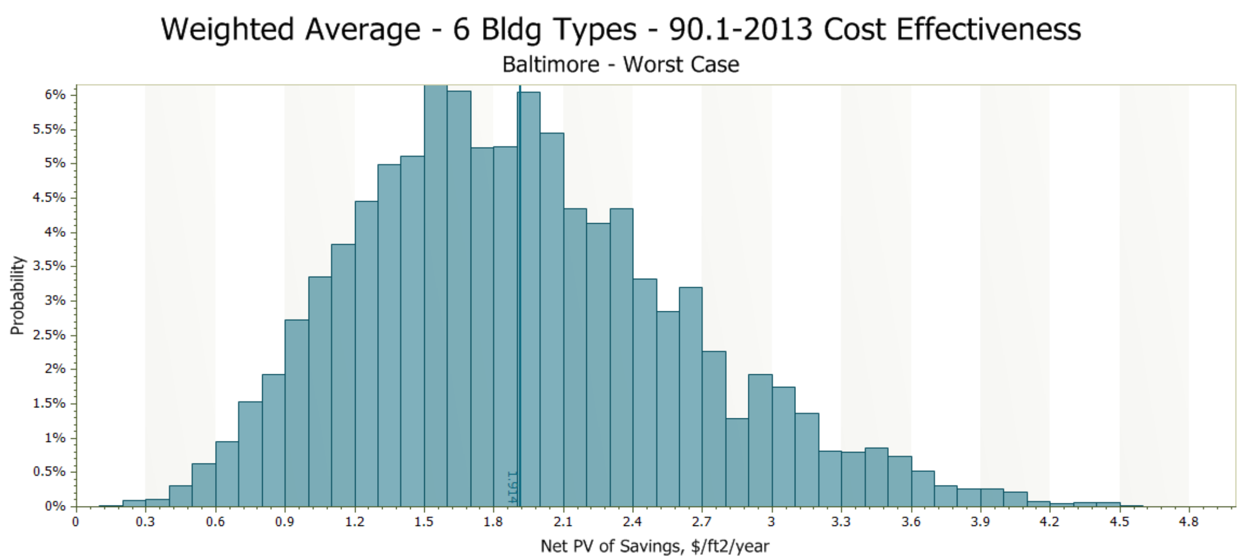


When the impact of the influencing parameters on the final NPV of savings is evaluated, we can see the range of impact each parameter has when the other parameters are held at their nominal state. The range of impact is displayed in a tornado diagram. The vertical line represents the NPV of savings for the

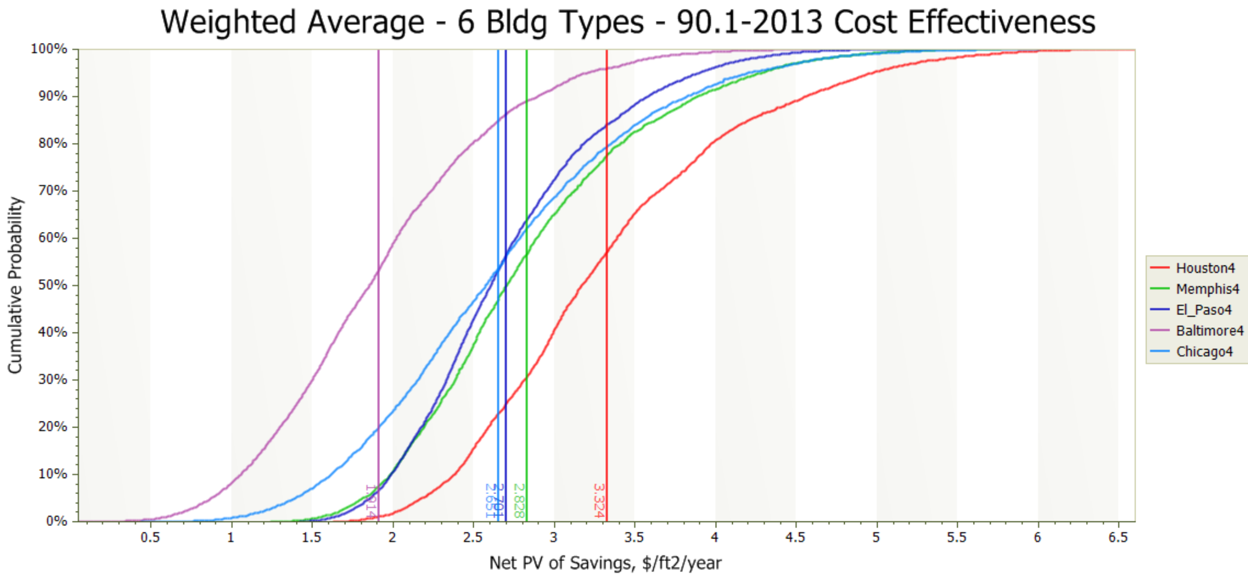
Houston climate zone with all parameters equal to the nominal position. The width of each bar shows the high and low result that each parameter's range of values will produce when other influencing parameters are held at their nominal value. Reviewing the tornado diagram indicates that the electric rate and savings performance variation have the largest impact on the NPV of savings.



The range of NPV savings result can be viewed for individual climate zones, and a histogram for the weighted average of six building types in Baltimore, the location with the lowest NPV of savings result, is shown below.



The histograms for each analyzed climate zone can be converted into a plot of cumulative probability, so they can be easily overlaid on one graph. The "S" shaped line shows the range of results and the vertical line shows the expected value, given the range and probabilities for all the input parameters.

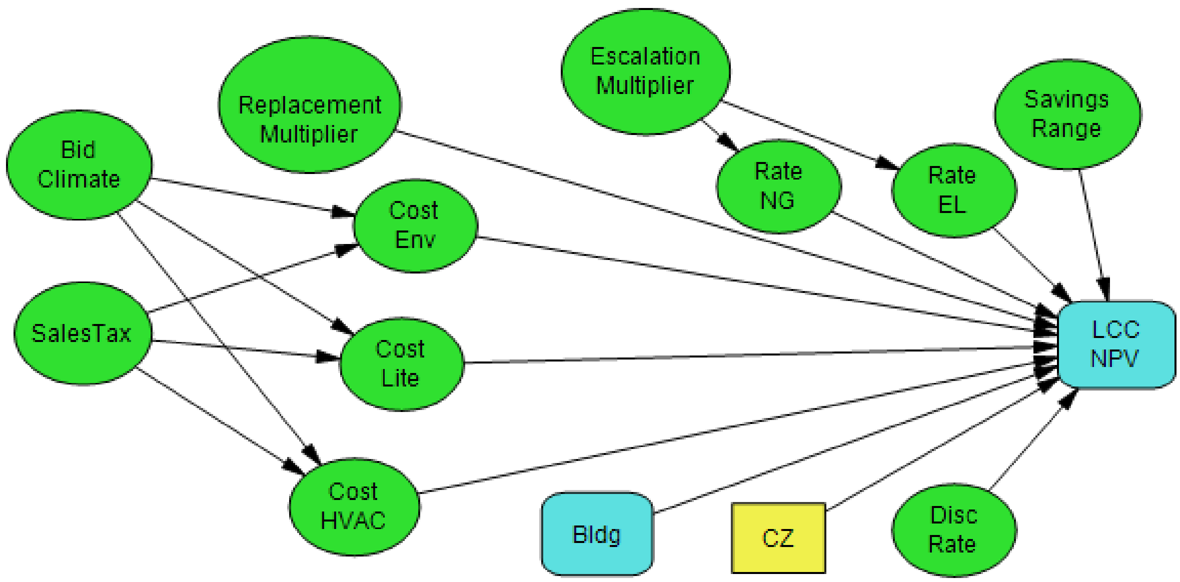


While in this example, the results across the entire range and combinations of parameter input in each climate zone analyzed were all cost-effective; in a case where some combinations fell below zero NPV savings, a code upgrade would be declared cost-effective as a whole if the expected value of NPV savings was greater than zero.

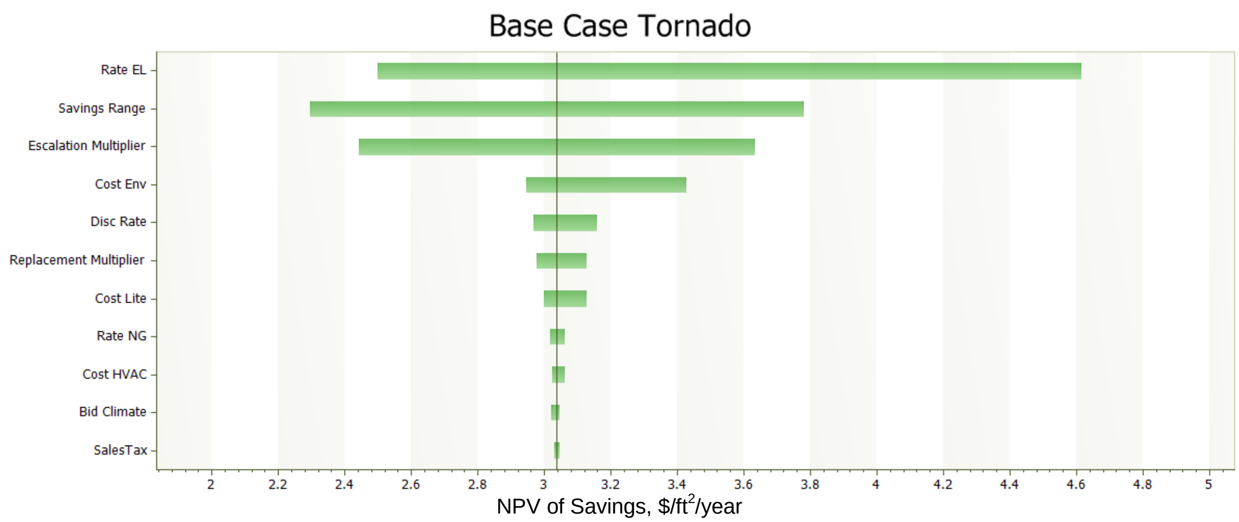
B.3 Example including Variable Economic Parameters

The previous example—based on preliminary results of the Scenario 1 analysis of Standard 90.1-2013 compared to 90.1-2010—can be expanded to include variation in the energy price escalation rates and discount rate used. Again, this analysis is intended to provide an example of the method, not a finished result. In a finished analysis, more research into each variable and the associated probabilities would be undertaken, and more documentation of that research and the selected range of parameter inputs would be provided.

There are often uncertainties regarding the predicted energy escalation rates and the discount rates used in the analysis. While these are established by federal regulation for federal projects, a view of the impact of varying those rates may be helpful from the private investment view. For illustration, the previous analysis was revised to include influence of varying the energy price escalation rates from 80% to 120% of their value as established by the Energy Information Administration and look at real discount rates from 0.5% to 7.0% rather than just 3.0%. The revised influence diagram is shown below:

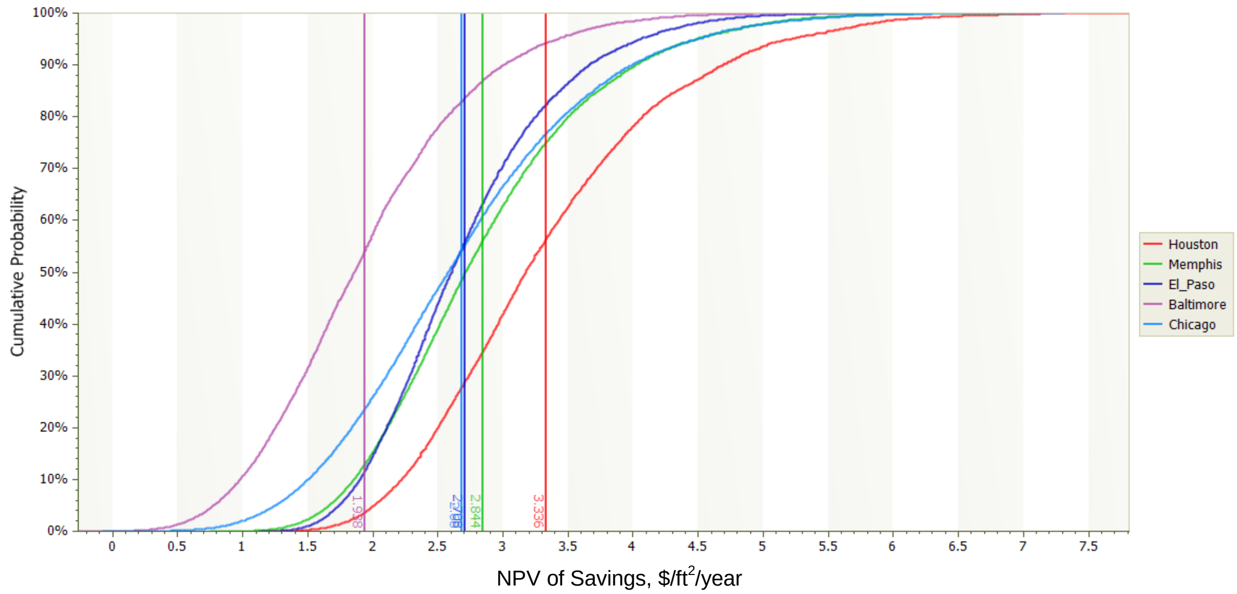


When a sensitivity analysis is run for the Houston climate zone, the energy price escalation multiplier does have a large impact, and the discount rate variation has a lesser impact.



