



NORTH CAROLINA BUILDING CODE COUNCIL

N.C. Gen. Stat. § 143-138(a1)(2) COST-BENEFIT ANALYSIS

FOR

**Request from Dan Dittman on behalf of the NC Office of State Fire
Marshal to amend the 2024 NC Energy Conservation Code, Section
R402 Building Thermal Envelope to reflect the requirements of North
Carolina General Assembly Session Law 2023-108, Section 6
“Amend Insulation Requirements for Unvented Attic and
Enclosed Rafter Assemblies”**

(Item B-6, Approved June 11, 2023)

Proposed Amendment: [https://www.ncosfm.gov/b-6-2024-ncecc-r402-
building-thermal-envelope](https://www.ncosfm.gov/b-6-2024-ncecc-r402-building-thermal-envelope)

Pursuant to N.C. Gen. Stat. § 143-138(a1)(2), the attached cost-benefit analysis was conducted by the U.S. Department of Energy's Pacific Northwest National Laboratory at the request of the North Carolina Building Code Council to determine the cost-effectiveness of the adoption of the proposed amendment to Section R402 Building Thermal Envelope and Appendix R1.2.1 of the 2024 North Carolina Energy Conservation Code required by Section 6 "Amend Insulation Requirements for Unvented Attic and Enclosed Rafter Assemblies" of North Carolina Session Law 2023-108. To implement the insulation requirements mandated by N.C. Sess. L. 2023-108, new sections R402.2.2.1 and R402.2.2.2 are added to Section R402, Table R402.1.2 is amended to add new footnote h, and Table R402.1.3 is amended to add new footnote k. In addition, certain changes and additions are made to the illustrations and text of Appendix R.1.2.1.

Compared to Section R402 of the 2018 North Carolina Energy Conservation Code, the proposed rule (2024611 Item B-6) also contains changes to Sections R402.1, R-402.1.1., R-402.1.2, R402.1.3, R402.1.4, R402.1.5, R402.2, R402.2.1, R402.2.2, R402.2.3, Table R402.1.2, Table R402.1.3, R402.2.4, R402.2.4.1, R402.2.5, R402.2.6, R402.2.7, R402.2.8, R402.2.8.1, R402.2.9, R402.2.9.1, R402.2.2.10, R402.2.10.1, Table R402.2.10, R402.2.11, R402.2.12, R402.3, R402.3.3, R402.3.4, R402.3.5, R402.4, R402.4.1, R402.4.1.1, Table R402.4.1.1, R402.4.1.2, R402.4.1.3, R402.4.2, R402.4.3, R402.4.4, R402.4.5, and R402.5 to implement updates consistent with the 2021 edition of the International Code Council's *International Energy Conservation Code* with North Carolina administrative and technical amendments. The cost-effectiveness of these other changes were addressed in the Council's cost-benefit analysis for the 2024 North Carolina Energy Conservation Code which is incorporated by reference herein and available at <https://www.ncosfm.gov/b-6-2024-ncecc-cost-analysis/open>.

MEMORANDUM



Date: **7/22/2024**

To: **Bridget Herring, North Carolina Building Code Council** Information Release # **PNNL-36249**

From: **Paula Zimin, Rob Salcido, Yulong Xie, Yun Joon**

Subject: **Cost-Effectiveness Analysis of the 2024 North Carolina Energy Conservation Code with R402 Air Impermeable Insulation Amendment**

The North Carolina Building Code Council (BCC) has adopted the 2024 North Carolina Energy Conservation Code (NCECC), an amended version of the 2021 International Energy Conservation Code (IECC). This updates the state's previous code (2018 NCECC), an amended version of the 2015 IECC. As part of North Carolina's Administrative Procedure Act, the 2024 NCECC was submitted to the North Carolina Rules Review Commission which approved all but one section of the code – Section R402 of the 2024 NCECC, which impacts low-rise multifamily buildings.¹ As required by Section 6 of North Carolina Session Law 2023-108 (page 26)², the Rules Review Commission requested that Section R402 Building Thermal Envelope (R402.1-R402.6) include an “optional alternative” for air impermeable ceiling insulation.³ The BCC is now in the process of promulgating an amendment for Section R402 to include Section 402.2.2.2, creating an alternative compliance pathway when using air impermeable ceiling insulation (R402 amendment).