Looking at the cumulative probability diagram for the weighted results of all six building types, we can see that the purple line for the Baltimore climate zone extends below zero NPV, because there are some combinations of the tested parameters that result in a NPV of savings less than zero; however, the preponderance of cases still have a positive net savings, and the expected values of NPV savings shown by the vertical lines for all climate zones are greater than zero. In fact the probability is so low that NPV is less than zero it is difficult to see the tail of the line for Baltimore on the chart. So a conclusion can be made that the code as a whole is cost-effective, even with savings, cost, and economic parameter input variation.

Weighted Average – 6 Building Types – 90.1-2013 Cost-Effectiveness



The U.S. Department of Energy's Building Energy Codes Program is an information resource on national model energy codes. We work with other government agencies, state and local jurisdictions, national code organizations, and industry to promote stronger building energy codes and help states adopt, implement, and enforce those codes.

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APPENDIX G

Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes

Prepared by ZT Taylor, VV Mendon, N Fernandez
(cited by March 24, 2023 *Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code*, at footnotes 7 and 12)

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Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes

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VV Mendon
N Fernandez

August 2015

Prepared for
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under Contract DE-AC05-76RL01830

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Preface to 2015 Revision

DOE supports the development of the International Code Council's (ICC) International Energy Conservation Code (IECC), the national model code adopted by or forming the basis of residential energy codes promulgated by a majority of U.S. states, as well as other voluntary building energy codes. DOE performs a cost-effectiveness analysis of proposed modifications to the codes as part of that support and also performs an analysis of cost-effectiveness of new code versions.[1] This document represents the methodology DOE uses in performing such analyses.

This document is an update to the U.S. Department of Energy's (DOE) cost-effectiveness methodology originally published in April, 2012. Changes include correction of a few typographical errors in life-cycle costing equations and building prototype descriptions; several modifications to the single-family building prototype used in simulating energy performance, including increasing the aspect ratio—and hence, the relative areas of exterior walls and ceilings—to better reflect typical new home construction, simplification of roof/ceiling configurations when non-roof components are being evaluated, and correction of the internal gains to reflect a three-bedroom house rather than a four-bedroom; and the addition of an abbreviated set of representative climate locations to be used when state-level aggregations are not needed.

The changes reflect DOE's experience using the methodology as well as public input on the methodology and DOE's proposed updates. DOE published a Request for Information (RFI) on Updating and Improving the DOE Methodology for Assessing the Cost-effectiveness of Building Energy Codes (Docket No. EERE-2015-BT-BC-0001)[2] in the Federal Register on April 14, 2015 (80 FR 19974). The notice sought public input on DOE's planned updates and improvements to the methodology.

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[1] Additionally, DOE is statutorily required to evaluate whether updates to the IECC would result in increased energy savings as compared to the prior version. (42 U.S.C. 6833(a)(5)(A)) The statutorily required determination is based solely on an assessment of energy savings. To the extent a quantitative analysis would be required for such a determination, DOE would rely on the energy savings portion of the methodology.

[2] Federal Register Docket: http://www.regulations.gov/#!documentDetail;D=EERE-2015-BT-BC-0001-0001

1.0 Introduction

The U.S. Department of Energy's (DOE's) Building Energy Codes Program has developed and established a methodology for evaluating the energy and economic performance of residential energy codes. This methodology serves two primary purposes. First, as DOE participates in the consensus processes of the International Code Council (ICC), the methodology described herein will be used by DOE to ensure that its proposals are both energy efficient and cost effective. Second, when a new version of the International Energy Conservation Code (IECC) is published, DOE will evaluate the new code as a whole to establish expected energy savings and cost effectiveness, which will help states and local jurisdictions interested in adopting the new codes. DOE's measure of cost-effectiveness balances longer-term energy savings against additions to initial costs through a life-cycle cost (LCC) perspective.

Evaluating cost effectiveness requires two primary steps—estimating the theoretical energy impact of a code change and assessing how that impact relates to the cost of implementing the change. The DOE methodology estimates the energy impact by simulating the effects of the code change(s) on typical new residential buildings, assuming both the old and new code provisions are implemented fully and correctly. The methodology does not estimate rates of code adoption or compliance. Cost effectiveness is defined primarily in terms of LCC evaluation, although the DOE methodology includes several metrics intended to be useful to states considering adopting new codes.

This document is arranged into three primary parts covering the following.

1. Estimating Energy Savings of Code Changes—by modeling changes to representative building types. The DOE methodology defines single- and multifamily prototype buildings, establishes typical construction and operating assumptions, and identifies climate locations to be used in estimating impacts in all climates zones and all states. The building prototypes include four foundation types and four heating equipment types to facilitate appropriate accounting for location-specific construction practices and fuel prices.

2. Estimating the Cost Effectiveness of Code Changes—by comparing energy cost savings to additions to first cost of the buildings. The methodology defines three metrics—LCC, simple payback period, and annual consumer cash flow—to be calculated; establishes sources for the economic parameters to be used in estimating those metrics; identifies a primary database of energy-efficiency measure costs; and defines three geopolitical levels at which those metrics will be reported (state, climate zone, national).

3. Aggregating Energy and Economic Results—across building types, foundation types, fuel/equipment types, and climate locations. The methodology establishes sources for weighting factors to be used in aggregating location-specific results to the three geopolitical levels.

2.0 Estimating Energy Savings of Code Changes

The first step in assessing the impact of a code change or a new code is estimating the energy savings of the associated changes. DOE will usually employ computer simulation analysis to estimate the energy impact of a code change (situations in which other analysis approaches might be preferred are discussed later). In some cases, DOE may rely on extant studies directly addressing the building elements involved in a proposed change if such can be identified. DOE intends to use the EnergyPlus™[3] software as the primary tool for its analyses. If necessary to more accurately capture the relevant impacts of a particular code change, DOE may supplement EnergyPlus with other software tools or performance databases. Such code changes will be addressed case by case.

Code changes affecting a particular climate zone will be simulated in representative weather locations. At least one location is chosen per climate zone in every U.S. state. DOE's methodology includes weighting factors based on recent housing starts data to allow the individual location results to be aggregated to climate-zone and national averages as needed. These methodologies, weighting factors, and other assumptions are described in the sections that follow.

2.1 Building Energy Use Simulation Assumptions and Methodology

The energy performance of most energy-efficiency measures can be estimated by computer simulation. Prototype buildings will be developed—one designed to comply with the baseline code and an otherwise identical building complying with the revised code. This comparison will be simulated in the relevant climate zones to estimate the overall energy impact of the new code. The inputs and assumptions used in the simulations are discussed in the following sections.

2.1.1 Energy Simulation Tool

DOE intends to use an hour-by-hour simulation tool to calculate annual energy consumption for relevant end uses. For most situations, the EnergyPlus software will be the tool of choice. EnergyPlus provides for a detailed hour-by-hour (or more frequent) simulation of a home's energy consumption throughout a full year, based on typical weather data for a location. It covers almost all aspects of residential envelopes; heating, ventilation, and air-conditioning (HVAC) equipment and systems; water heating equipment and systems; and lighting systems. Depending on how building energy codes evolve, it may be necessary to identify additional tools to estimate the impacts of more specialized changes.

DOE recognizes there are other tools that can produce credible energy estimates. DOE intends to use EnergyPlus as its primary tool, because it includes enhanced simulation capabilities, is under active development, and has the potential to include capabilities either unavailable or less sophisticated in other accepted simulation tools. EnergyPlus has capabilities for detailed simulation of the pressure-related interactions between duct leakage and air infiltration through the building envelope, enhanced capabilities for simulating residential attics and other unconditioned spaces, and the potential for analyzing detailed control strategies and specific hot water piping configurations.

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[3] http://www.energyplus.gov/

2.1.2 Prototypes

Simulations will be conducted for single-family and multifamily buildings. The prototypes used in the simulations are intended to represent, respectively, a typical new one- or two-family home or townhouse, and a low-rise multifamily building, such as an apartment, cooperative, or condominium. Four foundation types will be examined for all buildings: vented crawlspace, slab-on-grade, heated basement with wall insulation, and unheated basement with insulation in the floor above the basement. All buildings will be evaluated with central air conditioning and each of four heating system types: gas furnace, oil furnace, heat pump, and electric furnace. The multifamily prototypes will be simulated with a central oil-fired boiler instead of individual oil furnaces. If new code provisions relate to other less frequently used foundations or equipment types, supplemental prototype configurations will be developed as necessary.

Prototypes will be configured to meet the provisions of each code's primary prescriptive manifestation. DOE will address any future codes that may not have such primary requirements (e.g., a purely performance code) and codes for which the primary prescriptive path does not represent the likely practical manifestation of the code on a case-by-case basis.

Table 2.1 shows the characteristics DOE intends to assume for the single-family prototype. Note that any of these characteristics may be modified if impacted by a code change. The single-family prototype is configured as a simple rectangular building and is illustrated by the line drawing in Figure 2.1.

Table 2.1. Single-Family Prototype Characteristics

Parameter	Assumption	Notes
Conditioned floor area	2,376 ft^2 (plus 1,188 ft^2 of conditioned basement, where applicable)	Characteristics of New Housing, U.S. Census Bureau
Footprint and height	54-ft-by-22 ft, two-story, 8.5-ft-high ceilings	
Area above unconditioned space	1,188 ft^2	Over a vented crawlspace or unconditioned basement
Area below roof/ceilings	1,188 ft^2	Under a conditioned attic unless specific roof/ceiling measures warrant other (or multiple) roof/ceiling types
Perimeter length	152 ft	
Gross exterior wall area	2,584 ft^2	
Window area (relative to conditioned floor area)	Fifteen percent equally distributed to the four cardinal directions (or as required to evaluate glazing-specific code changes)	
Door area	42 ft^2	
Internal gains	86,761 Btu/day	2015 IECC, Table R405.5.2(1), assuming three bedrooms. May vary if homes of different size than the standard prototype are analyzed.
Heating system	Natural gas furnace, heat pump, electric furnace, or oil-fired furnace	Efficiencies will be based on prevailing federal minimum manufacturing standards.
Cooling system	Central electric air conditioning	Efficiency will be based on prevailing federal minimum manufacturing standards.
Water heating	Same as fuel used for space heating, or as required to evaluate domestic hot water-specific code changes	

Btu = British thermal units.
IECC = International Energy Conservation Code.

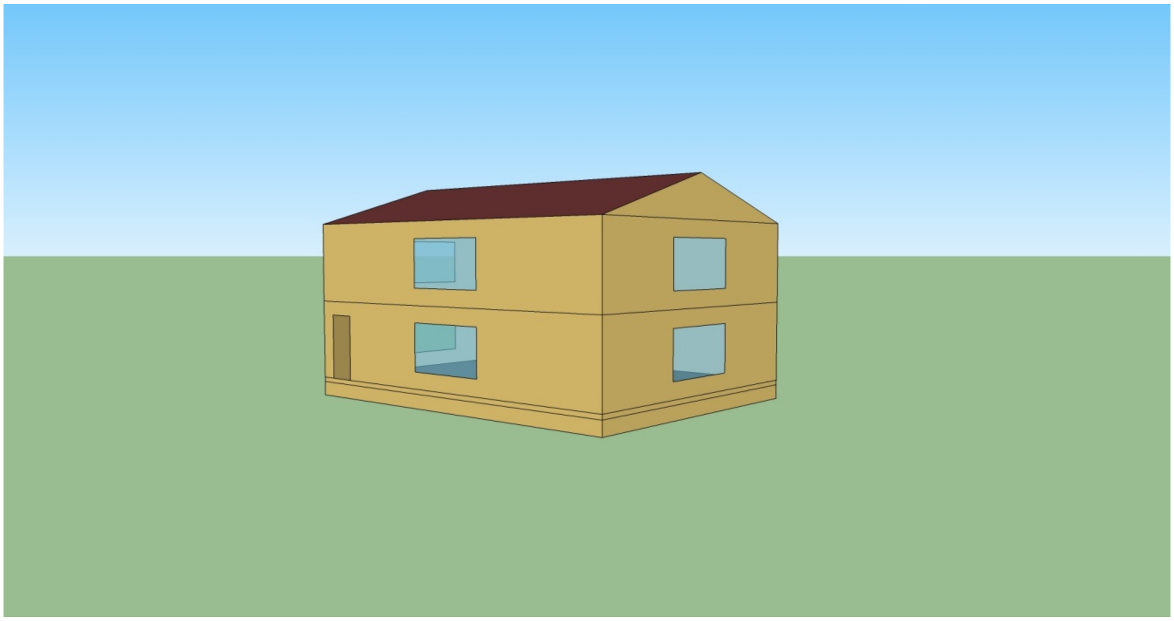

Figure 2.1. Single-Family Prototype

DOE will employ a three-story multifamily prototype having six dwelling units per floor, arranged in two rows with an open breezeway in between. The multifamily prototype characteristics to be used for DOE's analyses are shown in Table 2.2. The heating, cooling, and water-heating system characteristics are the same as for the single-family prototype (each dwelling unit is assumed to have its own separate heating and cooling equipment except when the heating fuel is oil, in which case a centralized oil-fired boiler is assumed). The multifamily prototype is illustrated by the line drawing in Figure 2.2.

Table 2.2. Multifamily Prototype Characteristics

Parameter	Assumption	Notes
Conditioned floor area	1,200 ft^2 per unit, or 21,600 ft^2 total (plus 1,200 ft^2 of conditioned basement on ground-floor units, where applicable)	Characteristics of New Housing, U.S. Census Bureau
Footprint and height	Each unit is 40 ft wide by 30 ft deep, with 8.5-ft-high ceilings. The building footprint is 120 ft by 65 ft.	
Area above unconditioned space	1,200 ft^2 on ground-floor units	Over a vented crawlspace or unconditioned basement
Wall area adjacent to unconditioned space	None	No attached garages or similar
Area below roof/ceilings	1,200 ft^2 on top-floor units	
Perimeter length	370 ft (total for the building), 10 ft of which borders the open breezeway	
Gross wall area	5,100 ft^2 per story, 2,040 ft^2 of which faces the open breezeway (15,300 ft^2 total)	
Window area (relative to gross wall area)	Twenty-three percent of gross exterior wall area, excluding walls facing the interior breezeway (or as required to evaluate glazing-specific code changes)	

Door area	21 ft^2 per unit (378 ft^2 total)	Assumed to open into the breezeway
Internal gains	54,668 Btu/day per unit (984,024 Btu/day total)	2015 IECC, Table R405.5.2(1), assuming two bedrooms per unit. May vary if buildings/units of different size than the standard prototype are analyzed.
Heating system	Natural gas furnace, heat pump, electric furnace, or centralized oil-fired boiler	Efficiency will be based on prevailing federal minimum manufacturing standards.
Cooling system	Central electric air conditioning	Efficiency will be based on prevailing federal minimum manufacturing standards.
Water heating	Same as fuel used for space heating, or as required to evaluate domestic hot water-specific code changes	

Btu = British thermal units.
IECC = International Energy Conservation Code.

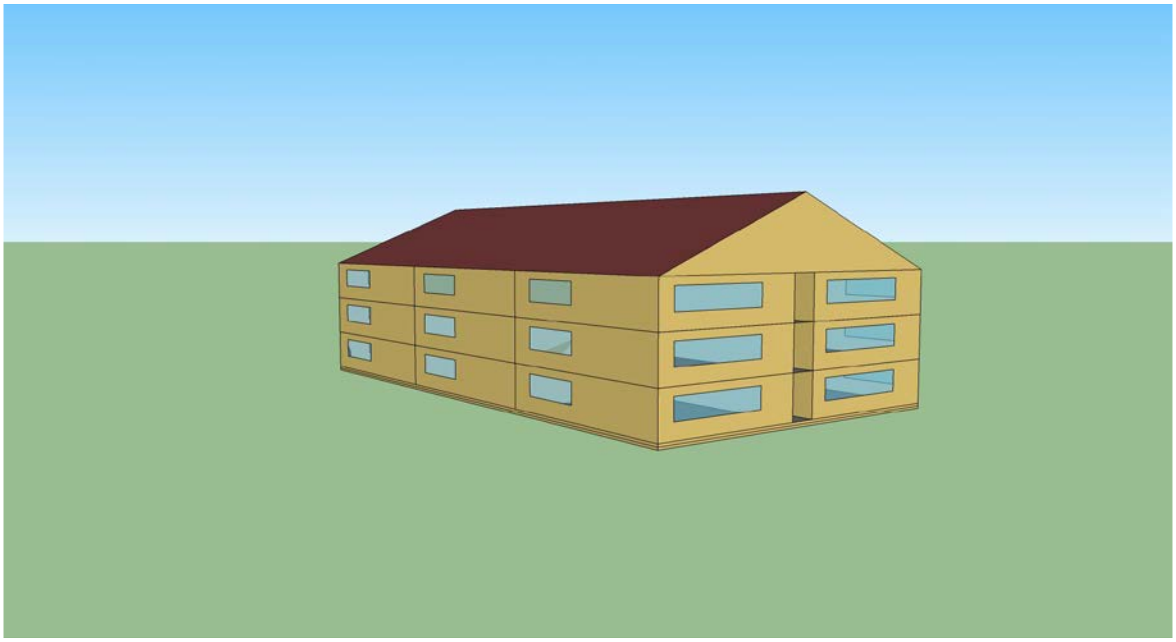

Figure 2.2. Multifamily Prototype

2.1.3 Default Assumptions

Some building components are not addressed by the code and many components may not change from one code to the next. For these components, inputs are identical in both pre- and post-revision simulations. While specific input values for these components are of secondary importance, it is important that they be reasonably typical of the construction types being evaluated. Assumptions and input values for these building components will be set to match shared code requirements (if such exist), shared standard reference design specifications from the codes' performance paths (if such exist), or to best estimates of typical practice. Typical practice assumptions will be taken from various sources, including prototypes and models used by DOE residential programs or other efficiency programs (e.g., Building America, Home Energy Rating System specifications).

2.1.4 Provisions Requiring Special Consideration

New code provisions that expand the code to include previously unaddressed building components may require special treatment. For example, editions of the IECC prior to 2009 had no duct testing requirement and hence analysis requires establishing a meaningful baseline leakage rate against which newer versions of the code can be compared. In these cases, rather than comparing one code to another, a new code must be compared to an unstated prior condition.[4] That prior condition can sometimes be based on the average or typical pre-code level used by builders, but this can sometimes understate the energy savings of the new code requirement. Returning to the example of a new requirement for testing the duct leakage rate, consider Figure 2.3. The curve represents a hypothetical distribution of leakage rates prior to the code's regulation of leakage rates. Even if the new code requirement was set equal to or worse than the pre-change average rate, savings would accrue from houses that would have had higher leakage rates. Data to establish such a pre-code distribution is often unavailable, so DOE intends to evaluate scope expansions on a case-by-case basis to determine the most appropriate way to estimate energy savings given the data available.

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[4] In DOE's proposal to add duct testing requirements to the 2009 IECC, energy savings was approximated based on findings from extant post-occupancy studies of duct leakage rather than by simulation. These studies included:

a) Hales D. 2001. *Washington State Energy Code Duct Leakage Study Report*. WSUCEEP01105, Washington State University Cooperative Extension Energy Program, Olympia, Washington. Available at: http://www.sos.wa.gov/library/docs/wsu/01_105Ductrptfinal_2008_004802.pdf . Accessed April 30, 2012.

b) Hales D, A Gordon, and M Lubliner. 2003. *Duct Leakage in New Washington State Residences: Findings and Conclusions.* KC-2003-1-3, *ASHRAE Transactions* 109(2):393-402.

c) Hammon RW and MP Modera. 1999. "Improving the Efficiency of Air Distribution Systems in New California Homes-Updated Report." Consol. Stockton, California.

d) Uniacke M. 2003. "Pressure-Testing Ductwork." *Journal of Light Construction*.

e) Sherman MH, IS Walker, and CP Wray. 2004. Instrumented Home Energy Rating and Commissioning Technical Reports. P500-04-012-A1**.** California Energy Commission through the Public Interest Energy Research Program, Sacramento, California.

f) Xenergy. 2001. Impact Analysis of the Massachusetts 1998 Residential Energy Code Revisions. Xenergy, Portland, Oregon. Available at: http://www.energycodes.gov/publications/research/documents/codes/Massachusetts_rpt.pdf . Accessed April 30, 2012.

g) Impacts of the 2009 IECC for Residential Buildings at State Level. 2009. Available at http://www.energycodes.gov/publications/techassist/IECC2009_Residential_Nationwide_Analysis.pdf.

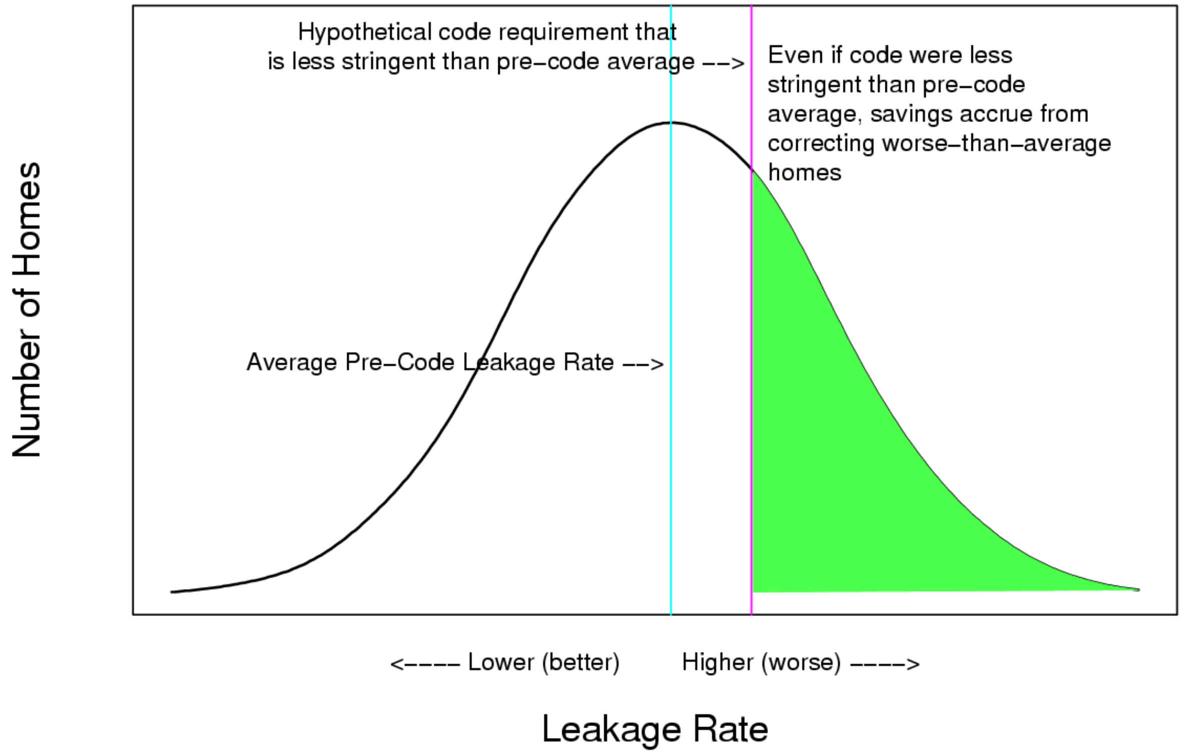

Figure 2.3. Illustration of Energy Savings from a Hypothetical Code Change that Improves the Worst-Performing Homes

3.0 Estimating the Cost Effectiveness of Code Changes

The intent of the DOE cost-effectiveness methodology is to determine whether code changes are economically justified from the perspective of a public policy that balances costs against energy savings over time. The DOE methodology accounts for the benefits of energy-efficient home construction that accrue to homeowners over 30 years. The methodology and assumptions are described in this section.