With this approved change, the North Carolina BCC requested an analysis to determine the associated consumer costs and benefits, as required by state law. To assess the R402 amendment on low-rise multifamily buildings, PNNL analyzed the cost-effectiveness of adopting the 2024 NCECC with the R402 amendment compared to the 2024 NCECC baseline.⁴

PNNL's analysis shows that building in compliance with the Section R402 amendment will result in higher costs and fewer benefits for residents in low-rise multifamily buildings when compared to the 2024 NCECC baseline in North Carolina. This approach will result in increased energy costs of 1.8%, equating to an additional \$24 in annual utility bills per unit for the average North

¹ Multifamily buildings three stories or less in height above grade plane.

² <https://www.ncleg.gov/EnactedLegislation/SessionLaws/PDF/2023-2024/SL2023-108.pdf>

³ <https://www.ncosfm.gov/b-6-2024-ncecc-r402-building-thermal-envelope/open>

⁴ The 2024 NCECC residential chapter is based on the 2021 IECC. Although several amendments are included in the 2024 NCECC, this analysis is focused on the prescriptive R-value compliance pathway (R401.2.1) which is consistent with the 2021 IECC. For the purposes of this memo, PNNL used the 2021 IECC R401.2.1 as the baseline for this analysis.

Carolina household in low-rise multifamily buildings, as detailed in Table 1. By adopting the R402 amendment, the State would yield fewer benefits, such as cost savings and reduced emissions compared to the 2024 NCECC baseline. If all low-rise multifamily units were constructed in compliance with the R402 amendment, collectively, North Carolina could expect to spend an estimated \$786,900 more in energy costs and emit an additional 6,000 metric tons of CO₂ emissions equivalent to the annual CO₂ emissions of nearly 1,300 cars on the road, when compared to homes built to the 2024 NCECC Baseline. Adopting the R402 amendment is expected to result in homes that are less energy efficient and more expensive to own and operate.

Table 1. Individual Consumer Impact of 2024 NCECC R402 Amendment⁵

Metric	Compared to the 2024 NCECC Baseline
Life-cycle cost savings of the 2024 NCECC	\$-598
Net annual consumer cash flow in year 1 of the 2024 NCECC ⁶	\$-29
Annual (year 0) energy cost savings of the 2024 NCECC (\$) ⁷	\$-24
Annual energy cost savings of the 2024 NCECC (%) ⁸	-1.8%

Table 2. Societal Benefits of 2024 NCECC R402 Amendment

State Impact	First Year
Energy cost savings, \$	-786,900
CO ₂ emission reduction, Metric tons	-6,000

Methodology

DOE's cost-effectiveness methodology typically evaluates 32 residential prototypes comprising two building types, four foundation types, and four HVAC types. The entire set is simulated with TMY3 weather data for 3A, 4A and 5A (representative weather files are not warm-humid), and 3A warm-humid (3AWH, representative coastal warm-humid weather file). For this analysis, changes are only evaluated for the low-rise multifamily prototypes.

⁵ A weighted average is calculated across building configurations and climate zones. Negative values indicate increased consumer costs and reduced savings when compared to the baseline code.

⁶ 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.

⁷ Annual energy savings is reported at time zero, before any inflation or price escalations are considered.

⁸ Annual energy savings is reported as a percentage of per unit energy use.

The analysis compares the 2024 NCECC R402 amendment with an unvented attic condition to a baseline standard vented attic condition compliant with minimum prescriptive requirements of the 2021 IECC.