3.1 Economic Metrics to be Calculated

DOE intends to calculate three metrics in evaluating the economics of code change proposals and in assessing new editions of residential building energy codes:

1. LCC
2. Simple payback period
3. Cash flow

LCC is the primary metric DOE will use to evaluate whether a particular code change is cost effective. The payback period and cash flow analyses provide additional information that DOE believes is helpful to others participating in the code-change processes and to states and jurisdictions considering adoption of new codes. These metrics are discussed further in the following sections.

3.1.1 Life-Cycle Cost

LCC[5] is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified time period. Any code change resulting in a net LCC less than or equal to zero (i.e., monetary benefits exceed costs) will be considered cost effective. The methodology considers only direct costs (and savings) to the consumer. Secondary or societal effects, such as reductions in carbon emissions, or externalities, such as impacts on manufacturers, are not considered. DOE will use LCC for determining the cost effectiveness of code change proposals, and for the code as a whole, as it is the most straightforward approach to achieving the desired balance of first costs and longer-term energy savings.

The key feature of LCC analysis is the summing of costs and benefits over multiple years, which requires cash flows in different years to be adjusted to a common year for comparison. This is done with a *discount rate* that accounts for changes in the value of money over time (i.e., the "time value" of money). Like most LCC implementations, DOE's methodology sums cash flows in year-zero dollars (the present year), which allows the use of standard discounting formulas. Cash flows adjusted to year zero are termed *present values*. The procedure described herein combines concepts from two ASTM International standard practices, E917[6] and E1074.[7] The resultant procedure is both straightforward and

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[5] LCC analysis is sometimes referred to as *net present value* analysis or *engineering economics*, and sometimes expressed in terms of *life-cycle savings*.

[6] ASTM International. "Practice for Measuring Life-Cycle Costs of Buildings and Building Systems." 2010. E917, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. ASTM International, West Conshohocken, Pennsylvania.

comprehensive and is in accord with the methodology recommended and used by the National Institute of Standards and Technology.[8]

Present values can be calculated in either *nominal* or *real* terms. In a nominal analysis, all compounding rates (e.g., discount rate, mortgage interest rate, fuel price escalation rate) include the effect of general inflation, and cash flows in future years are assumed to rise with the general rate of inflation. An exception is mortgage payments, which remain constant from year to year regardless of inflation. In a real analysis, inflation is assumed to be zero, and all compounding rates are adjusted to remove the effect of inflation. The relationship between a nominal rate $R_{nominal}$ and a real rate R_{real} is expressed as a function of the inflation rate $R_{inflation}$:

$$(1 + R_{nominal}) = (1 + R_{real}) \times (1 + R_{inflation}) \qquad (3.1)$$

Consequently:

$$R_{nominal} = (1 + R_{real}) \times \left(1 + R_{inflation}\right) - 1 \qquad (3.2)$$

$$R_{real} = \left[\frac{(1+R_{nominal})}{(1+R_{inflation})}\right] - 1 \qquad (3.3)$$

The two approaches are algebraically equivalent. DOE intends to conduct economic analyses of residential energy codes in nominal terms, because accounting for mortgage cash flows and associated income tax effects is more straightforward. Consumers are generally familiar with nominal rates, because, for example, mortgage interest rates are generally quoted in nominal terms.

The net LCC of a code change is defined formally as the present value (*PV*) of all costs and benefits summed over the period of analysis.[9] Because it is defined in terms of costs, the net LCC of a code change must be zero or negative for the change to be considered cost effective, as shown in Equation 3.4.

$$LCC = PV(Costs) - PV(Benefits) \qquad (3.4)$$

A future cash flow (positive or negative) is brought into the present (i.e., time zero) by assuming a discount rate (R_d or simply d). The discount rate is an annually compounding rate[10] by which future cash flows are discounted in value. It can be thought of as representing the minimum rate of return demanded of the investment in energy-saving measures. It is sometimes referred to as an alternative investment rate and chosen to approximate a homeowner's best alternative investment with risk similar to that of energy efficiency measures. Thus, the present value of a cash flow in year y (CF_y) is defined as:

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[7] ASTM International. "Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems." 2010. E1074, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. ASTM International, West Conshohocken, Pennsylvania.
[8] For a detailed discussion of LCC and related economic evaluation procedures specifically aimed at private sector analyses, see Ruegg and Petersen (Ruegg RT and SR Petersen. 1987. *Comprehensive Guide to Least-Cost Energy Decisions*, NBS Special Publication 709. National Bureau of Standards, Gaithersburg, Maryland).
[9] In this methodology, the term LCC is generally used to mean a *net* life-cycle cost because we are comparing the energy impacts of two scenarios rather than simply summing the total cost of ownership of a single scenario.
[10] The analysis can be done for other compounding periods (e.g., monthly), but for simplicity DOE uses annual periods for the subject analyses.

$$PV = \frac{CF_y}{(1+d)^y} \tag{3.5}$$

The present value of a stream of annual cash flows over the period of analysis, *N* years, is then the sum of all of those discrete cash flows:

$$PV = \sum_{y=0}^{N} \left[\frac{CF_y}{(1+d)^y}\right] \tag{3.6}$$

For an annualized stream of cash flows *A* that is the same from year to year, such as a mortgage payment with a term of *N* years, Equation 3.6 is equivalent to:

$$PV = A \times \left[\frac{(1+d)^N - 1}{d \times (1+d)^N}\right] \tag{3.7}$$

For an annualized stream of cash flows that is escalating with time, such as the energy cost savings (ES), that increases (or decreases) from year to year because of escalations in fuel prices, Equation 3.8 can be used (*e* is the fuel price escalation rate, *N* is the number of years):

$$PV = ES \times \left[\frac{1+\mathrm{e}}{d-\mathrm{e}}\right] \times \left[1 - \left(\frac{1+\mathrm{e}}{1+d}\right)^N\right] \tag{3.8}$$

Or, if the escalation rate *e* is equal to the discount rate *d*:

$$PV = ES \times N \tag{3.9}$$

DOE intends to compute and publish annual cash flow impacts, as well as the net LCC at time zero. Equation 3.6 will generally be preferred to Equations 3.7 and 3.8, because it allows presentation and analysis of all the yearly cash flows during the LCC analysis period. Equations 3.7 and 3.8 are algebraically equivalent to 3.6, and useful when year-by-year cash flows are not needed.

The primary cash flows relevant to LCC analysis of energy code changes are detailed below.

- The *down payment cost* associated with the code changes is the down payment rate (R_{DP}) multiplied by the total cost of the code changes (*C*, or the "first cost") and is incurred at the onset (year zero):

$$down\ payment = R_{DP} \times C \tag{3.10}$$

- On top of the down payment is a *mortgage fee*, which represents the additional cost of obtaining credit due to the additional cost of efficiency measures. It is the cost of the code changes (*C*) multiplied by the mortgage fee rate (R_{MF}). The mortgage fee is not tax deductible. Some mortgages involve other up-front fees used to buy down the mortgage interest rate. These payments, often referred to as "points," are tax deductible because they are essentially prepaid interest on the loan. DOE's methodology assumes that all interest payments are accounted for in the mortgage interest rate, so there are no tax deductible up-front costs. The mortgage fee is calculated as:

$$mortgage\ fee = R_{MF} \times C \times (1 - R_{DP}) \tag{3.11}$$

- *Property tax* occurs every year, beginning with year one and continuing through the analysis period *P*. It represents additional tax paid as a result of efficiency measures giving the home a higher value.

It is the property tax rate (R_{PT}) multiplied by the cost of efficiency measures C, and further adjusted annually by a factor E_H representing the home price escalation rate. This assumes the initial tax appraisal of the house increases directly with the amount of the code-related cost increase, and that the year-to-year tax assessment increases in step with the escalating home price. The property tax cost in year y is calculated as:

$$property\ tax_y = R_{PT} \times C \times (1 + E_H)^y \tag{3.12}$$

- *Energy savings* occur every year, starting at year one and continuing through the analysis period P. They are equal to the modeled energy cost savings at year zero (ES_0), adjusted annually by a fuel price escalation factor E_F. The energy savings in year y are given by:

$$ES_y = ES_0 \times (1 + E_F)^y \tag{3.13}$$

- *Mortgage payments* occur every year throughout the mortgage term T, and are unchanging (i.e., unaffected by inflation). The annual mortgage payment is calculated dividing the additional loan amount by a standard uniform series present worth factor using the mortgage interest rate (R_{MI}) as the discounting factor. The additional loan amount is simply the initial cost of efficiency measures less the down payment. However, because mortgage interest rates are generally quoted as annual rates but used to calculate monthly payments, we calculate annual mortgage payments as 12 times a standard monthly payment. The annual mortgage payment is given by:

$$mortgage\ payment = \frac{(1-R_{DP}) \times C \times 12}{\left[\frac{\left(1+\frac{R_{MI}}{12}\right)^{12T}-1}{\frac{R_{MI}}{12}\times\left(1+\frac{R_{MI}}{12}\right)^{12T}}\right]} \tag{3.14}$$

- *Tax deductions* for mortgage interest payments and property tax payments begin in year one and continue through the end of the analysis period P. They are calculated as the marginal income tax rate (R_{IT}) multiplied by the sum of mortgage interest payments and property tax payments each year. Property tax payments are calculated as shown above. Mortgage interest payments are the mortgage interest rate (R_{MI}) multiplied by the loan balance each year. The loan balance is simply the present value (at year y) of the remaining stream of mortgage payments, discounted at the mortgage interest rate. Thus the tax deduction in year y is given by:

$$tax\ deduction_y = R_{IT} \times \left\{ \begin{matrix} property\ tax_y + \\ mortgage\ payment \times R_{MI} \times \left[\frac{(1+R_{MI})^{T-y+1}-1}{R_{MI}\times(1+R_{MI})^{T-y+1}}\right] \end{matrix} \right\} \tag{3.15}$$

- The methodology accounts for *replacement costs* of efficiency measures that have an expected useful life L less than the analysis period. It is assumed that a failed measure is replaced with an identical measure at the same first cost, escalated per the home price escalation rate (E_H). For a measure m with a service life L that is less than the analysis period P, a replacement cost $RC_{m,y}$ is incurred at the end of any year when the service life expires. That is:

$$RC_{m,y} = \begin{cases} 0, & y \bmod L \neq 0 \\ (1 + E_H)^y \times FC_m, & y \bmod L = 0 \end{cases} \tag{3.16}$$

Where FC_m is the first cost of measure m and "y mod L" refers to the *modulo* operator, which gives the remainder after dividing y by L.

- Finally, there is a *residual value* for efficiency features with remaining useful life at the end of the analysis period. This is related to the replacement costs in that a feature replaced shortly before the end of the analysis period would have a higher residual value than one nearing the end of its service life. At the end of the analysis period *P*, the residual value of each efficiency measure is based on straight-line "depreciation" of its inflated first cost based on the number of years left in its useful life. That is, the residual value for measure *m* (RV_m) is a beneficial cash flow occurring at the end of year *P* and is given by:

$$RV_m = (1 + E_H)^P \times FC_m \times \left(\frac{P \bmod L}{L}\right) \tag{3.17}$$

Each of the cash flow components above is discounted to a time-zero present value and the results summed to compute the net LCC.

3.1.2 Simple Payback Period

The simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in fuel prices, tax effects, measure replacements, resale values, etc. The payback period *P*, which has units of *years*, is defined as the marginal cost of compliance with a new code (*C*), divided by the annual marginal benefit from compliance (ES_0, the energy cost savings in year zero), as shown in Equation 3.18:

$$P = \frac{C}{ES_0} \tag{3.18}$$

The simple payback period is a metric useful for its ease of calculation and understandability. Because it focuses on the two primary characterizations of a code change—cost and energy performance—it allows an assessment of cost effectiveness easy to compare with other investment options and requires a minimum of input data. The simple payback period is used in many contexts, and is written into some state laws governing the adoption of new energy codes. However, because simple payback ignores many of the longer-term factors in the economic performance of an energy-efficiency investment, DOE does not use the payback period as a primary indicator of cost effectiveness for its own decision-making purposes.

3.1.3 Cash Flow Analysis

In the process of calculating LCC, year-by-year cash flows are computed. These can be useful in assessing a code change's impact on consumers and will be shown by DOE for the code changes it analyzes. The cash flow analysis simply shows each year's net cash flow (benefits minus costs) separately (in nominal dollars), including any time-zero cash flows, such as a down payment. Two aspects of cash flow analysis are of particular interest to consumers. First, the net annual cash flow shows how annual cost outlays are compensated by annual energy savings. This value ignores the mortgage down payment and other up-front costs, focusing instead on a new code's impact on consumers' ability to make monthly mortgage payments. Second, the number of years to positive cash flow shows the time required for cumulative energy savings to exceed cumulative costs, including both increased mortgage payments and the down payment and other up-front costs.

3.2 Economic Parameters and Other Assumptions

Calculating the metrics described in Section 3.1 requires defining various economic parameters. Table 3.1 shows the primary parameters of interest and how they apply to the three metrics. The actual current values are presented at the end of this section.

Table 3.1. Economic Parameters for Cost-Effectiveness Metrics

Parameter	Needed For
First costs Fuel prices	Payback Cash flow LCC
Fuel price escalation rates Mortgage parameters Inflation rate Tax rates (property, income) Period of analysis Residual value	Cash flow LCC
Discount rate	LCC

The actual values chosen for these parameters are considered by DOE to be representative of a typical home buyer with a 30-year mortgage. DOE will consult and cite authoritative sources to establish assumptions for each of these financial, economic, and fuel price parameters. Whenever possible, DOE will use sources discussed in the following sections. Where multiple sources for any parameter are identified, DOE will use those deemed best documented and reliable. Most economic parameters vary with time. DOE will periodically review its parameter estimates and update them to account for changing economic conditions, availability of updated data or projections from the selected sources, or identification of better data sources.

First Cost

A key step in assessing the cost effectiveness of a proposed code change or a newly revised code is estimating the first cost of the changed provision(s). The *first cost* of a code change refers to the marginal cost of implementing the change. For DOE's analyses, it refers to the retail cost (the cost to a home buyer) prior to amortizing that cost over multiple years through the home mortgage. It includes the price paid by the home buyer, including materials, labor, overhead, and profit, minus any tax rebates or other incentives generally available to home buyers when the new code takes effect.

DOE has collected energy-efficiency measure cost data from several sources and made them available on a public website "Building Component Cost Community (BC3) database"[11]. For each application of this cost-effectiveness analysis methodology, DOE will use first costs drawn from the BC3 database. Where costs differ among the sources or there are otherwise questions about the currency of any measure data, DOE will choose measure costs based on the specifics of the analysis (e.g., location, time period of interest), by seeking corroborating estimates from other sources (e.g., *RS Means Residential Cost Data*,[12] national home hardware suppliers such as Lowes and The Home Depot), and/or by consulting recent studies by others (DOE's own Building America[13] program, those generated from the ENERGY STAR[14] program, and buildings-oriented research publications such as American Society of Heating, Refrigerating and Air-Conditioning Engineers' [ASHRAE] Transactions).

DOE anticipates that as building energy codes advance and incorporate more energy features, the traditional cost sources may be insufficient for estimating the first costs of code changes. Where new technologies or techniques are involved, current cost data are often unreliable indicators of the long-term costs of such measures after taking into account economies of scale and builder/contractor learning curves. DOE will address such measures on a case-by-case basis, and document any cost adjustments along with the relevant analysis.

Mortgage Parameters

The majority of homes purchased are financed. The 2014 Characteristics of New Housing report from the Census Bureau reports that 91% of new homes were purchased using a loan while only 9% were purchased with cash.[15] Accordingly, DOE calculates cost-effectiveness assuming the home buyer finances the purchase through a 30-year mortgage.

Mortgage Interest Rate(R_{MI})

DOE will use the current rate for each analysis. Currently, Freddie Mac reports that conventional 30-year real estate loans have averaged about 5% since the beginning of 2009 [16](though historical rates have been higher. The Federal Housing Finance Agency reports similar rates[17]. Thus DOE is currently using a mortgage rate of 5%.

Loan Term (T)

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[11] U.S. Department of Energy, Energy Efficiency & Renewable Energy. 2015. Building Component Cost Community (BC3) Database. Accessed August, 2015, at http://bc3.pnnl.gov

[12] RSMeans Reed Construction Data. 2015. Accessed August, 2015 at http://www.rsmeans.com/

[13] U.S. Department of Energy, Energy Efficiency & Renewable Energy. 2015. Building America –Resources for Energy Efficient Homes. Accessed August, 2015, at http://www.buildingamerica.gov/.

[14] Energy Star. 2015. News Room. Available online at http://www.energystar.gov/

[15] U.S. Census Bureau. 2015. Characteristics of New Single-Family Houses Sold – Financing. Accessed August, 2015 at https://www.census.gov/construction/chars/sold.html

[16] Freddie Mac. 2015. 30-Year Fixed-Rate Mortgages Since 1971. Accessed August, 2015, at http://www.freddiemac.com/pmms/pmms30.htm.

[17] Federal Housing Finance Agency. Periodic Summary Table. Accessed August, 2015, at http://www.fhfa.gov/Default.aspx?Page=252.

For real estate loans, 30 years is by far the most common term and is the value DOE uses in its analyses. According to Table C-14A-OO of the 2013 American Housing Survey (U.S. Census), approximately 55% of all home loans have a term between 28 and 32 years, with 30 being the median.

Down Payment (R_{DP})

The 2013 American Housing Survey reports a wide range of down payment amounts for loans for new homes (see Table 3.2).[18] DOE assumes a down payment of 10%. Among the possible rates, this is probably most representative of first-time home buyers who have little significant equity to bring forward from a previous home. It is among the more common ranges for down payments (13.6% of all mortgages have down payments in the 6-10% range).

Table 3.2. Down Payment - 2013 American Housing Survey, Table 3-14

Percent of Purchase Price	Percentage of Homes
No down payment	10.42
Less than 3 percent	7.57
3-5 percent	11.39
6-10 percent	14.06
11-15 percent	5.59
16-20 percent	12.52
21-40 percent	11.76
41-99 percent	6.53
Bought outright	9.68
Not reported	10.47

Points and Loan Fees (R_{MF})

Points represent an up-front payment to buy down the mortgage interest rate and are tax deductible. DOE assumes all interest is accounted for by the mortgage rate and so points are taken to be zero. The loan fee is likewise paid up front in addition to the down payment and varies from loan to loan. DOE assumes the loan fee to be 0.6% of the mortgage amount, based on recent data from Freddie Mac Weekly Primary Mortgage Market Survey[19]

Discount Rate (R_d)

The purpose of the discount rate is to reflect the time value of money. Because DOE's economic perspective is that of a homeowner, that time value is determined primarily by the owner's best alternative investment at similar risk to the energy features being considered—in this case a typical homeowner who holds a home throughout a 30-year mortgage term. DOE sets the discount rate equal to

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[18] 2013 American Housing Survey. 2015. Accessed August, 2015 at http://www.census.gov/programs-surveys/ahs/data/2013/national-summary-report-and-tables---ahs-2013.html
[19] Freddie Mac. 2015. Weekly Primary Mortgage Market Survey® (PMMS®). Accessed August, 2015 at http://www.freddiemac.com/pmms/.

the mortgage interest rate in nominal terms. Because mortgage prepayment is an investment available to consumers who purchase homes using financing, the mortgage interest rate is a reasonable estimate of a consumer's alternative investment rate.

Period of Analysis (*P*)

DOE's economic analysis is intended to examine the costs and benefits impacting all the consumers who live in the house. Energy-efficiency features generally last longer than the average length of home ownership, so a longer analysis period is used. Assuming a single owner keeps the house throughout the analysis period accounts for long-term energy benefits without requiring complex accounting for resale values at home turnover.

DOE uses a 30-year period of analysis to capture long-term energy savings, and to match the typical mortgage term. Although 30 years is less than the overall life of the home, some efficiency measures, equipment in particular, require replacement during that period. It will be assumed that replacements are of equivalent efficiency and cost. The impact of the selection of any particular analysis term is ameliorated by the effect of the discount rate in aligning future costs and benefits with present values.

Property Tax Rate (R_{PT})

Property taxes vary widely within and among states. The median property tax rate reported by the 2013[20] American Housing Survey (U.S. Census Bureau 2013, Table C-10-OO) for all homes is $11 per $1,000 in home value. Therefore, for purposes of code analysis, DOE assumes a property tax rate of 1.1%. For state-level analyses, state-specific rates will be used, as appropriate.

Income Tax Rate (R_{IT})

The marginal income tax rate paid by the homeowner determines the value of the mortgage tax deduction. The 2009 American Housing Survey on "income characteristics" reports a median income of $72,000 for purchasers of new homes (U.S. Census Bureau 2013, Table C-09-AO). The Internal Revenue Service Statistics of Income Tax Stats, Table 2.1 for 2008 (latest year available) reported that most tax payers in this income bracket itemize deductions (e.g., over 73% in this bracket took a deduction for cash contributions).[21] DOE accounts for income tax deductions for mortgage interest. A family earning $72,000 in 2015, with a married-filing-jointly filing status, would have a marginal tax rate of 15%, which is DOE's current assumption. Where state income taxes apply, rates will be taken from state sources or collections of state data, such as provided by the Federation of Tax Administrators.[22]

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[20] The 2007 survey used as financial characteristics data is not available in the 2009 Survey.
[21] Internal Revenue Service. 2012. Tax Statistics - Produced by the Statistics of Income Division and Other Areas of the Internal Revenue Service. Accessed April 27, 2012 at http://www.irs.gov/taxstats/index.html (last updated April 10, 2012).
[22] Federation of Tax Administrators. Accessed August, 2015, at www.taxadmin.org.

Inflation Rate (R_{INF})

The inflation rate R_{INF} is necessary only to give proper scale to the mortgage payments so that interest fractions can be estimated for tax deduction purposes. It does not affect the present values of cash flows, because all other rates are expressed in nominal terms (i.e., are already adjusted to match the inflation rate). The assumed inflation rate must be chosen to match the assumed mortgage interest rate (i.e., be estimated from a comparable time period). Estimates of the annual inflation rate are taken from the most recent Consumer Price Index (CPI) data published by the Bureau of Labor Statistics[23] At the time of writing, the most recent annualized CPI was reported to be 1.6%.

Residual Value (*RV*)

The residual value of energy features is the value assumed to be returned to the home buyer upon sale of the home (after 30 years). As previously shown, it is calculated assuming straight-line depreciation of each measure's value against the useful life of that measure.

Home Price Escalation Rate (E_H)

DOE assumes that home prices have a real escalation rate of 0%. That is, the rate of home value appreciation is assumed to equal the general rate of inflation. While many homes do experience non-zero increases in value over time, the factors that influence future home prices (location, style, availability of land, etc.) are too varied and situation-specific to warrant direct accounting in this methodology.