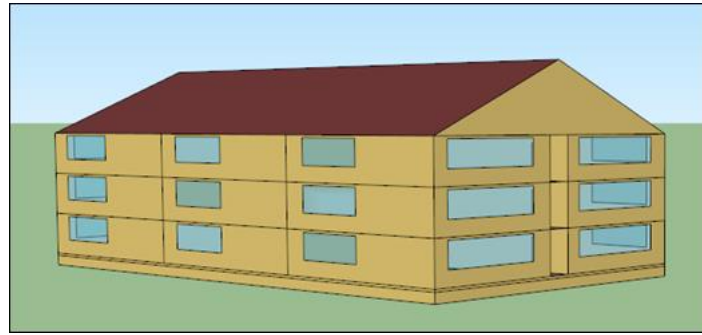


Figure 1. PNNL Low-rise Multifamily Prototype

The low-rise multifamily prototype buildings are modified to reflect the design condition required under the 2024 NCECC air impermeable insulation amendment. The 2024 NCECC design condition includes an unvented attic with insulation in the roof framing. Figure 2 illustrates the unvented attic construction. The proposed amended code language for Section R402 specifies the following provisions for allowing air impermeable insulation in an unvented attic.

- Air impermeable insulation in roof deck framing (identified in Figure 2 below in yellow)
 - R-20 for climate zone 3.
 - R-25 for climate zones 4 & 5.
- R-3 air impermeable insulation on exposed roof deck framing, increasing overall insulative value by a weighted factor based on the framing ratio.
- Balanced mechanical ventilation system.
- Air infiltration < 3.0 ACH50.
- Duct systems all located inside building thermal envelope.

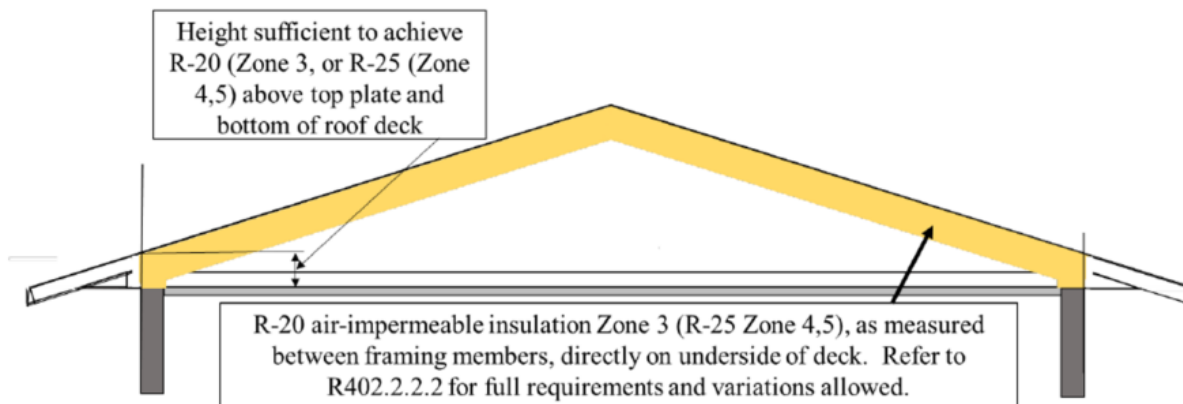


Figure 2. Unvented attic construction based on 2024 NCECC Section R402 air impermeable insulation amendment requirements.

Construction cost differences between the 2024 NCECC with R402 amendment and the 2024 NCECC baseline are estimated per multifamily unit and based on the 2024 RSMeans Cost Database and other sources. National cost estimates are adjusted by a North Carolina-specific construction cost multiplier from the 2024 RSMeans.

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 standard 30-year mortgage 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 with R402 amendment) is lower than that of the baseline code, 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 (\$/gal)
0.1449	1.452	3.942

With the exception of the discount rate, 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.⁹ North Carolina requires that a 7% discount rate be used when preparing fiscal notes associated with proposed rules, so DOE is using a 7% discount rate in this analysis. The parameters are summarized in Table 4 for reference.