Resale Value Fraction (R_R)

DOE will assume that energy-efficiency measures have a residual value calculated from strait-line depreciation based on an assumed useful life. Most measures are assumed to last for the life of the home, which is assumed to be 60 years. Measures that need replacement at some point during the 30-year analysis period will have a residual value based on the remaining life per Equation 3.17.

Fuel Prices

Fuel prices are needed to determine the energy cost savings from improved energy efficiency. Both current fuel prices and fuel price escalation rates are needed to establish estimated fuel prices in future years.

DOE will use the most recently available national average residential fuel prices from the DOE Energy Information Administration. If fuel prices from the most recent year(s) are deemed unusually high or low, DOE may consider using a longer-term average of past fuel prices. However, reported fuel price escalation rates (see below) may be tied to specific recent-year prices, so departures from the recent-year prices will be approached with caution. For air conditioning, fuel prices from the summer will be used, and for space heating, winter prices will be used. Fuel price escalation rates will be obtained from the most recent Annual Energy Outlook to account for projected changes in energy prices. Table 3.3 summarizes the values discussed above.

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[23] Bureau of Labor Statistics. Consumer Price Indexes. Accessed August, 2015, at http://www.bls.gov/cpi/.

Table 3.3. Summary of Current Economic Parameter Estimates

Parameter	Symbol	Current Estimate
Mortgage Interest Rate	I	5%
Loan Term	M_L	30 years
Down Payment Rate	R_D	10% of home price
Points and Loan Fees	R_M	0.6% (non-deductible)
Discount Rate	D	5% (equal to Mortgage Interest Rate)
Period of Analysis	L	30 years
Property Tax Rate	R_P	1.1% of home price/value
Income Tax Rate	R_I	15% federal, state values vary
Home Price Escalation Rate	E_H	Equal to Inflation Rate
Inflation Rate	R_{INF}	1.6% annual
Fuel Prices and Escalation Rates		Latest national average prices based on current Energy Information Administration data and projections[24]; price escalation rates taken from latest Annual Energy Outlook.

[24] U.S. Department of Energy. 2015a. *Electric Power Monthly*. DOE/EIA-0226, Washington, D.C.
U.S. Department of Energy. 2015b. *Natural Gas Monthly*. DOE/EIA-0130, Washington, D.C.

4.0 Aggregating Energy and Economic Results

DOE will report its energy and cost analysis results at different levels:

1. State—Energy and cost-effectiveness assessments of a new code are often needed by states considering adoption of the code. For such purposes, DOE will report energy savings and cost effectiveness results aggregated to the individual state level and by climate zone within each state. At this level, DOE will report all major analysis results, including energy savings, net LCC, annual cash flows, and simple payback periods.
2. Climate zone—DOE will aggregate its energy and economic analysis results to the climate zone level. The IECC's requirements vary by climate zone, so this is the natural aggregation for evaluation of proposed changes. At this level, DOE will report energy savings, net LCCs, and annual cash flows.
3. National—When assessing the overall impact of new codes, DOE will report results aggregated to a national average. At this level, only energy savings will be reported.

Aggregating to state, zone, and national levels involves a weighted averaging of results across several variables, including building type, foundation type, heating system/fuel type, and housing starts by climate location. Unless otherwise noted, the weighted averaging scheme assumes that those variables are independent, which means the weighting factors can be applied in arbitrary order. However, to facilitate reporting at the levels above, the weighting scheme is applied to climate location last. That is, energy simulation results (or computed LCCs) for a given location are first averaged across the foundation type, system type, and building type variables, then the weighted location-specific results are aggregated to the desired geographical regions. Because location weights are based on housing starts (permits) and those data differ between single-family and multifamily, the building-type weighting occurs after the foundation and system type weightings.

4.1 Aggregation across Foundation Types

Residential buildings typically have one of three foundation types: basement, crawlspace, or slab-on-grade. The 2010 Census data indicates that 52% of new single-family homes have slab-on-grade, 30% have a basement, and 18% have a crawlspace. For DOE's analyses, basements are divided into two categories: heated and unheated. Therefore, four foundation configurations are examined:

1. Crawlspace
2. Slab on grade
3. Heated basement
4. Unheated basement

National Association of Home Builders (NAHB) survey data provide a breakdown on foundation types in new housing by nine Census divisions. However, there are considerable differences in the use of foundation types within these Census divisions. As a primary example, the NAHB data indicate that homes in the South Atlantic division have a significant number of basements. However, it is well known that basements are very rare in warm/wet climates, like Florida, and most homes with basements are likely in the relatively colder states in the South Atlantic division, such as West Virginia and Maryland.

Therefore, data from DOE’s 2009 Residential Energy Consumption Survey (RECS) will be used to establish foundation shares. The advantage of the RECS database is that it provides data for 27 regions, with each region consisting of either a single state or a combination of a few states. The disadvantage of RECS is that it covers existing housing of all vintages, including both older and newer buildings. However, the RECS data suggest the type of foundation used by region has been relatively stable over time.

Table 4.1 shows the assumptions about foundation type used in the aggregation of results. These percentages will be used for both single-family and multifamily.

Table 4.1. Foundation Type Shares (percent) by State

State	Slab	Heated Basement	Unheated Basement	Crawlspace
Connecticut, Rhode Island, Vermont, New Hampshire, Maine	16.8	23.8	45.5	13.9
Massachusetts	15.8	21.2	51.9	11.2
New York	20.4	25.9	41.7	12
New Jersey	26.9	18.3	30.6	24.2
Pennsylvania	28.9	24.6	32.8	13.7
Illinois	22.5	39.4	14.1	24.1
Ohio and Indiana	27.5	29.9	21.2	21.4
Michigan	15.7	36.2	27.3	20.8
Wisconsin	14.9	45	29.7	10.4
Minnesota, Iowa, North Dakota, South Dakota	22.1	46.9	15.5	15.5
Kansas and Nebraska	29.8	32.7	14.9	22.5
Missouri	24.8	36.4	20.8	17.9
Virginia	33.2	24.2	9.8	32.8
Maryland, Delaware, and West Virginia	28	30.7	18.3	23
Georgia	57.1	6.6	9.7	26.7
North Carolina and South Carolina	38.7	2.3	4.1	54.9
Florida	87.7	0	0.4	11.8
Alabama, Mississippi, Kentucky	44.1	8.6	10.6	36.7
Tennessee	35.3	7.2	9	48.4
Arkansas, Louisiana, and Oklahoma	66.9	0.6	2.9	29.7
Texas	79.6	0.3	0.4	19.8
Colorado	30.7	28.2	9.9	31.2
Utah, Wyoming, Montana, Idaho	26.7	36.6	11	25.6
Arizona	90.7	0.6	3.1	5.6
Nevada and New Mexico	86.1	2.5	0.8	10.7
California	59	1.2	4.9	34.9
Washington, Oregon, Alaska, Hawaii	37	8.9	3.1	51

4.2 Aggregation across Heating Equipment and Fuel Types

Residential buildings have a variety of different of space heating equipment types. According to U.S. Census data for new construction in 2014, the most common types of heating fuels in homes are natural gas (including liquefied petroleum gas) with a 60% share, electricity with a 38% share, and oil with a 1% share (Census Characteristics of New Housing[25] Heating systems types are 57% warm-air furnace, 39% heat pump, and 2% hot water or steam. Eighty-two percent of the heat pumps are electric, 18% are gas.

Four combinations of HVAC equipment and fuel are examined:

1. Natural gas with a forced air furnace
2. Liquefied petroleum gas/propane with a forced air furnace
3. Electric resistance with a forced air furnace
4. Electric heat pump with forced air distribution

Central electric air conditioning is assumed for all geographic locations and all four heating types. According to Census data, 91% of single-family homes and 98% of new multifamily units built in 2014 had central air conditioning installed [26]

Heating system shares used in DOE's analyses are taken from NAHB survey data (NAHB 2009). The NAHB data provide more detail than the Census data (9 regions compared to 4 regions for the Census data). NAHB surveyed 1,400 homebuilders throughout the United States. The percent shares by heating type for new construction in each Census division are shown in Table 4.2 and Table 4.3.

Table 4.2. Heating System Shares by Census Division, Single Family (percent)

Census Division	Electric Heat Pump	Gas Heating	Oil Heating	Electric Furnace
New England	10.8	57	31.1	1.1
Middle Atlantic	24.5	69.2	4.6	1.7
East North Central	22.5	76.2	0.5	0.7
West North Central	39.6	56.7	0.2	3.4
South Atlantic	78.9	19	0.1	2
East South Central	68.9	28.9	0	2.1
West South Central	37.5	48.1	0	14.5
Mountain	19.4	77.8	0.2	2.6
Pacific	34	62.9	0.2	2.9

[25] United States Census Bureau. Characteristics of New Single-Family Houses Completed. Accessed April 27, 2012 at http://www.census.gov/construction/chars/completed.html.
[26] United States Census Bureau. Characteristics of Units in New Multifamily Buildings Completed. Accessed April 27, 2012 at http://www.census.gov/construction/chars/mfu.html.

Table 4.3. Heating System Shares by Census Division, Multifamily (percent)

Census Division	Electric Heat Pump	Gas Heating	Oil Heating	Electric Furnace
New England	3	66	30.4	0.7
Middle Atlantic	39.5	49.6	6.1	4.9
East North Central	3.3	96.5	0.1	0.1
West North Central	24.8	68	3	4.3
South Atlantic	74.9	24.2	0	1.1
East South Central	94.1	1.8	0	4.1
West South Central	6.9	10.1	52.9[27]	30.2
Mountain	2.8	97.2	0	0
Pacific	14.9	84.2	0.2	0.8

4.3 Aggregation across Building Type (Single-family and Multifamily) and Climate Zone

To facilitate climate-specific energy estimates, DOE will be using a number of weather locations that give reasonable climate coverage at both the climate-zone and state level. One weather location per climate zone in each state is used, including all unique combinations of the zone (temperature-oriented zone designation in the IECC), moisture regime (moist, dry, marine), and warm-humid designation (equivalent to ASHRAE's definition of warm-humid climates). This results in 119 weather locations to be used in the DOE analyses.

Census building permit data at the county level for 2010[28] will be used to estimate single-family and multifamily shares and to give appropriate weight to each climate location within a state and/or larger code zone.

4.3.1 Estimate of Low-Rise Multifamily Construction

The IECC's residential provisions limit multifamily buildings to structures that are three stories or less above grade. High-rise multifamily buildings are considered commercial buildings within the IECC and are not considered in this analysis. As building permit data do not differentiate high-rise from low-rise, Census data (Characteristics of New Housing[29]), will be used to estimate the number of housing units in structures with three stories or less. These data indicate that recent construction trends have favored high-rise multifamily buildings. In the late 1990s, less than 10% of new multifamily dwelling units were in buildings of four or more stories. In new buildings in 2014, 46% of multifamily units were in buildings of four or more stories. Therefore, a 5-year average of the Census data (2010-2014) was used to estimate the proportion of multifamily units that are in low-rise buildings. Table 4.4 shows the

[27] DOE believes there is an error in the source table resulting in a large overstatement in Oil Heating use in the West South Central region. The value, 52.9%, is set to zero and the shares for the other fuel/equipment types are renormalized to sum to 100% for purposes of DOE's analyses.
[28] United States Census Bureau. Building Permits. Accessed August, 2015, at http://censtats.census.gov/bldg/bldgprmt.shtml.
[29] United States Census Bureau. Characteristics of Units in New Multifamily Buildings Completed. Accessed August, 2015, at http://www.census.gov/construction/chars/mfu.html.

percentage of building permits that are assumed to fall under the scope of residential buildings in the IECC. These estimates are assumed to hold for each state in the specified region.

Table 4.4. Proportion of Multifamily Dwelling Units with Three or Fewer Stories

Census Region	Percentage of multifamily dwelling units that are three stories or less
Northeast	33
Midwest	74
South	68
West	52

4.3.2 State-Level Aggregations

Forty-one of the 50 U.S. states contain more than one IECC climate zone within their borders. To determine average impacts of the IECC within each state, the share of residential construction within each climate zone must be identified for states containing more than one zone. Census building permit data at the county level for 2010 will be used to determine these shares.[30]

4.3.3 Representative Weather Locations

Table 4.5 shows the single-family and multifamily building permit data by climate zone for each state, along with the weather location used to represent the associated climate zone. The EnergyPlus building energy simulations are run using the latest Typical Meteorological Year weather files (TMY3).[31] There are 1,020 locations nationwide with TMY3 weather data, including Guam, Puerto Rico, and the U.S. Virgin Islands. Nonetheless, there are a few state/zone combinations that do not contain a TMY3 weather file. In these cases, a best representative TMY3 data location outside the state is chosen.

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[30] United States Census Bureau. Building Permits. Accessed August, 2015, at http://censtats.census.gov/bldg/bldgprmt.shtml.

[31] National Solar Radiation Data Base. 1991-2005 Update: Typical Meteorological Year 3. Accessed August, 2015, at http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 4.5. Housing Permits and Weather Data by Climate Zone in Each State

State	Climate Zone[32]	TMY3 Location	Single-Family Permits	Multifamily Permits
Alabama	2A	Mobile	1577	94
Alabama	3A	Montgomery	5531	764
Alabama	3A,WH	Birmingham	1594	798
Alaska	7	Anchorage	601	41
Alaska	8	Fairbanks	65	0
Arizona	2B	Phoenix	9409	719
Arizona	3B	Kingman	696	28
Arizona	4B	Prescott	307	58
Arizona	5B	Flagstaff	343	88
Arkansas	3A	Little Rock	3454	1512
Arkansas	3A,WH	Shreveport	51	5
Arkansas	4A	Springfield	1143	119
California	2B	Tucson	102	0
California	3B	Los Angeles	21167	6513
California	3C	San Francisco	3585	3416
California	4B	Sacramento	384	3
California	4C	Arcata	196	13
California	5B	Reno	233	21
California	6B	Eagle	26	0
Colorado	4B	Trinidad	23	1
Colorado	5B	Colorado Springs	7760	1514
Colorado	6B	Eagle	462	8
Colorado	7	Gunnison	545	26
Connecticut	5A	Hartford	2632	569
Delaware	4A	Wilmington	2673	258
District of Columbia	4A	Baltimore	177	364
Florida	1A	Miami	2045	1680
Florida	2A	Tampa	27995	3909
Georgia	2A	Savannah	2915	501
Georgia	3A	Atlanta	9245	931
Georgia	3A,WH	Macon	1487	133
Georgia	4A	Chattanooga	1132	44
Hawaii	1A,WH,T	Honolulu	1432	515
Hawaii	1A,WH,SC	Honolulu	771	0
Idaho	5B	Boise	2669	154

[32] The suffixes A, B, and C represent moisture regimes moist, dry, and marine, respectively. “WH” indicates the zone/regime is a warm humid location. “T” indicates the location is in the Tropical zone. “SC” indicates the location is in the Tropical zone and applies to special provisions for homes that are semi-conditioned and meet other special conditions required for the 2015 IECC’s alternative Tropical zone requirements.

State	Climate Zone[32]	TMY3 Location	Single-Family Permits	Multifamily Permits
Idaho	6B	Pocatello	899	169
Illinois	4A	St Louis	1736	538
Illinois	5A	Peoria	5888	2757
Indiana	4A	Evansville	1924	188
Indiana	5A	Indianapolis	7849	2135
Iowa	5A	Des Moines	4956	1100
Iowa	6A	Mason City	996	62
Kansas	4A	Topeka	3926	796
Kansas	5A	Goodland	48	22
Kentucky	4A	Lexington	5983	1296
Louisiana	2A	Baton Rouge	7723	481
Louisiana	3A	Monroe	20	1
Louisiana	3A,WH	Shreveport	2467	251
Maine	6A	Portland	2636	89
Maine	7	Caribou	75	8
Maryland	4A	Baltimore	8394	2227
Maryland	5A	Harrisburg	95	0
Massachusetts	5A	Boston	5839	1417
Michigan	5A	Lansing	6041	830
Michigan	6A	Alpena	1426	84
Michigan	7	Sault Ste Marie	236	12
Minnesota	6A	Minneapolis-St Paul	5440	1839
Minnesota	7	Duluth	1613	117
Mississippi	2A	Mobile	1765	351
Mississippi	3A	Jackson	1769	91
Mississippi	3A,WH	Tupelo	893	96
Missouri	4A	St. Louis	6660	1922
Missouri	5A	Kirksville	241	42
Montana	6B	Helena	1322	387
Nebraska	5B	Omaha	3779	1139
Nevada	3B	Las Vegas	4623	471
Nevada	5B	Reno	738	128
New Hampshire	5A	Manchester	1146	213
New Hampshire	6A	Concord	744	128
New Jersey	4A	Newark	5024	1873
New Jersey	5A	Allentown	2354	824
New Mexico	3B	Lubbock	953	130
New Mexico	4B	Albuquerque	1282	115
New Mexico	5B	Flagstaff	927	46
New York	4A	New York City	1810	2964
New York	5A	Albany	5702	987
New York	6A	Binghamton	2447	257
North Carolina	3A	Wilmington	9552	2358

State	Climate Zone[32]	TMY3 Location	Single-Family Permits	Multifamily Permits
North Carolina	3A,WH	Charlotte	3657	373
North Carolina	4A	Raleigh-Durham	12419	2263
North Carolina	5A	Elkins WV	419	80
North Dakota	6A	Bismarck	789	191
North Dakota	7	Minot	1295	1037
Ohio	4A	Cincinnati	953	213
Ohio	5A	Columbus	9650	1968
Oklahoma	3A	Oklahoma City	6864	824
Oklahoma	4B	Amarillo	2	0
Oregon	4C	Portland	4435	852
Oregon	5	Redmond	741	36
Pennsylvania	4B	Philadelphia	3821	540
Pennsylvania	5A	Harrisburg	12472	710
Pennsylvania	6A	Bradford	593	0
Rhode Island	5A	Providence	727	91
South Carolina	3A	Charleston	7979	574
South Carolina	3A,WH	Columbia	4712	287
South Dakota	5A	Sioux City	171	28
South Dakota	6A	Pierre	2015	505
Tennessee	3A	Memphis	1463	576
Tennessee	4A	Nashville	10167	2559
Texas	2B	Houston	44064	7604
Texas	2A	San Antonio	870	56
Texas	3B	Fort Worth	314	234
Texas	3A	Wichita Falls	15908	3887
Texas	3A,WH	El Paso	5181	1842
Texas	4B	Amarillo	636	280
Utah	3B	Saint George	873	11
Utah	5B	Salt Lake City	5084	857
Utah	6B	Vernal	926	398
Vermont	6A	Burlington	980	148
Virginia	4A	Richmond	13820	1948
Washington	4C	Seattle	10550	2464
Washington	5B	Spokane	3889	845
Washington	6B	Kalispell	263	3
West Virginia	4A	Charleston	1139	150
West Virginia	5A	Elkins	657	237
Wisconsin	6A	Madison	6735	2216
Wisconsin	7	Duluth	952	15
Wyoming	5B	Scottsbluff	18	4
Wyoming	6B	Cheyenne	1366	388
Wyoming	7	Jackson Hole	162	24

4.3.4 Representative Weather Locations for Abbreviated Analyses

When conducting analyses at the national and climate zone level (i.e., not requiring state-level aggregations of results) or when conducting exploratory or iterative analyses, DOE may use an abbreviated set of climate locations. The abbreviated set, designed to cover all climate zones, moisture regimes, and other climate designations by which requirements vary in the IECC, includes 17 distinct locations,[1] as shown in Table 4.6**.** . Permits data used for aggregation weights are developed by summing the weights from Table 4.5 for all locations in the same climate zone/regime.

Table 4.6. Housing Permits and Weather Data by Climate Zone in Abbreviated Climate Locations

Climate Zone[2]	TMY3 Location	Single-Family Permits	Multifamily Permits
1A	Miami	2045	1680
1A,T	Honolulu	1432	515
1A,SC	Honolulu	771	0
2A	Houston	86114	12953
2B	Phoenix	10383	775
3A	Memphis	77016	13712
3B	El Paso	33508	9004
3C	San Francisco	3585	3416
4A	Baltimore	82854	20280
4B	Albuquerque	2637	457
4C	Salem	15181	3332
5A	Chicago	70635	15160
5B	Boise	22396	3693
6A	Burlington	24784	5522
6B	Helena	5259	1352
7	Duluth	5475	1281
8	Fairbanks	65	0

[1] There are actually 16 locations with Honolulu being used twice, once each for normal and semi-conditioned homes in the Tropical climate zone.

[2] The suffixes A, B, and C represent moisture regimes moist, dry, and marine, respectively. “T” indicates the location is in the Tropical zone. “SC” indicates the location is in the Tropical zone and applies to special provisions for homes that are semi-conditioned and meet other special conditions required for the 2015 IECC’s alternative Tropical zone requirements.

5.0 Conclusion

The U.S. Department of Energy (DOE) established this methodology to document the process for evaluating the energy and economic performance of residential energy codes. DOE's measure of cost-effectiveness balances longer-term energy savings against additions to initial costs through a life-cycle cost perspective. As DOE participates in code development processes, the method serves to ensure DOE proposals are both energy efficient and cost-effective. In addition, DOE will use this approach to evaluate recently published codes, which will help states and local jurisdictions better understand the impacts of updating residential energy codes.

The U.S. Department of Energy's Building Energy Codes Program is an information resource on national model energy codes. We work with other government agencies, state and local jurisdictions, national code organizations, and industry to promote stronger building energy codes and help states adopt, implement, and enforce those codes.

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APPENDIX H

Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code

Prepared by Matthew Tyler

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December 12, 2022

MEMORANDUM

Date:	**12/12/2022**		
To:	**North Carolina Building Code Council**	Information Release #	**PNNL-SA-180329**
From:	**Matthew Tyler**		
Subject:	**Cost-Effectiveness of Proposed 2024 North Carolina Energy Conservation Code**		

Moving to the proposed 2024 North Carolina Energy Conservation Code from the 2018 North Carolina Energy Conservation Code is expected to be cost-effective for North Carolina. This assessment of cost-effectiveness is based on expected changes in construction cost relative to energy cost savings. The analysis is based on six building prototypes[1] and three of the 16 climate zones in the United States.

Climate zones are defined in ASHRAE Standard 169, with the hottest being climate zone 0 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating moist or humid, B indicating dry, and C indicating marine. Most of North Carolina is in climate zone 3A, the Blue Ridge Mountains are in climate zone 4A, and a few counties in the northwest corner are in climate zone 5A.

The analysis included the following six building prototypes: small office, large office, standalone retail, primary school, small hotel, and mid-rise apartment.

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes. Net LCC savings is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The costs include initial equipment and construction costs, maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective, which is the case here.

Two LCC scenarios[2] are analyzed with the inputs shown in Table 1 and the differences are outlined here:

- Scenario 1: represents publicly-owned buildings, considers initial costs, energy costs, maintenance costs, and replacement costs without borrowing or taxes. These LCC results per square foot are shown in Table 2 by building type and climate zone.

[1] https://www.energycodes.gov/prototype-building-models#Commercial
[2] https://www.energycodes.gov/methodology

- Scenario 2: represents privately-owned buildings, considers initial costs, energy costs, maintenance costs, replacement costs, borrowing costs (financing of the incremental first costs), and tax impacts (such as mortgage interest and depreciation deductions using corporate tax rates). These LCC results per square foot are shown in Table 3 by building type and climate zone.

The energy prices used in the analysis are:

- Electricity price: $0.0877/kWh
- Natural gas price: $0.8800/therm

These prices are the state average commercial energy costs. This is a weighted average by monthly retail sales of electricity and natural gas for commercial buildings in North Carolina. The prices and sales data are from the United States Energy Information Administration (EIA) *Electricity Power Monthly* and *Natural Gas Monthly.*[3,4]

Table 4 below shows the economic impact of upgrading to the 2024 Energy Conservation Code by building type in terms of the annual energy cost savings in dollars per square foot. Table 5 shows the additional construction cost per square foot required by the additional energy code requirements.