⁹ 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	0.9% of mortgage amount
Loan term	30 years
Down payment	10% of home value
Nominal discount rate	7%
Inflation rate	2.2%
Marginal federal income tax	22%
Marginal state income tax	4.5%
Property tax	0.82%

Consumer Impacts

The 2024 NCECC R402 amendment is not cost-effective for households in low-rise multifamily units in North Carolina when compared to 2024 NCECC baseline. Based on a 30-year life-cycle cost analysis, the average consumer can expect to spend nearly \$598 more with a multifamily unit built to the 2024 NCECC R402 amendment as compared to the baseline.

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,¹⁰ and annual energy cost savings. The LCC and Net Annual Cash Flow (year one savings) are shown as negative in all climate zones, indicating higher energy and incremental construction costs associated with the R402 amendment. When the LCC and cash flow is negative, the simple payback and years to positive savings metrics cannot be calculated.

Table 8 shows the climate zone specific incremental construction costs per unit when comparing the 2024 NCECC R402 amendment to the 2024 NCECC baseline, based on the low-rise multifamily prototypes used in this analysis.

¹⁰Consumer 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 R402 Amendment compared to the 2024 NCECC Baseline

Climate Zone	Life-Cycle Cost Savings (\$)
3A	-\$634
3AWH	-\$335
4A	-\$623
5A	-\$737

Table 6. Consumer Cash Flow from Compliance with the 2024 NCECC R402 Amendment compared to the 2024 NCECC Baseline

	Cost/Benefit	3A	3AWH	4A	5A	State Average
A	Incremental down payment and other first costs	\$8	\$5	\$8	\$7	\$7
B	Annual energy savings (year one) ¹¹	-\$26	-\$13	-\$26	-\$33	-\$24
C	Annual mortgage increase	\$4	\$3	\$4	\$4	\$4
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	\$0.1	\$0.1	\$0.1	\$0.1	\$0.1
E						
=	Net annual cash flow savings (year one)	-\$30	-\$16	-\$30	-\$37	-\$28
[B-(C+D)]						
F						
=	Years to positive savings, including up-front cost impacts*	NA	NA	NA	NA	NA
[A/E]						

*Number of “years to positive savings” cannot be calculated for changes which are found to be not cost effective.

¹¹ 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 R402 Amendment compared to the 2024 NCECC Baseline

Climate Zone	Simple Payback (Years)
3A	NA
3AWH	NA
4A	NA
5A	NA

Table 8. Multifamily Construction Cost Increase for the 2024 NCECC Amendment compared to the 2024 NCECC Baseline¹²

Multifamily Prototype Apartment/Condo				
Climate Zone	Crawlspace	Heated Basement	Slab	Unheated Basement
3A	\$452	\$452	\$452	\$452
3AWH	\$452	\$452	\$452	\$452
4A	\$630	\$630	\$630	\$630
5A	\$630	\$630	\$630	\$630

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.¹³

¹² 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.

¹³ https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Disclaimer for DOE Technical Analysis

Technical assistance and support provided by DOE through a technical assistance request is separate and distinct from any application and programmatic requirements for any federal funding opportunity and does not constitute an endorsement of any application for federal funding. Results from this request, including any technical assistance findings, are bound within the scope of this specific request and should not be interpreted as a determination for eligibility in any funding program. Qualification for federal funding opportunities is determined solely through the established application process and review processes, including eligibility and review criteria therein, and within the established application period for a given opportunity. Any questions regarding DOE funding initiatives should be directed to the cognizant office: Building Technologies Office for inquiries regarding Section 40511 of the Bipartisan Infrastructure Law (BIL) and the Office of State and Community Energy Programs for inquiries regarding Section 50131 of the Inflation Reduction Act (IRA).