The added construction cost is negative for some building types, which represents a reduction in first costs and a savings that is included in the net LCC savings. This is due to the following:

- Fewer light fixtures are required when the allowed lighting power is reduced. Also changes from fluorescent to LED technology results in reduced lighting costs in many cases and longer lamp lives, requiring fewer lamp replacements.
- Smaller heating, ventilating, and air-conditioning (HVAC) equipment sizes can result from the lowering of heating and cooling loads due to other efficiency measures, such as better envelope. For example, the 2024 Energy Conservation Code has more stringent envelope and fenestration U-factors. This results in smaller equipment and distribution systems, resulting in a negative first cost.

The state averages by building type and climate zone shown in Table 2 through Table 5 are weighted averages based on weightings shown in Table 6. These weighting factors are based on the floor area of new construction and major renovations for the six analyzed building prototypes.

Again, when net LCC is positive, the updated code edition is considered cost-effective, which is the case for all analyzed building types in Scenarios 1 and 2.

[3] https://www.eia.gov/electricity/monthly/
[4] https://www.eia.gov/naturalgas/monthly/

Table 1. Economic Analysis Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period – Years	30	30
Nominal Discount Rate	3.10%	5.25%
Real Discount Rate	3.00%	3.34%
Inflation	0.10%	1.85%
Electricity Price, per kWh	$0.0877	$0.0877
Natural Gas Price, per therm	$0.8800	$0.8800
Energy Price Escalation, uniform present value factors	Electric 19.17, Gas 23.45	Electric 17.37, Gas 21.25
Loan Interest Rate	NA	5.25%
Federal Corporate Tax Rate	NA	21.00%
State Corporate Tax Rate	NA	2.50%

Table 2. Net LCC Savings, Scenario 1 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$4.36	$5.33	$6.87	$6.82	$15.68	$7.39	$6.84
4A	$4.73	$5.92	$6.08	$7.12	$15.45	$6.44	$6.75
5A	$4.08	$6.40	$6.28	$4.93	$15.07	$3.36	$5.82
State Average	$4.38	$5.33	$6.79	$6.82	$15.64	$7.32	**$6.83**

Table 3. Net LCC Savings, Scenario 2 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$4.07	$4.66	$6.14	$5.92	$14.91	$6.66	$6.14
4A	$4.38	$5.14	$5.42	$6.21	$14.70	$5.85	$6.11
5A	$3.84	$5.56	$5.59	$4.38	$14.35	$3.04	$5.24
State Average	$4.09	$4.66	$6.07	$5.93	$14.88	$6.60	**$6.13**

Table 4. Annual Energy Cost Savings ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.176	$0.180	$0.242	$0.170	$0.240	$0.267	$0.227
4A	$0.184	$0.180	$0.204	$0.191	$0.227	$0.263	$0.220
5A	$0.181	$0.197	$0.215	$0.208	$0.231	$0.080	$0.189
State Average	$0.177	$0.180	$0.238	$0.172	$0.238	$0.266	**$0.226**

Table 5. Incremental Construction Cost ($/ft²)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.342	($1.275)	($0.993)	($2.137)	$0.603	($0.695)	($0.878)
4A	$0.183	($1.669)	($0.957)	($1.999)	$0.610	($0.255)	($0.651)
5A	$0.539	($1.805)	($1.037)	($0.670)	$0.572	($0.468)	($0.719)
State Average	$0.333	($1.276)	($0.991)	($2.117)	$0.604	($0.670)	**($0.863)**

Table 6. Construction Weights by Building Type

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	10.0%	11.1%	24.3%	11.9%	2.6%	33.2%	93.1%
4A	0.7%	0.0%	2.3%	0.8%	0.4%	2.0%	6.2%
5A	0.0%	0.0%	0.4%	0.1%	0.0%	0.1%	0.7%
State Average	10.7%	11.1%	27.1%	12.8%	3.0%	35.3%	100.0%

APPENDIX I

Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code

Prepared by Vrushali Mendon, Rob Salcido, and YuLong Xie

U.S. Department of Energy
Pacific Northwest National Laboratory
902 Batelle Boulevard
Richland, WA 99354

December 12, 2022

MEMORANDUM

Date:	**12/12/2022**
To:	**Bridget Herring, North Carolina Building Code Council**
From:	**Vrushali Mendon, Rob Salcido, and YuLong Xie**
Subject:	**Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code**

Information Release # **PNNL-180509**

The State of North Carolina is in the process of updating their current residential energy code, the 2018 North Carolina Energy Conservation Code (NCECC) which is an amended version of the 2015 International Energy Conservation Code (IECC), to the 2024 NCECC, which is an amended version of the 2021 IECC. The Building Code Council of North Carolina requested an analysis on the energy, environmental, and economic impacts of the proposed code. To assess these impacts, PNNL analyzed the cost-effectiveness of adopting the 2024 NCECC compared to the 2018 NCECC.

Moving to the 2024 NCECC is cost-effective for both single-family and low-rise multifamily residential buildings when compared to the 2018 NCECC in North Carolina. The new code will provide energy cost savings of 18.7%. This equates to $399 of annual utility bill savings for the average North Carolina household as detailed in Table 1. Adopting the 2024 NCECC will also result in societal benefits such as cost savings and reduced greenhouse gas emissions. During the first year alone, North Carolina residents could expect to save over $15,372,000in energy costs and reduce CO_2 emissions by 130,700 metric tons, equivalent to the annual CO_2 emissions of nearly 29,000 cars on the road. Adopting the 2024 NCECC in North Carolina is expected to result in homes that are energy efficient, more affordable to own and operate, and based on newer industry standards for health, comfort, and resilience.

Table 1. Individual Consumer Impact[1]

Metric	Compared to the 2018 NCECC
Life-cycle cost savings of the 2024 NCECC	$4,347
Net annual consumer cash flow in year 1 of the 2024 NCECC [2]	$144
Annual (year 0) energy cost savings of the 2024 NCECC ($)[3]	$399
Annual energy cost savings of the 2024 NCECC (%)[4]	18.7%

Table 2. Societal Benefits

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	15,372,000	5,331,440,000
CO_2 emission reduction, Metric tons	130,700	65,815,000
CH_4 emissions reductions, Metric tons	9.4	4,700
N_2O emissions reductions, Metric tons	1.310	660
NOx emissions reductions, Metric tons	78.5	39,500
SOx emissions reductions, Metric tons	50.3	25,300

Table 3. Statewide Jobs Impact

Statewide Impact	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	755	22,500
Jobs Created Construction Related Activities	1,270	37,900
Total Jobs Created	2,025	60,400

Methodology

DOE's cost-effectiveness methodology evaluates 32 residential prototypes comprising two building types, four foundation types, and four HVAC types. The entire set is simulated with TMY3 weather data representing climate zone 3A, 3AWH, 4A and 5A in this analysis.

Construction cost differences between the 2024 NCECC and the 2018 NCECC were taken directly from DOE/PNNL reports on the cost-effectiveness of new code editions. National cost

[1] A weighted average is calculated across building configurations and climate zones.
[2] The annual cash flow is defined as the net difference between annual energy savings and annual cash outlays (mortgage payments, etc.), including all tax effects but excluding up-front costs (mortgage down payment, loan fees, etc.). First-year net cash flow is reported; subsequent years' cash flow will differ due to the effects of inflation and fuel price escalation, changing income tax effects as the mortgage interest payments decline, etc.
[3] Annual energy savings is reported at time zero, before any inflation or price escalations are considered.
[4] Annual energy savings is reported as a percentage of whole building energy use.

estimates were adjusted by a North Carolina-specific construction cost multiplier[5] and appropriate Consumer Price Index (CPI) multipliers[6] to bring costs into 2022 dollars.

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes. LCC is the calculation of the present value of costs over a 30-year period including initial equipment and construction costs, energy savings, maintenance and replacement costs, and residual value of components at the end of the 30-year period. When the LCC of the updated code (e.g., the 2024 NCECC) is lower than that of the previous code (the 2018 NCECC), the updated code is considered cost-effective.

The energy savings from the simulation analysis are converted to energy cost savings using fuel prices found in Table 3. Fuel prices are escalated over the analysis period based on an escalation factor of 1.6% for all fuel types.

Table 3. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Fuel Oil ($/MBtu)
0.116	1.253	2.422

The financial and economic parameters used in calculating the LCC and annual consumer cash flow are based on the latest DOE cost-effectiveness methodology to represent the current economic scenario.[7] The parameters are summarized in Table 4 for reference.

Table 4. Economic Parameters Used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	5%
Loan fees	0.6% of mortgage amount
Loan term	30 years
Down payment	10% of home value
Nominal discount rate (equal to mortgage rate)	5%
Inflation rate	1.6%
Marginal federal income tax	15%
Marginal state income tax	5.25%
Property tax	1.1%

[5] https://www.energycodes.gov/sites/default/files/2021-11/Location_Factors_Report.pdf
[6] https://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/
[7] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Consumer Impacts

Moving to the 2024 NCECC is cost-effective for households living in single-family and low-rise multifamily units in North Carolina. Based on a 30-year life-cycle cost analysis, the average consumer can expect to save nearly $4,347 and see a positive cashflow in 3 years.

Table 5 through Table 7 display typical cost-effectiveness metrics analyzed in DOE national and state energy code analyses. These metrics include climate zone specific life-cycle cost savings, consumer cash flow timeframe,[8] and annual energy cost savings. Tables 8 and 9 show the climate zone specific incremental construction costs when updating to the 2018 IECC based on the single-family and multifamily prototypes used in this analysis.

[8] Consumer Cash Flow: Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)

Table 5. Life-Cycle Cost Savings of the 2024 NCECC compared to the 2018 NCECC

Climate Zone	Life-Cycle Cost Savings ($)
3A	3,918
3AWH	3,596
4A	8,005
5A	6,079

Table 6. Consumer Cash Flow from Compliance with the 2024 NCECC compared to the 2018 NCECC

	Cost/Benefit	3A	3AWH	4A	5A
A	Incremental down payment and other first costs	$429	$429	$421	$534
B	Annual energy savings (year one) [9]	$395	$381	$545	$523
C	Annual mortgage increase	$236	$236	$231	$294
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$31	$31	$30	$38
E = [B-(C+D)]	Net annual cash flow savings (year one)	$129	$114	$283	$191
F = [A/E]	Years to positive savings, including up-front cost impacts	4	4	2	3

[9] Annual energy savings as reported at year 1, after considering discount rate, inflation, and price escalations.

Table 7. Simple Payback Period for the 2024 NCECC Compared to the 2018 NCECC

Climate Zone	Simple Payback (Years)
3A	11
3AWH	11
4A	8
5A	10

Table 8. Total Single-Family Construction Cost Increase for the 2024 NCECC Compared to the 2018 NCECC

Single-family Prototype House			
Climate Zone	**Crawlspace**	**Slab**	**Unheated Basement**
3A	$4,763	$5,194	$4,763
3AWH	$4,763	$5,194	$4,763
4A	$4,755	$5,186	$4,755
5A	$6,057	$6,487	$6,057

Table 9. Multifamily Construction Cost Increase for the 2024 NCECC Compared to the 2018 NCECC per Dwelling Unit[10]

Multifamily Prototype Apartment/Condo			
Climate Zone	**Crawlspace**	**Slab**	**Unheated Basement**
3A	$1,803	$1,867	$1,803
3AWH	$1,803	$1,867	$1,803
4A	$1,552	$1,616	$1,552
5A	$2,029	$2,092	$2,029

[10] In the multifamily prototype model, the heated basement is added to the building, and not to the individual apartments. The incremental cost associated with heated basements is divided among all apartments equally.

For a more detailed description of the approach PNNL uses to evaluate residential energy code cost-effectiveness, including building prototypes, energy and economic assumptions, and other considerations, please review the latest DOE Residential Cost-Effectiveness Methodology.[11]

[11] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf