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Montana Residential Code Compliance Evaluation

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Executive Summary

Introduction

In 2023, NEEA commissioned an evaluation of the residential new construction market's response to the 2018 and 2021 International Energy Conservation Code (IECC) with Montana amendments. NEEA selected a consulting team led by Industrial Economics, Inc. (IEc), with subcontractors Resource Refocus LLC and RedPoint LLC, to conduct the evaluation. The main study objective was to assess statewide compliance with the 2018 and 2021 IECC with Montana amendments. Additional objectives were to provide statewide findings regarding the proportion of homes with gas versus electric primary space heating, the proportion of homes with gas versus electric water heating, and the proportion of homes with above-code elements.

Methodology

The study follows the sampling methodology specified in the U.S. Department of Energy (DOE)'s Residential Building Energy Code Field Study: Data Collection & Analysis. DOE's methodology requires 63 observations for each of seven key measures (listed below), which are to be collected through on-site inspections at newly constructed homes. The analysis presented in this report relies on on-site inspection data from newly constructed single-family homes across the state. [1] On-site data was used to model compliance under both the 2018 and 2021 IECC with Montana amendments, which are described in more detail in Appendix B – 2018 vs. 2021 Montana Code Requirements.

The study assesses statewide compliance levels for the following seven key measures in DOE's methodology:

1. Envelope tightness (air changes per hour (ACH) at 50 Pascals).
    - For envelope tightness only, the study provides statewide findings as well as findings for urban (within city limits) and rural (outside of city limits) jurisdictions separately. This was to address anecdotal reports suggesting differences in envelope tightness between urban and rural areas.
2. Windows (U-factor and solar heat gain coefficient (SHGC)).
3. Wall insulation (assembly U-factor).
4. Ceiling insulation (R-value).
5. Lighting (percent high efficacy).
6. Foundation insulation (including floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation R-values).
7. Duct tightness (expressed in cubic feet per minute (cfm) per 100 sq. ft. of conditioned floor area (CFA) at 25 Pascals).

Using data collected on the seven individual code requirements, the study provides estimates of statewide energy code compliance based on the share of newly constructed homes that meet the minimum code requirements from an energy consumption perspective.

The analysis was split into three main components:

- **Statistical analysis** to assess compliance at the individual measure level.
- **Modeling analysis** to estimate the energy consumption of both an observed and code-compliant population of homes. The observed population is based on the data collection,

[1] Prior to implementing DOE's field methodology (on-site inspections), the team explored using permit data but found that sufficient data were not available.

while the code-compliant population assumes each home exactly meets the code requirements.
- **Savings analysis** to project the potential savings with improved energy code compliance relative to the 2018 and 2021 IECC with Montana amendments. Savings are reported per home and statewide.

Lastly, the team conducted interviews with five builders and five code officials across Montana to better understand the compliance process, barriers to meeting specific code requirements, and their perceptions about the building energy code.

Results

This study provides insight into 2018 and 2021 IECC with Montana amendments code compliance both at a measure and whole home level. All of Montana is in IECC climate zone 6B (CZ6), which is defined as cold and dry. More detailed information about the code requirements can be found in the Montana Residential Code section below.

Key observations from the statistical analysis of data collected from 143 homes include:

- Overall, compliance results are similar under the 2018 and 2021 IECC with Montana amendments.
- Compared to the compliance rates under the 2012 IECC with Montana amendments, under the 2018 and 2021 IECC with Montana amendments:
    - Compliance rates continue to be high (>95%) for window U-factor, wall R-value, and unvented crawl wall R-value.
    - Compliance rates continue to be low (<50%) for wall U-factor and slab edge R-value.
    - Compliance rates increased for envelope tightness and basement wall U-factor.
    - Compliance rates decreased for ceiling R-value, unvented crawl U-factor, and adjusted duct tightness.
    - Most measures had similar average efficiency levels when looking at the observed values for each measure.[2] However, efficiency levels decreased for ceiling insulation R-values and duct tightness, while they increased for envelope tightness and basement wall U-factor.
    - Overall compliance has notably decreased.
- Areas for improvement include wall insulation installation quality (IIQ), ceiling insulation amount and IIQ, basement wall insulation amount and IIQ, unvented crawl wall IIQ, slab insulation amount, and duct tightness.

The energy analysis results are shown in the histograms below, which show the weighted average regulated energy use intensity (EUI) of the observed data set compared to the expected weighted average regulated consumption based on homes that exactly met the prescriptive code requirements.[3] These results estimate that the average new-construction home in Montana uses

[2] Compliance rates quantify the percentage of observations that meet or exceed the prescriptive requirements. This is a binary metric. Efficiency levels consider the range and average of the on-site observations.

[3] Regulated end uses include heating, cooling, lighting (interior + exterior), fans, and domestic hot water. The weights were defined by the frequency of field-observed heating system and foundation type combinations (which is how the PNNL prototype files are differentiated).

more energy than would be expected relative to a home built to the current minimum state code requirements under both code cycles. Based on the observed data set:

- **2018 IECC with Montana amendments (Figure ES-1):** The average observed regulated EUI is 52.2 kBtu/ft^2-yr (dashed blue line). In comparison, homes exactly meeting minimum prescriptive energy code requirements have an average EUI of 47.2 kBtu/ft^2-yr (solid blue line). The EUI for a "typical" home in the state uses about 10.6% more regulated energy than a code-compliant home.
- **2021 IECC with Montana amendments (Figure ES-2):** The average observed regulated EUI is 50.9 kBtu/ft^2-yr, while the code-compliant EUI is 45.5 kBtu/ft^2-yr.[7] The EUI for a "typical" home in the state uses about 12% more regulated energy than a code-compliant home.

Each of the models generated in the modeling analysis was compared to a minimally code-compliant model with the same heating and foundation type. In this comparison, 86.1% of the simulated population had a regulated EUI less than or equal to the 2018 IECC with Montana amendments code compliant model. This means that the analysis predicts 86.1% compliance and 13.9% non-compliance statewide. For the 2021 IECC with Montana amendments, which has stricter requirements for ceilings and lights, there was 84.7% compliance.

Note, the simulated population includes homes with above-code measures, which improves the average performance statewide. This is why the *average* home underperforms the code-compliant average by 10.6%, but there is still 13.9% non-compliance for the 2018 IECC with Montana amendments based on the individual models.

There is a substantial difference between the compliant and non-compliant home populations under both the 2018 and 2021 IECC with Montana amendments. When including above-code performance, on average the compliant population uses about 10% less energy than a code-compliant baseline while the non-compliant population uses about 20% more.

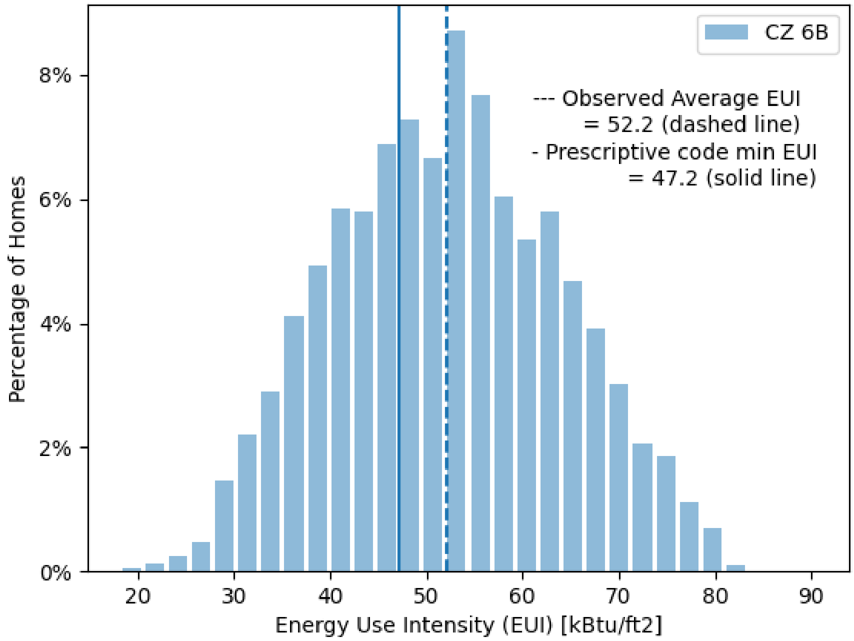

Figure ES-1. Statewide EUI analysis for 2018 IECC with Montana amendments

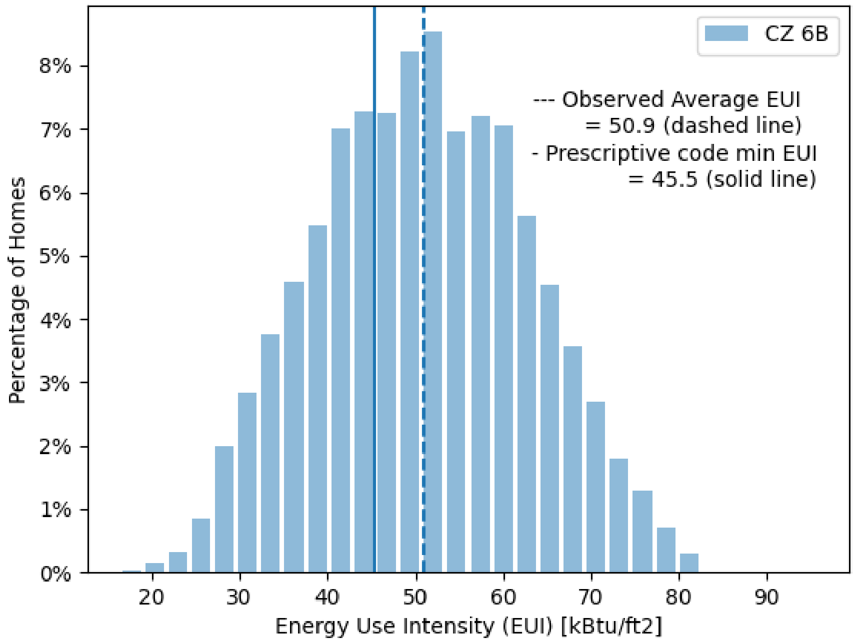

Figure ES-2. Statewide EUI analysis for 2021 IECC with Montana amendments

The tables below summarize the potential measure-level savings that could be the target for future education, training, and outreach activities. Under the 2018 IECC with Montana amendments, potential statewide annual energy savings are 24,636 MMBtu, which would result in $352,064 in energy cost savings and 1,380 metric tons (MT) CO_{2e} in emission reductions. Over a 30-year period, this would save 11.5 million MMBtu, $164 million, and 641,741 MT CO_{2e} (**Table ES-1**). Under the 2021 IECC with Montana amendments, potential statewide annual energy savings are 26,747 MMBtu, which would result in $382,906 in energy cost savings and 1,499 MT CO_{2e} in emission reductions. Over a 30-year period, this would save 12.4 million MMBtu, $178 million, and 696,998 MT CO_{2e} (**Table ES-2**).[4]

Table ES-1. Annual statewide savings potential under the 2018 IECC with Montana amendments

Key Measure	Annual Savings		
	Energy (MMBtu)	Cost ($)	Carbon (MT CO2e)
Duct Leakage	8,442	125,521	477
External Wall Insulation	7,999	113,502	447
Ceiling Insulation	4,882	69,613	273
Envelope Tightness	3,150	40,983	173
Foundation Insulation	162	2,446	9
TOTAL	**24,636 MMBtu**	**$352,064**	**1,380 MT CO2e**

[4] 5-year, 10-year, and 30-year savings are included in the Savings Analysis Results section. These calculations followed the methodology specified in *DOE's Residential Building Energy Code Field Study: Data Collection & Analysis*. Details on the energy cost and emission factor assumptions are included in the Montana Fuel Prices and Emission Factors section in Appendix C.

Table ES-2. Annual statewide savings potential under the 2021 IECC with Montana amendments

Key Measure	Annual Savings		
	Energy (MMBtu)	Cost ($)	Carbon (MT CO2e)
Duct Leakage	8,608	127,159	486
External Wall Insulation	7,925	112,645	443
Ceiling Insulation	6,913	99,662	388
Envelope Tightness	3,141	40,972	173
Foundation Insulation	162	2,469	9
TOTAL	**26,747 MMBtu**	**$382,906**	**1,499 MT CO2e**

Recommendations

Recommendations to improve code compliance and recommendations for future studies are summarized below. The main body of the report provides additional detail for each recommendation.

Recommendations to Improve Code Compliance

Education and outreach efforts can focus on the key variables with potential savings. From highest to lowest, the majority of the potential savings are in duct leakage, external wall insulation, ceiling insulation, and envelope tightness. There is also room for improvement in foundation insulation compliance, however the potential savings are comparatively small.

Reduce duct leakage by relocating ducts to conditioned spaces or enhancing duct sealing in unconditioned spaces. Duct leakage has the highest potential savings from improved compliance under the 2018 and 2021 IECC with Montana amendments, representing 34% and 32% of the potential annual energy savings respectively. This measure also had the highest potential savings (49%) in the previous study of the 2012 IECC with Montana amendments. Of the 63 on-site visits, 8 of the observations were completely in unconditioned space and 17 were partially located in unconditioned space. Education and outreach efforts can focus on either moving ducts to conditioned spaces or improving duct sealing in unconditioned spaces.

Improve the quality of external wall insulation installation. The potential savings from improved compliance for external wall insulation represent 32% of the 2018 IECC with Montana annual energy savings and 29% of the 2021 IECC with Montana amendment savings. External wall insulation also had the second highest potential savings (39%) in the previous study of the 2012 IECC with Montana amendments. Nearly all of the observations met or exceeded the R-21 insulation requirement, but about three quarters of the observations had Grade II or III IIQ.[5] So, the amount of insulation is generally sufficient, but education and outreach efforts could focus on installation quality.

Improve both the quantity and quality of ceiling insulation, including compliance with increased R-value requirements. Ceiling insulation represents 20% of the 2018 IECC with

[5] Minimum R-values are specified in code, but IIQ is not. However, improper installation can affect overall assembly performance. To accurately model performance, DOE recommends using IIQ as a modifier to calculate assembly U-factors (Bartlett et al 2022). Following the RESNET assessment protocol for cavity insulation, Grade I is the best quality installation and Grade III is the worst (RESNET 2024).

Montana amendments annual energy savings from improved compliance and 25% of the 2021 IECC with Montana amendment savings. Ceiling R-value requirements increased from R-49 to R-60 under the 2021 IECC with Montana amendments. In contrast to the wall insulation, for ceiling insulation, both the amount of ceiling insulation and the installation quality are areas for improvement. Observed R-values were 38% compliant under the 2018 IECC with Montana amendments and 5% compliant under the 2021 IECC with Montana amendments. Forty-four percent of the IIQ observations were Grade II and III.

Enhance envelope tightness, aiming for increased compliance and tighter average envelopes. There is room for modest savings in improved envelope tightness, which represents 13% and 12% of the 2018 and 2021 IECC with Montana amendment savings, respectively. Compared to the previous study of the 2012 IECC with Montana amendments, the rate of compliance increased (73% to 84%) and the average envelope is tighter (3.5 to 2.9 ACH).

Improve foundation insulation compliance, particularly in basement wall insulation, unvented crawlspace wall insulation, and slab insulation. There is room for improvement in foundation insulation compliance, but this is unlikely to result in substantial savings. Foundation insulation represents 1% of the potential annual savings under both the 2018 and 2021 IECC with Montana amendments. Areas for improvement include basement wall insulation amount and IIQ, unvented crawlspace wall IIQ, and slab insulation amount.

Recommendations for Future Studies & Education Opportunities

Future studies and education can focus on key areas to enhance code compliance and building performance.

Reevaluate the feasibility of using permit data for future compliance assessments. The team initially sought to use permit data to assess compliance. Permit data are not currently a feasible approach based on current building permit practices in Montana, namely because building permits are not issued in most unincorporated jurisdictions across the state, meaning a large portion of new building activity cannot be observed from permits alone.[6] Further, some jurisdictions that issue building permits do not include the energy code values that would be needed for analysis. If a greater number of counties outside of incorporated city limits begin to issue building permits, and energy code information is more consistently added to permits, a future study could reassess the feasibility of using permit data.

Investigate whether building code compliance rates differ between urban and rural areas and between enforced and unenforced areas. Although the sample sizes of homes observed during this study were too small to statistically test the differences in compliance levels between rural and urban areas, feedback from the interviews and anecdotal evidence from the field team and other study participants suggested that there may be lower rates of compliance and/or less awareness of aspects of the building code in rural areas (especially rural, unenforced areas).[7] The team assessed differences between urban and rural homes for envelope tightness and found

[6] The Montana State Department of Labor and Industry maintains a list of all jurisdictions that issue building permits (enforced areas) across the state: https://bsd.dli.mt.gov/building-codes-permits/certified-government. While most of these jurisdictions are within incorporated city limits, three counties (Deer Lodge, Missoula, and Silver Bow) also issue residential building permits in unincorporated county areas. Throughout this study we refer to any permit-issuing jurisdiction as an “enforced” area, and non-permit-issuing jurisdictions as “unenforced.”

[7] For the purposes of this study, NEEA and the team define “rural” areas as all unincorporated parts of the state and define “urban” areas as all incorporated parts of the state.

compliance rates to be slightly higher in urban areas (88%) than rural (76%), although the average ACH values were similar in both urban and rural areas. Future studies may want to further study whether code compliance rates differ in urban versus rural areas. NEEA may also want to further study code compliance in enforced versus unenforced areas to see if code compliance is lower in the areas of the state that do not issue building permits.

Enhance education and training to improve builders' understanding of air tightness, proper ventilation practices, and the value of building higher performing homes. During the interviews, two of the five builders expressed a concern that building homes to meet the current envelope tightness requirements had caused mold to grow in attics of their homes where moisture was able to enter but air was not able to escape. They also noted that there was increased window condensation in these homes. These builders suggested that there may be some benefits to building homes with slightly lower envelope tightness levels. One also expressed a concern that the added costs of building a home to the current code did not add value to the homeowner. This feedback suggests that there are training opportunities to improve builders' understanding of air tightness and proper ventilation practices to ensure they meet code envelope requirements without negative effects, and to explain the value proposition of building higher performing homes.

Additionally, the field team identified two educational opportunities to address awareness:

- **Increase heat recovery ventilation (HRV) and energy recovery ventilators (ERV) system awareness.** HRV and ERV systems are whole-home ventilation systems that maintain sufficient fresh air while reducing energy usage through a heat exchanger on the exhaust air.[8] Installing these systems can mitigate the negative impacts that builders associated with tighter homes (mold and window condensation), while improving home comfort and performance. The field team noted that awareness of these systems and their benefits was low across the builder community and could be improved with additional outreach. Further, as the 2024 IECC requires an HRV or ERV system to be installed, increased education in the near term can help prepare builders for potential code changes.
- **Address regional building practices affecting home performance.** The field team observed some regional building trends that may have been associated with the common practices of area-specific subcontractors. For example, the team found that insulation installations varied across the state. The team typically only found spray foam insulation in Bozeman and in higher end builds, whereas most of the rest of the state used fiberglass batt insulation. In Billings, the team found a lack of caulking to seal cracks and improved insulation quality. The team also noted differences in the performance of HVAC systems being installed across the state, which may be driven by builder preferences. Identifying areas where insulation practices could be improved, and/or HVAC equipment is less efficient, and providing educational resources to local subcontractors in those areas could improve statewide building performance.

[8] The heat exchanger in an HRV system only transfers heat, while an ERV system transfers both moisture and heat.

1 Introduction

Background and Study Objectives

Residential building energy codes have the potential to significantly affect energy consumption throughout the Northwest (Montana, Montana, Oregon, and Washington). In collaboration with regional stakeholders, the Northwest Energy Efficiency Alliance (NEEA) identifies new potential energy code measures, participates in the public process by providing data and analysis, and works with state code bodies to support code implementation. To assess the extent to which the energy savings goals of these efforts are realized in the market, NEEA commissions evaluation studies measuring the market's response to updated building energy codes in the residential new construction sector in the Northwest.

In 2023, NEEA commissioned an evaluation of the residential new construction market's response to the 2018 and 2021 International Energy Conservation Code (IECC) with Montana amendments. NEEA selected a consulting team led by Industrial Economics, Inc. (IEc), with subcontractors Resource Refocus LLC and RedPoint LLC, to conduct the evaluation. This report describes the evaluation's objectives, methods, and results.

The main study objective was to assess statewide compliance with both the 2018 and 2021 IECC with Montana amendments. The study follows the methodology specified in the U.S. Department of Energy (DOE)'s Residential Building Energy Code Field Study: Data Collection & Analysis. Based on an analysis of on-site data from newly constructed single-family homes across the state, the study assesses statewide compliance levels for the following seven key code elements:

1. Envelope tightness (ACH at 50 Pascals).
    - For envelope tightness only, the study provides statewide findings as well as findings for urban (within city limits) and rural (outside of city limits) jurisdictions separately. This was to address anecdotal reports suggesting differences in envelope tightness between urban and rural areas.
2. Windows (U-factor and solar heat gain coefficient (SHGC)).
3. Wall insulation (assembly U-factor).
4. Ceiling insulation (R-value).
5. Lighting (percent high efficacy).
6. Foundation insulation (including floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation R-values).
7. Duct tightness (expressed in cubic feet per minute (cfm) per 100 sq. ft. of conditioned floor area (CFA) at 25 Pascals).

Using data collected on individual code requirements, the study provides estimates of statewide energy code compliance based on the share of the homes that meet the minimum code requirements from an energy consumption perspective.

This report includes results from the:

- **Statistical analysis** to assess compliance at the individual measure level.
- **Modeling analysis** to estimate the energy consumption of both an observed and code-compliant population of homes.
- **Savings analysis** to project the potential savings with improved energy code compliance relative to the 2018 and 2021 IECC with Montana amendments.

In addition, this report provides statewide findings regarding:

- Proportion of homes with gas versus electric primary space heating.
- Proportion of homes with gas versus electric water heating.
- Proportion of homes with above-code elements.

Montana Residential Code

This study assesses compliance for homes built under the 2018 IECC with Montana amendments, which went into effect on February 13, 2021, and the 2021 IECC with Montana amendments, which went into effect on June 10, 2022. This serves in part as an update to the Pacific Northwest National Laboratory's (PNNL) 2019 *Montana Residential Energy Code Field Study,* which summarized compliance under Montana's previous code (2012 IECC with Montana amendments). For the remainder of the report, PNNL's 2019 field study will be referred to as the "previous study."

All of Montana is in IECC climate zone 6B (CZ6), which is defined as cold and dry. **Table 1** summarizes the differences between the last three code cycles in Montana. Of note:

- Fenestration U-factor became more stringent under the 2018 Montana amendment and remained that way under the 2021 Montana amendment (0.32 to 0.30 Btu/h-ft^2-°F).
- Wood-frame wall U-factors also became more stringent under the 2018 code updates and remained that way under the 2021 code (0.057 to 0.045 Btu/h-ft^2-°F), following the IECC requirements. However, both the 2018 and 2021 IECC with Montana amendments allow for an R-21 construction, which is not compliant under the standard IECC.
- The ceiling R-value requirements increased from R-49 to R-60 under the 2021 IECC with Montana amendments, following the IECC updates. However, the U-factor remained the same, which differed from the 2021 IECC requirements.
- The percentage of high-efficacy lighting requirements increased with each code cycle (2012 75%, 2018 90%, 2021 100%), also following the IECC requirements.

Table 1. 2012, 2018, and 2021 IECC with Montana amendments

IECC Code Section	Component	CZ	2012 IECC with Montana amendments	2018 IECC with Montana amendments	2021 IECC with Montana amendments	Units
R402.4.1.2	Envelope Tightness	6B	4	4	4	ACH at 50 Pa
R402.1	Fenestration U-factor	6B	0.32	0.3	0.3	Btu/h-ft²-°F
	Fenestration SHGC	6B	NR	NR	NR	N/A
	Wood-framed R-value (U-factor)	6B	20 or 13+5 (0.057)	21 or 13+10 (0.045)	21 or 20+5ci or 13+10ci or 0+15ci (0.045)	h-ft²-°F/Btu (Btu/h-ft²-°F)
	Mass wall R-value (U-factor)	6B	15/20 (0.060)	15/20 (0.060)	15/20 (0.060)	h-ft²-°F/Btu (Btu/h-ft²-°F)
	Ceiling R value (U-factor)	6B	49 (0.026)	49 (0.026)	60 (0.026)	h-ft²-°F/Btu (Btu/h-ft²-°F)
R404.1	Lighting equipment	6B	75	90	100	% high efficacy
R402.1	Floor R-value (U-factor)	6B	30 (0.033)	30 (0.033)	30 (0.033)	h-ft²-°F/Btu (Btu/h-ft²-°F)
	Basement wall R-value (U-factor)	6B	15/19 (0.050)	15/19 (0.050)	15ci or 19 or 13+5ci (0.050)	h-ft²-°F/Btu (Btu/h-ft²-°F)
	Slab R-value and depth	6B	10, 4 ft	10, 4 ft	10ci, 4 ft	h-ft²-°F/Btu
	Crawlspace wall R-value (U-factor)	6B	15/19 (0.055)	15/19 (0.055)	15ci or 19 or 13+5ci (0.055)	h-ft²-°F/Btu (Btu/h-ft²-°F)
R403.3.4	Duct leakage (prescriptive)	6B	4	4	4	ft3/min per 100 ft² of CFA at 25 Pa

2 Methodology

Overview

Based on the DOE's Residential Building Energy Code Field Study: Data Collection & Analysis, the following seven key variables were assessed for code compliance:

- Envelope tightness (ACH at 50 Pascals)
    - For envelope tightness, the study provides statewide findings as well as findings for urban and rural jurisdictions separately. NEEA requested this breakout to understand how code compliance may differ between urban versus rural areas.
- Windows (U-factor & solar heat gain coefficient).
- Wall insulation (assembly U-factor).
- Ceiling insulation (R-value).
- Lighting (percent high efficiency).
- Foundation insulation (including floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation; R-value).
- Duct tightness (expressed in cfm per $100ft^2$ of conditioned floor area at 25 Pascals).

To complete the statewide savings calculations, two additional required data points were:

- Heating type: electric resistance, gas furnace, oil furnace, or heat pump.
- Foundation type: slab, crawlspace, heated basement, unheated basement.

On-Site Inspections

The on-site data collection followed DOE's Residential Building Energy Code Field Study: Data Collection & Analysis. Highlights of the DOE methodology for single-family residential buildings include[9]:

- Results based on an energy metric and reported at the state level.
- A focus on individual energy efficiency measures within new single-family homes.
- Data confidentiality built into the experimental design – no identifiable data is shared.
- Sample designed around a single site visit prioritizing key items.
- Sample designed with statistically significant results in mind at the state-wide level.

The fieldwork prioritized the seven key code elements listed above, while collecting as much additional information as possible from each site.

DOE's methodology requires at least 63 observations of each of the key items with the observations distributed across the area to reflect recent construction activity. **Appendix A** provides the sample plan used in the current study. The team selected the sample plan from among the 10 sample plan options provided by DOE, with input from a Technical Advisory Group (TAG) convened by IEc and

[9] Residential Building Energy Code Field Study: Data Collection & Analysis Methodology. September 2022. https://www.energycodes.gov/sites/default/files/2022-09/bto-Res-Field-Study-Methodology--updated.pdf

NEEA.[10] After discussion, the TAG decided to include two-family dwellings and townhouses in the study along with single-family detached homes.[11]

The DOE methodology allows one site visit per home. As homes are in varying stages of construction when inspected (rough-in or final), the total number of homes inspected is always larger than the minimum number of observations required, as data on all seven required items will not be available for collection during any given inspection due to the varying phase at which they can be observed. The team conducted a total of 143 inspections to obtain at least 63 observations for each key measure.

Interviews

Overview

To help provide ground-truthing for the on-site results, and as a supplemental source of information to give insight into code compliance across the State, the team conducted interviews with five code officials and five builders across Montana. The interviews focused on asking builders and code officials about the following topics:

- Difficulties builders face in complying with the seven key measures or any other aspects of the energy code (for example, costs of obtaining materials, installation costs, availability of skilled labor, rigor of enforcement of the building energy code, clarity of code requirements, and pressure from homeowners).
- How compliance/permitting process differs across jurisdictions (for builders working in multiple jurisdictions only)
- If building departments have hosted any trainings/workshops or shared materials with builders seeking additional guidance to help with energy code compliance (code officials only)
- Department size (FTEs)/level of effort required for enforcement activities (code officials only)

Sample, Approach, and Limitations

The team worked with NEEA to develop a list of code officials to target for interviews. This list contained a combination of high building activity urban areas (like Missoula, Billings, Bozeman, and Kalispell) and rural, unincorporated areas. The team contacted the full list, albeit with the intent to balance respondents from each of these areas. The team was able to conduct interviews with code officials from five jurisdictions that provided a good balance of urban and rural areas: two large urban areas, two unincorporated areas, and one unincorporated county. The interviews lasted for roughly 20-30 minutes, following the interview guide that the team developed in collaboration with NEEA.

The team contacted over 20 builders and was able to achieve the target of five interviews. Recruitment was slow, and although the team tried to prioritize builders working across the state

[10] Convening a TAG is a standard recommended step in DOE's methodology. TAG participants for this study included representatives from the Montana Homes Collaborative, Montana State University, the Montana State Department of Labor and Industry, Montana Department of Environmental Quality, PNNL, and the city of Bozeman.

[11] The DOE methodology allows for these homes to be included in the sampling frame if TAG members agree they are a substantial part of new construction. Using U.S. Census Building Permit data, the team determined that these made up a substantial share of the new housing market in the cities of Bozeman and Billings and included a share of these homes in the sample relative to overall permits issued (Three of 13 observations in Bozeman and one of 12 in Billings).

and in different markets, builders who typically built high performance homes were more responsive. As a result, three of the five respondents self-identified as high-performance home builders. The builders the team was able to interview were recruited after being recommended by contacts at NEEA, and at the Montana Department of Environmental Quality (DEQ). Each interview took approximately 20 minutes to complete, and builders were provided with a $175 incentive.

Permit Data and Limitations

Prior to implementing DOE's field methodology (on-site inspections), the team initially set out to gather and review single family residential new construction permits to inform an estimate of code compliance for the seven key measures identified above. This approach included a planned review of available permit data in both urban and rural areas (70 permits from each for a total of 140) to address any key differences between these geographic groups, where urban areas are defined as those designated as incorporated by the U.S. Census and rural defined as unincorporated areas. Because NEEA and the team wanted to explore the possibility of conducting the study relying primarily on permit data, the team began these permit review efforts in the spring of 2023, one year prior to conducting the full on-site inspection approach which informs the results presented in this study.

Ultimately, the team contacted 21 jurisdictions selected from the permit sample. Of these jurisdictions, eight did not respond or provide any data, seven provided data with only pass/fail information and no values, five had no local code enforcement, and one provided data with values for key measures. Because of the issues, described in greater detail below, and the lack of usable permit data from the largest/fastest growing jurisdictions in the state (Gallatin County, which does not have local enforcement, and the cities of Billings, Bozeman, Missoula, and Missoula County, all of which have data that does not contain energy code values), the team and NEEA determined that it is not feasible to assess code compliance in Montana using permit data.

Lack of Building Permit Data in Unenforced Areas: After drawing an initial sample, the team began outreach to jurisdictions in Montana to obtain permit data. Initial responses from two of the most active areas for new construction in the state, Yellowstone County (home to Billings) and Gallatin County (home to Bozeman), revealed that although the large cities in each County issue building permits, building permits are not issued in the unincorporated areas of these Counties. Newly built homes outside of locally enforced areas are required only to receive electrical and plumbing permits, both of which are overseen by the Montana Department of Labor and Industry (DLI). Upon receiving this information, the team reached out to contacts in the Environmental Standards Division at the DLI, along with the Montana DEQ, both of whom confirmed that local jurisdictions are not required to enforce building codes and shared that this limitation also applies to many smaller cities, towns, and unincorporated county areas across the state. Both contacts also confirmed that because the State law requires new homes to be built to code, regardless of local enforcement status, builders would be liable if a home was found not to meet code. However, the State does not conduct inspections for energy code compliance at homes in areas without local enforcement, so this is largely unenforced.

The team found that 41 jurisdictions in Montana enforce the building code locally. This represents just under half (47%) of the 87 localities where the Census data indicated building activity occurred over the past three years.[12] Homes in jurisdictions without local enforcement represented 32%of the IEc-drawn sample for planned permit reviews. The team asked contacts at both the Montana DEQ and DLI for their thoughts on code compliance in areas with no local enforcement and sought to understand whether there were any ways to obtain data about these homes without conducting site visits. While both indicated that they generally thought homes were being built to code due to most builders working in some areas with enforcement (who would presumably follow similar practices in unenforced areas), they also expressed some uncertainty about practices in rural areas. Each contact acknowledged, however, that confirming this hypothesis would be difficult without permit data or site visits.

Lack of Energy Data Contained in Permits: Of the eight jurisdictions that provided permit data or had data that were publicly available online, seven jurisdictions do not track specific values (for example, R-values for insulation) when issuing permits. Rather, these jurisdictions track only whether a home passed or failed inspection for key measures. Because the team require actual values to model statewide building practices, these permits do not provide enough information to be used in the analysis.[13]

Several of the jurisdictions with the highest building activity in Montana lack energy data within their permits including the cities of Billings, Bozeman, Missoula, and Whitefish, along with Missoula County. Follow-up conversations with officials in two cities indicated that these cities do not keep records of specific energy values from on-site inspections. Only one jurisdiction provided data showing the actual values from inspection results.

Lack of Response: Despite multiple email and phone requests, several jurisdictions provided either no response or a lack of definitive response to the team's requests for permit data (for example, one code official indicated that they needed to further discuss whether they could provide data but did not follow up). In some cases, building officials indicated that they were the sole employee of the jurisdiction's building department and therefore struggled to find time to complete this task. Non-responding jurisdictions represented eight out of 21 jurisdictions contacted. While these were generally smaller entities that did not make up a substantial percentage of the overall permit sample list (16%), these areas represent an important piece of the market in Montana as building practices may be different in smaller localities than larger, more populated, areas with greater resources to use towards code enforcement.

Data Analysis

Following the DOE methodology, data analysis was split into three phases, which are described in the following sections:

- **Statistical analysis** assess compliance at the individual measure level.
- **Modeling analysis** to estimate the energy consumption of both an observed and code-compliant population of homes.

[12] The 87 localities included in the Census data comprise all incorporated cities/towns and unincorporated county areas where electrical permits were issued for new home starts over the past three years. The state of Montana and Census Bureau use these electrical permits to determine the number of new homes because building permits are not issued in unenforced areas.

[13] Although IEc considered attempting to model statewide compliance and building practices based on pass/fail rates in the building permits, the team determined that this approach would not accurately capture building practices, because any "failures" in the permits require builders to fix the issue to obtain a passing rating (that is, by design there should be no failing measures in permit data, and if there were these could not be considered final).

- **Savings analysis** to project the potential savings with improved energy code compliance relative to the 2018 and 2021 IECC with Montana amendments.

Statistical Analysis

The statistical analysis assessed compliance at the individual measure level based on observations from the on-site data sets. Observed distributions were plotted on histograms for each of the key measures. In addition, summary tables provide information on the range, average, and compliance rates for the key measures at the statewide levels. The histograms and summary tables provide insight into the prevalence of installed measures and the range of below-code and above-code observations, which can help identify areas for improvement.

Energy Analysis

Following the DOE methodology, this study uses an energy metric to assess compliance. As described in DOE's 2022 *DOE Residential Building Energy Code Field Study: Data Collection & Analysis Methodology*, earlier studies only tracked whether a measure complied or not, which did not provide information on the level of noncompliance nor the resulting energy impact. An energy metric provides information on the energy saving potential by measure, which can inform more fine-tuned training and education efforts. As described in the methodology, "An energy metric has the further benefit of allowing the results to be compared against different baseline and across geographic regions, which is of significant interest to utilities, government agencies, and others supporting energy-efficiency programs…. Ultimately, the results are used to identify household savings opportunities, develop more effective and targeted training programs, create, and validate more accurate energy forecasts, inform industry consensus processes, and serve as a baseline for broader energy-efficiency programs and Research and Development (R&D) efforts."

To complete the energy analysis, the measure distributions from the statistical analysis were used as inputs into a large-scale Monte Carlo energy modeling analysis. Monte Carlos are a general group of algorithms that all contain some stochastic element. They are often implemented with calculations where there is uncertainty in input variables, interactions between variables, and/or an interest in doing a sensitivity analysis. For this study, a Monte Carlo analysis was used to simulate a representative sample of potential measure combinations without having full sets of measure inputs from any given home (due to permit data, site visit, and construction schedule limitations).

The team developed a set of custom EnergyPlus models based on PNNL's 2018 and 2021 residential prototype models for the foundations, HVAC types, and climate zones observed in Montana. The team first developed a code-minimum set of models (exactly meeting minimum code requirements). Modeling details are included in the EnergyPlus and OpenStudio section in **Appendix C – Modeling Methodology**. These custom code-compliant models were then used as inputs for the OpenStudio Parametric Analysis Tool to simulate the as-built conditions observed for the key measures.[14] This resulted in upwards of 12,000 simulations within the state. for each code cycle.

The output of this task was a histogram that compares the actual statewide average energy consumption to 2018 and 2021 code-compliant baselines, which mirrors the previous Montana field study. Specifically, a histogram shows the weighted average regulated energy use intensity

[14] OpenStudio uses the EnergyPlus simulation engine and the EnergyPlus files generated can be extracted.

(EUI) of the observed data set compared to the expected weighted average regulated consumption based on homes that exactly met the prescriptive code requirements.[15]

Savings Analysis

The statistical analysis identified key measures that frequently did not meet code requirements. The savings analysis estimated the potential savings if these measures were brought to compliance. Potential savings were calculated for each of these measures individually. Another set of models was analyzed to compare the code-compliant EUI to that of a building where all measures are compliant except for the individual measure being studied. The difference in energy use represents the savings potential of increased compliance for that measure. The savings analysis reported the potential energy savings at the level of the individual home and statewide, as well as statewide energy cost and emissions savings if the measure was brought to compliance. Savings were weighted using construction starts to obtain the average statewide energy savings potential. In addition, Montana-specific fuel prices and emission factors were used to calculate the potential energy cost and emission savings. Details on the energy cost and emission factor assumptions are included in the Montana Fuel Prices and Emission Factors section in Appendix C.

Limitations

In general, the data collected for each individual home is an incomplete data set, so it is not possible to determine whether individual homes are compliant. As discussed above, this study relies on an energy compliance metric instead.

The prototype Monte Carlo modeling approach means that no individual homes were modeled. As a result, site-specific variables such as size, height, orientation, window area, and floor-to-ceiling height are not included in the analysis. Further, these variables are not a component of the Montana code.

The savings analysis methodology does not account for interactive effects between measures. However, isolating the savings potential by measure will help stakeholders to prioritize where they should focus their efforts to increase compliance. As an illustrative example of interactive effects, high-efficacy lighting lowers the lighting energy use, but it can also result in higher heating and lower cooling demand. As noted in the *DOE Residential Building Energy Code Field Study,* "In a typical real building, the savings potential might be higher or lower; however, additional investigation indicated that the relative impact of such interactions is very small and could safely be ignored without changing the basic conclusions of the analysis."

Following the completion of the Monte Carlo analysis, but prior to the finalization of this report, a member of the field inspection team self-identified an error in how they had classified some lightbulbs during their fieldwork (namely, mistaking new generation clear-glass LED lightbulbs for incandescent bulbs). The team reviewed photos for the 26 homes where the inspector called their own results into question and determined if/when bulbs had been misidentified at 24 of these homes. In the two cases where the correct types of bulbs could not be confirmed from the photos, the team replaced these observations with extra lighting data collected at other homes that were not initially used in the 63 modeled lighting observations. The team conducted an analysis to determine the maximum impact of the new lighting observations on statewide compliance, and found that the new, higher rate of LEDs in the data would affect the overall EUI and the statewide

[15] Regulated end uses include heating, cooling, lighting (interior + exterior), fans, and domestic hot water. The weights were defined by the frequency of field-observed heating system and foundation type combinations (which is how the PNNL prototype files are differentiated).

compliance rate by less than one percent. Given the small magnitude of the change, the team and NEEA decided to apply a post-modeling adjustment to the modeled EUI/savings and statewide compliance rate rather than reconduct the modeling analysis. All values in this report include the adjustment, and lighting-specific histograms have been updated to show compliance based on the corrected lighting values.

Finally, following the completion of data analysis and modeling, the team identified three homes that may have been permitted under the 2018 IECC code with Montana amendments (the prior version of the code, which was replaced by the 2021 IECC with Montana amendments in mid-2022). Upon closer review, the team found that one of these homes was permitted under the 2021 code, one under the 2018 code (with a permit issued less than a month before the code change), and was unable to determine when the third was permitted. The team assessed the measures used in the analysis at the 2018 and uncertain code year homes. The analysis did not include any data from measures where the requirements changed between the 2018 and 2021 code (ceiling insulation and lighting requirements) at the uncertain code year home, but did include ceiling insulation from the 2018 home. At this home the ceiling insulation met the 2018 code requirements but not the 2021 code requirements.

3 Compliance Results

Statistical Analysis Results

Key observations from the analysis of data collected from 143 homes include:

- Overall, compliance results are similar under the 2018 and 2021 IECC with Montana amendments.
- Compared to the compliance rates under the 2012 IECC with Montana amendments, under the 2018 and 2021 IECC with Montana amendments:
  - Compliance rates continue to be high (>95%) for window U-factor, wall R-value, and unvented crawl wall R-value.
  - Compliance rates continue to be low (<50%) for wall U-factor and slab edge R-value.
  - Compliance rates increased for envelope tightness and basement wall U-factor.
  - Compliance rates decreased for ceiling R-value, unvented crawl U-factor, and adjusted duct tightness.
  - Most measures had similar average efficiency levels when looking at the observed values for each measure.[16] However, efficiency levels decreased for ceiling insulation R-values and duct tightness, while they increased for envelope tightness and basement wall U-factor.
  - Overall compliance has notably decreased.
- Areas for improvement include wall insulation installation quality (IIQ), ceiling insulation amount and IIQ, basement wall insulation amount and IIQ, unvented crawl wall IIQ, slab insulation amount, and duct tightness.

About half of the individual observations were compliant with the 2018 and 2021 IECC with Montana amendments. In comparison, in the previous study about two thirds were compliant with 2012 IECC with Montana amendments. However, since the data collected for each individual home is an incomplete data set, it is not possible to determine whether the homes are compliant as a whole from the individual observations. As noted above, this study relies on an energy compliance metric instead. In the current study, 86% of the individual energy models were code-compliant under the 2018 IECC with Montana amendments and 84.7% were compliant under the 2021 IECC with Montana amendments. In comparison, the previous study showed 94.4% compliance under the 2012 IECC with Montana amendments. The EUI for a "typical" home under the 2018 IECC with Montana amendments uses about 10.6% more regulated energy than a code-compliant home. Under the 2021 IECC with Montana amendments, the average home uses about 12% more energy than a code-compliant home. In comparison, the previous study found that typical homes used about 2% more regulated energy than a code-compliant home under the 2012 IECC with Montana amendments. The current study shows a notable decrease in compliance as compared to the previous study. The driving factors here are more stringent codes, decreased compliance in four key measures, and decreased performance for two key measures.[17] These results are discussed

[16] Compliance rates quantify the percentage of observations that meet or exceed the prescriptive requirements. This is a binary metric. Efficiency levels consider the range and average of the on-site observations.

[17] Compliance rates quantify the percentage of observations that meet or exceed the prescriptive requirements. This is a binary metric. Performance considers how the observations affect overall efficiency by looking at the range and average.

further in the **Energy Analysis Results** and the **Comparison to the 2012 IECC with Montana Amendments** sections below.

Table 2 summarizes the number of observations for each key item. More detailed results for each of these key measures are included in the sections below.

Table 2. Observation counts

Measure	Observations
Envelope Tightness	63
Window SHGC	61
Window U-factor	63
Wall Insulation R-value	61
Wall Insulation U-factor	63
Ceiling Insulation R-Value	63
Ceiling Insulation R-Value	63
Lighting	63
Floor insulation R-value	N/A
Floor insulation U-factor	N/A
Basement wall R-value	14
Basement wall U-factor	14
Unvented Crawl R-value	44
Unvented Crawl U-factor	44
Slab Edge R	5
Raw Duct Tightness	63
Adjusted Duct Tightness	63

Foundation, Space Heating, and Domestic Hot Water Types

The three foundation types observed in Montana were unvented crawlspaces (63.1%), slab on grade (19.2%), and heated basements (17.7%), as shown in **Table 3**. In the previous study, foundations were also a mix of unvented crawlspaces (55%), heated basements (32%), and slab on grade (13%).

Table 3. Montana foundation types

Foundation Type	Statewide
Unvented Crawlspace	63.1%
Vented Crawlspace	0.0%
Slab	19.2%
Basement	17.7%

Natural gas furnaces represented 86.5% of the heating systems. The remaining 13.5% of the heating systems were electric, 7.9% heat pump, 3.2 electric resistance, and 2.4% were unknown, as shown in **Table 4**. In the previous study of the 2012 IECC with Montana Amendments, only 2% of the heating systems were electric, so this is a notable shift toward electric systems. The heating types in the previous study were 96% gas furnaces, 2% gas boilers, and 2% electric heat pumps.

Table 4. Montana space heating fuel source and type

Space Heating		Statewide
Fuel Source	Gas	86.5%
	Electric	13.5%
Type	Gas Furnace	86.5%
	Electric Heat Pump	7.9%
	Electric Resistance	3.2%
	Electric Unknown[18]	2.4%

Forty percent of the domestic hot water (DHW) systems use natural gas, while 59.8% are electric, as shown in **Table 5**. Seventy-eight percent of the observations are tank systems and 22% are tankless systems. Of the 55 electric DHW systems, only one is a heat pump. In the previous study of the 2012 IECC with Montana Amendments, 64% of the DHW systems were gas, 36% were electric, and only 5% of these systems were tankless. So, there was a 24% shift from gas to electric and a 17% shift toward tankless systems. None of the DHW systems were heat pumps in the previous study.

Table 5. Montana DHW fuel source and type

Domestic Hot Water		Statewide
Fuel Source	Gas	40.2%
	Electric	59.8%
Type	Tank	77.8%
	Tankless	22.2%

Key Elements

The following sections include histograms and summary tables for the key measure observations. **Figure 1** shows the elements of an example histogram. The x-axis shows the value of the key measure metric observed, while the y-axis shows the number of observations with that value. The box in the upper right shows the total number of observations and the statewide distribution average. The vertical dotted lines show the code requirement, which is also noted in a summary table below each histogram.

For insulation observations, two sets of results are shown throughout the results section. The first is the wall R-value and the second is the expected assembly U-factor, which also accounts for the IIQ grades observed on-site. IIQ is discussed in more detail in Impact of Insulation Installation Quality section. The R-value results indicate whether the correct R-value insulation is installed. The U-factor results show whether the combination of the installed R-value and the IIQ grade meet the U-

[18] For these observations, site visits confirmed that an electric heating system would be installed, but the final type was not observable.

factor requirements. Non-compliance for insulation may result from the wrong amount of insulation, improper installation, or a combination of both.

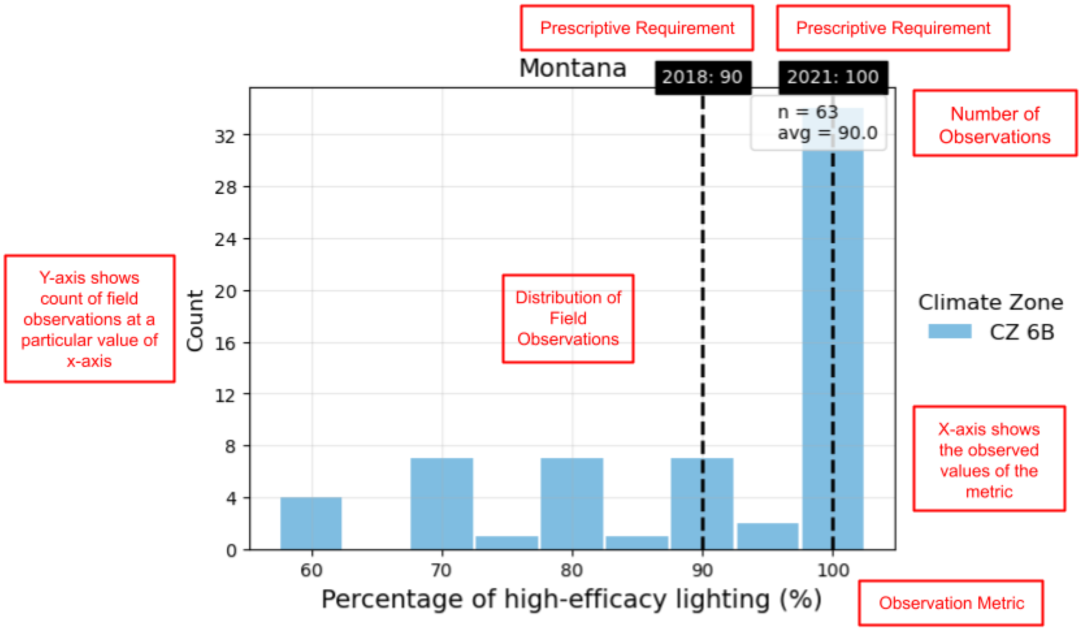

Figure 1. Example histogram

Envelope Tightness

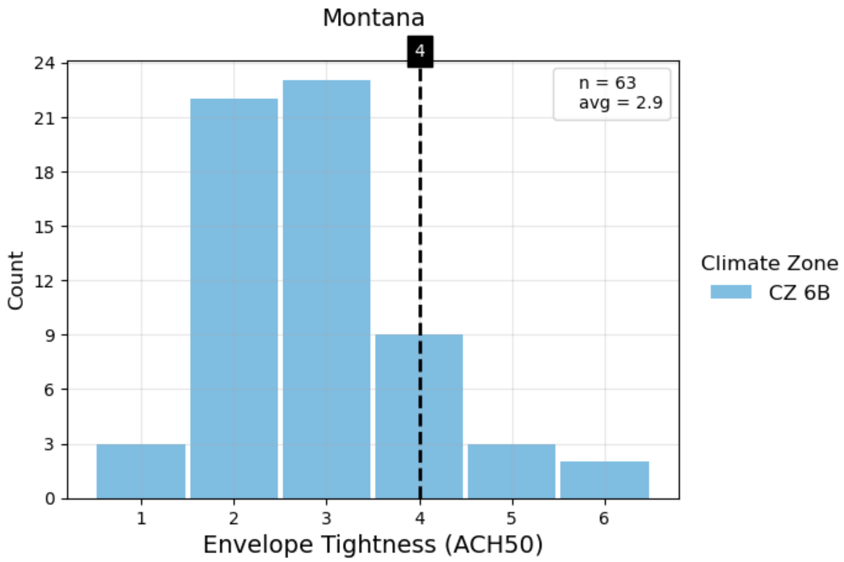

Figure 2. Envelope tightness (ACH50)

Table 6. Envelope tightness (ACH50)

Climate Zone	CZ6
Number	63
Range	1.0 to 6.6
Average	2.9
Requirement	4
Compliance Rate	53 of 63 (84%)

Interpretations:

- Eighty-four percent of the observations met or exceeded the prescriptive code requirement for envelope tightness.
- The distribution shows significantly lower air leakage (tighter envelope) than expected based on the current code requirement, with a statewide average of 2.9 ACH as compared to the required 4 ACH. The observations ranged from 1 to 6.6 ACH.
- In the previous study of the 2012 IECC with Montana amendments, envelope tightness was 73% compliant with a range of 1.4 to 4.6 and an average of 3.5 ACH50. So, the rate of compliance increased, and the average envelope is tighter than the previous study.

As noted above, NEEA also wanted to assess whether air tightness compliance rates differ between urban (within city limits) and rural (outside of city limits) jurisdictions. This was to address anecdotal reports suggesting differences in envelope tightness between urban and rural areas.

In the chart and table below, the same data set is separated by urban versus rural homes. Eighty-eight percent of the urban homes were compliant, while 76% of the rural homes were compliant, so there is a small difference in envelope tightness compliance for rural and urban homes in this set of observations. However, there are twice as many urban homes as rural homes, and in both the rural and urban sets, only five homes were non-compliant. In both the rural and urban sets, the average ACH is 2.9 and the range is similar.

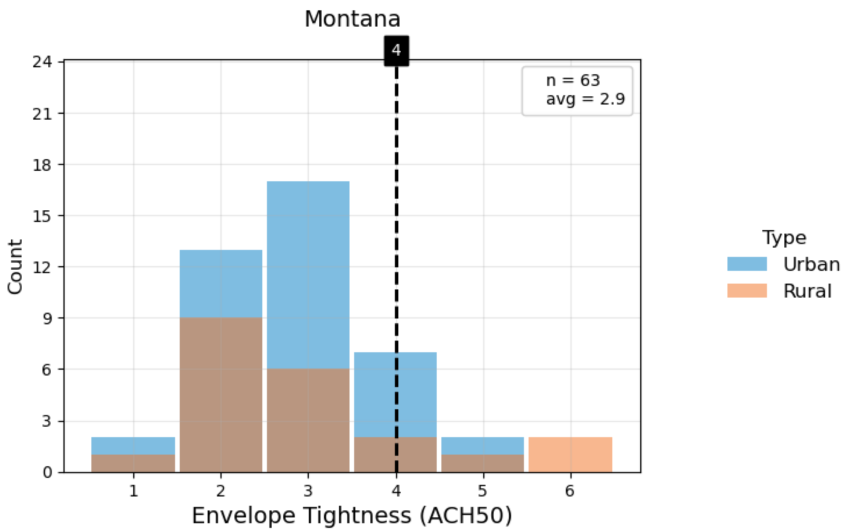

Figure 3. Envelope tightness (ACH50) in urban versus rural homes

Table 7. Envelope tightness (ACH50) in urban versus rural homes

Type	Urban	Rural	Statewide
Number	42	21	63
Range	1.2 to 6.6	1.0 to 6.0	1.0 to 6.6
Average	2.9	2.9	2.9
Requirement	4	4	4
Compliance Rate	37 of 42 (88%)	16 of 21 (76%)	53 of 63 (84%)

Windows

U-factor

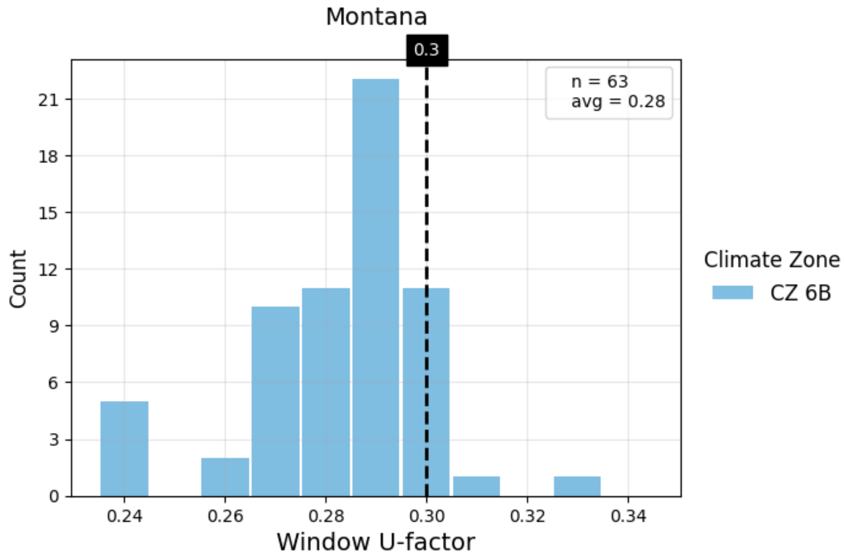

Figure 4. Window U-factor

Table 8. Window U-factor

Climate Zone	CZ6
Number	63
Range	0.24 to 0.33
Average	0.28
Requirement	0.30
Compliance Rate	61 of 63 (97%)

Interpretations:

- As noted above, window U-factor became more stringent under the 2018 IECC with Montana amendments and remained that way under the 2021 IECC with Montana amendments (0.32 to 0.30 Btu/h-ft^2-°F).
- Even with the stricter requirements, 97% of the observations met or exceeded the prescriptive code requirement. The average window U-factor was 0.28 and the range was 0.24 to 0.33 Btu/h-ft^2-°F.
- These results are very similar to the previous study of the 2012 IECC with Montana amendments where this measure was 96% compliant with an average of 0.29 and a range of 0.24 to 0.34 Btu/h-ft^2-°F.

Solar Heat Gain Coefficient

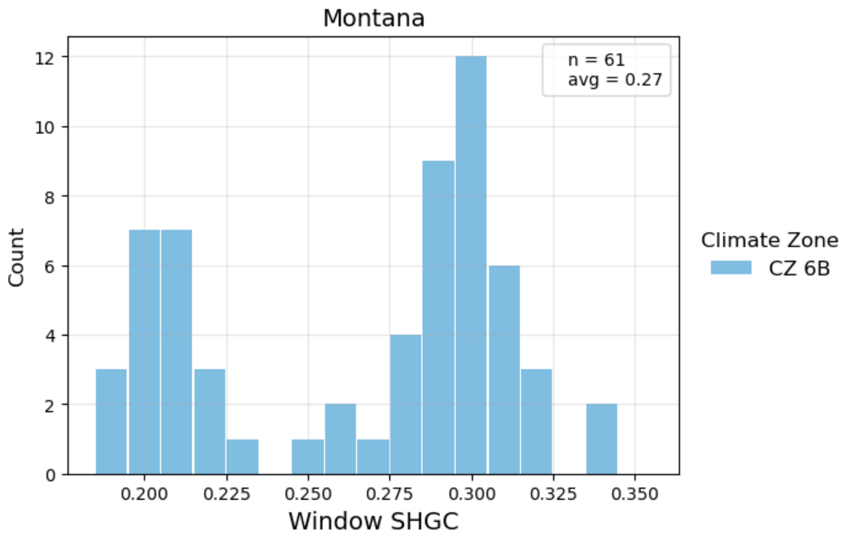

Figure 5. Window SHGC

Table 9. Window SHGC

Climate Zone	CZ6
Number	61
Range	0.19 to 0.34
Average	0.27
Requirement	NR
Compliance Rate	NA

Interpretations:

- There is no SHGC requirement in Montana or in the IECC for CZ6, but as a point of comparison, the prescriptive requirement under the 2018 and 2021 IECC is 0.25 in CZs 1-3 and 0.40 is CZ4 (except marine).
- The window SHGC values ranged from 0.19 to 0.34 with an average of 0.27.

- These results are similar to the previous study of the 2012 IECC with Montana amendments. SHGC values ranged from 0.19 to 0.54 with an average of 0.27.

Wall Insulation

For insulation observations throughout the results section, two charts are shown. The first is the R-value and the second is the expected assembly U-factor, which also accounts for the IIQ grades observed on-site.

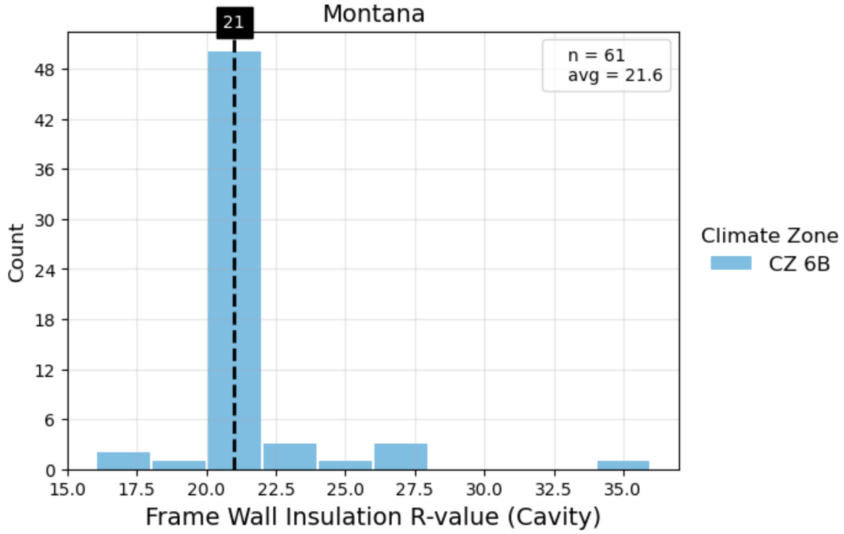

Figure 6. Wall R-values

Table 10. Wall R-values

Climate Zone	CZ6
Number	61
Range	18 to 34
Average	21.6
Requirement	21
Compliance Rate	58 of 61 (95%)

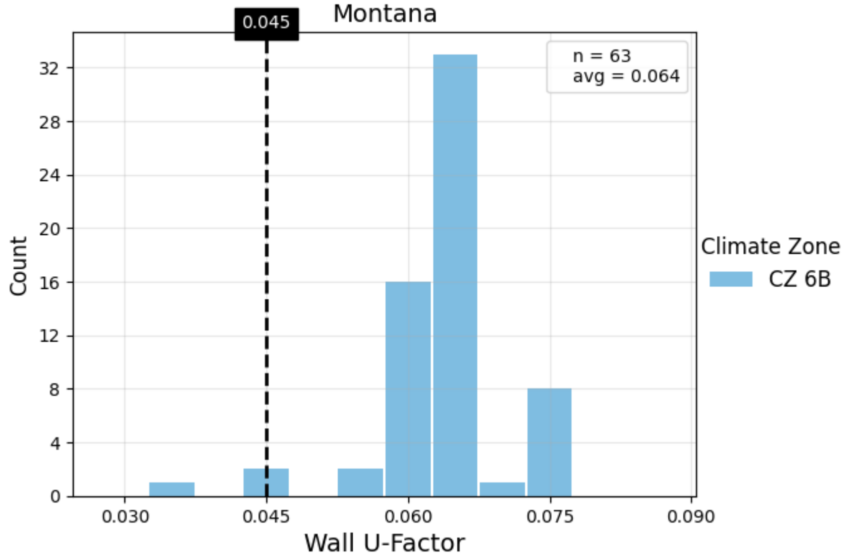

Figure 7. Wall U-factor

Table 11. Wall U-factor

Climate Zone	CZ6
Number	63
Range	0.033 to 0.076
Average	0.064
Assembly U-Factor (expected)	0.045
Compliance Rate	1 of 63 (2%)

Interpretations:

- As noted above, wood-frame wall U-factors became more stringent under the 2018 code updates and remained that way under the 2021 updates (0.057 to 0.045 Btu/h-ft^2-°F). For wood-framed walls, IECC requires either R-20+5 or R-13+10, both with a U-factor of 0.045. In both versions of the code, Montana amended this to allow R-21 but kept the U-factor at 0.045. Based on IECC's "Table RF102.1 Assembly U-Factors for Wood Frame Walls" no R-21 construction would meet the U-factor requirement. The currently observed R-21 constructions would be 0.058, which would meet the R-value requirement, but not the U-factor requirement.
- Ninety-five percent of the observations met or exceeded the prescriptive code requirements for wall insulation R-value, but only 2% of the U-factors did.[19] The average cavity R-value was 21.6 and the average U-factor was 0.064. The low U-factor compliance is due to two factors. First, the majority of homes selected the R-21 option, which met the prescriptive R-value requirement, but not the prescriptive U-factor requirement. Second, nearly three quarters of the wall IIQ observations were Grade II or III, which resulted in lower U-factors.
- In the previous study of the 2012 IECC with Montana amendments, all the observations met or exceeded the prescriptive R-value requirement, but only 3% of the U-factor observations

[19] Two wall assemblies used continuous insulation, so there are 63 U-factor observations, but only 61 cavity R-value observations.

did. In all non-compliant cases, the IIQ was Grade II. The average U-factor was 0.063 Btu/h-ft²-°F.

- Wall insulation installation quality is an area for improvement.

Ceiling Insulation

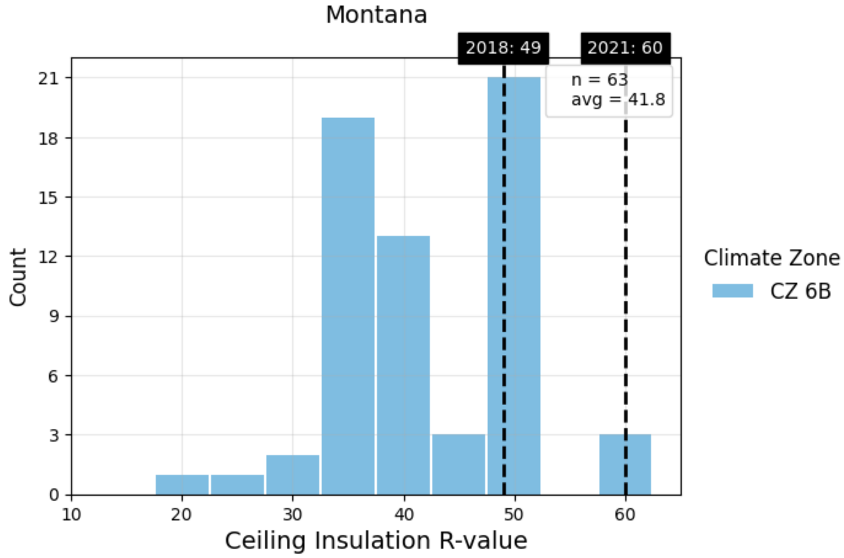

Figure 8. Ceiling R-value

Table 12. Ceiling R-value, 2018 and 2021

Climate Zone	CZ6	Climate Zone	CZ6
Number	63	*Number*	63
Range	19 to 60	*Range*	19 to 60
Average	41.8	*Average*	41.8
Requirement	49	*Requirement*	60
Compliance Rate	24 of 63 (38%)	*Compliance Rate*	3 of 63 (5%)

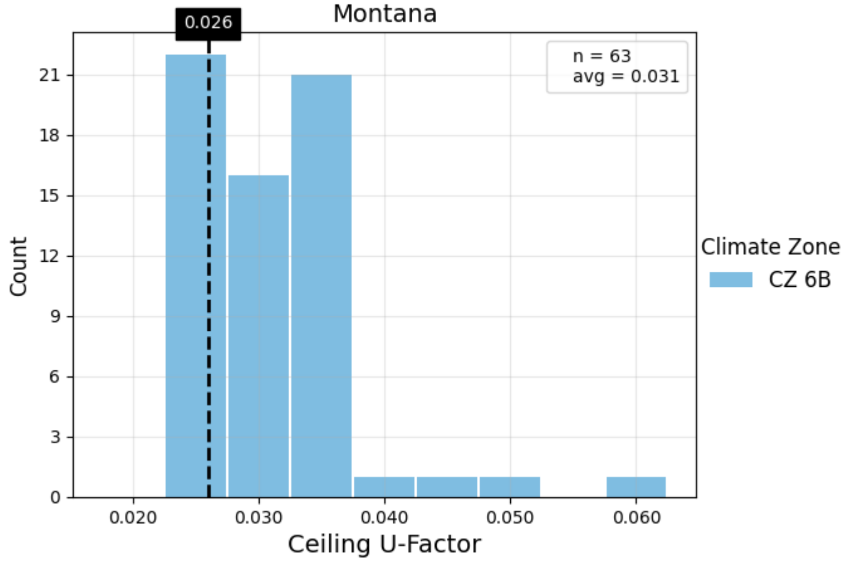

Figure 9. Ceiling U-factor

Table 13. Ceiling U-factor

Climate Zone	CZ6
Number	63
Range	0.024 to 0.060
Average	0.031
Assembly U-Factor (expected)	0.026
Compliance Rate	22 of 63 (35%)

Interpretations:

- As noted above, the ceiling R-value requirements increased from R-49 to R-60 under the 2021 IECC with Montana amendments, while the U-factor remained the same (0.026). In contrast to the wall insulation amendment, the ceiling U-factor is less stringent than the ceiling R-value.
- The average R-value was R-41.8 and ranged from R-19 to R-60. These observations would be 38% compliant under the 2018 IECC with Montana amendments and 5% compliant under the 2021 IECC with Montana amendments. Thirty-five percent of the U-factor observations were compliant. Forty-four percent of the IIQ observations were Grade II and III. So, both the amount of ceiling insulation as well as the installation quality are likely areas for improvement.
- In the previous study of the 2012 IECC with Montana amendments, ceiling insulation was 100% compliant for the R-value and 97% compliant for the U-factor. All of the R-value observations were either R-49 or R-50, with an average of R-49.3, and 97% of the IIQ observations were Grade I.
- It is unexpected that the average ceiling insulation R-value decreased from R-49.3 in the previous study to R-41.8 in the current study. One possible explanation is that more than half of the observations measured the blown-in insulation depth and then multiplied that by an assumed R-value per inch to determine the total R-value. In contrast, since all of the observations in the previous study were exactly R-49 or R-50, it is likely that these were not

calculated estimates (for example, they may have been labeled batts insulation). In the current study, the team assumed R-2.2 per inch for blown fiberglass and 3.1 per inch for blown cellulose in the attic, which follows the PNNL Commercial Field Guide. These may be conservative estimates. In the 2021 ASHRAE Handbook of Fundamentals Table 26.8, the R-value of loose-fill glass fiber (in attics greater than 12 inches) ranges from 2.7 to 2.8, while cellulose ranges from 3.6 to 3.7. If the midpoint of the ASHRAE ranges were used instead, the average R-value would increase from R-41.8 to R-46.7.

Lighting

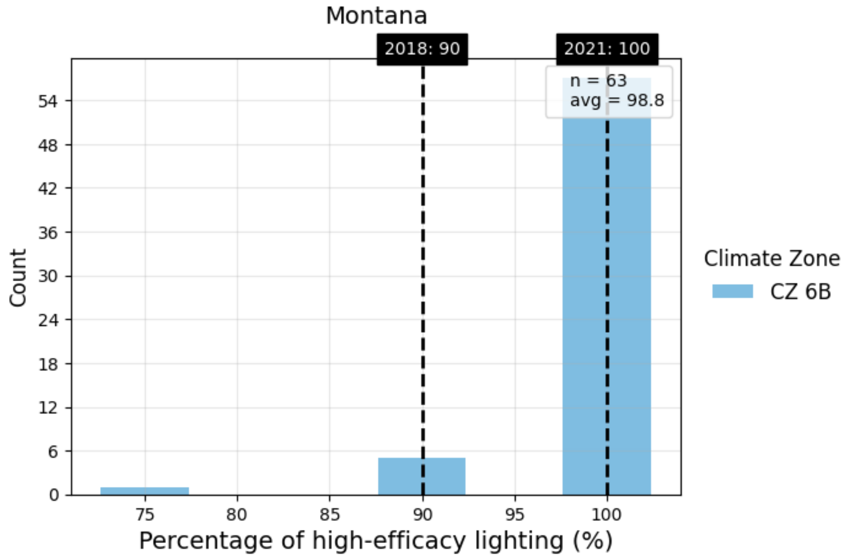

Figure 10. High-efficacy lighting percentage

Table 14. High-efficacy lighting percentage, 2018 and 2021

Climate Zone	CZ6
Number	63
Range	75.0 to 100.0
Average	98.8
Requirement	90
Compliance Rate	62 of 63 (98%)

Climate Zone	CZ6
Number	63
Range	75.0 to 100.0
Average	98.8
Requirement	100
Compliance Rate	57 of 63 (90%)

Interpretations:

- As noted above, the percent of high-efficacy lighting requirements increased with each code cycle (2012 75%, 2018 90%, 2021 100%).
- The 63 observations ranged from 75% to 100% with an average of 98.8% high-efficacy lighting. The results are 98% compliant under the 2018 IECC with Montana amendments and 90% compliant under the stricter 2021 code.
- In the previous study of the 2012 IECC with Montana amendments, this measure was 91% compliant. The average was 91% high-efficacy lighting and ranged from 45% to 100%.

Foundation Insulation

The three foundation types observed in Montana were unvented crawlspaces (63.1%), slab on grade (19.2%), and heated basements (17.7%).

Basement Wall Insulation (Conditioned Basements)

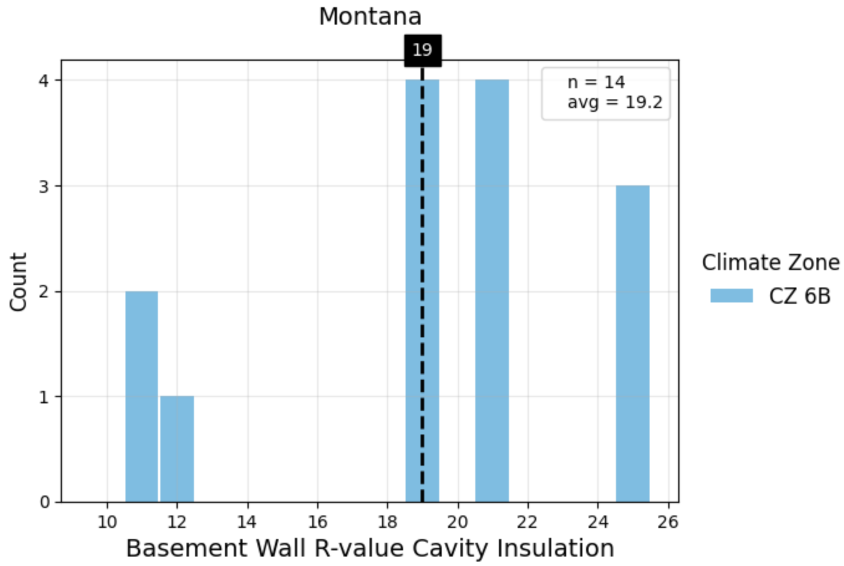

Figure 11. Basement wall R-value

Table 15. Basement wall R-value

Climate Zone	CZ6
Number	14
Range	11 to 25
Average	19.2
Requirement	19
Compliance Rate	11 of 14 (79%)

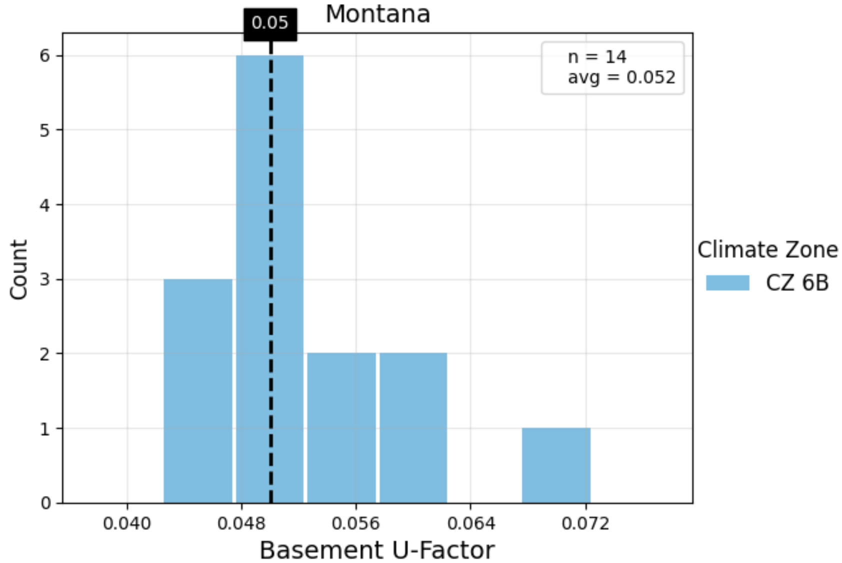

Figure 12. Basement wall U-factor

Table 16. Basement wall U-factor

Climate Zone	CZ6
Number	14
Range	0.046 to 0.068
Average	0.052
Assembly U-Factor (expected)	0.050
Compliance Rate	9 of 14 (64%)

- Basement R-value were 79% compliant. The average basement R-value was R-19.2 and ranged from R-11 to R-25. Basement U-factor were 64% compliant, with an average of 0.052. Of the 14 observations, two were Grade II and one was Grade III.
- In the previous study of the 2012 IECC with Montana amendments, 81% of the R-values were compliant, while only 8% of the U-factors were. For the 37 observations, the average R-value was R-18, and the average U-factor was 0.060. The study found problems with both the IIQ and the amount of insulation.
- Compared to the previous study, both the average R-value and the average U-factor have improved. However, there is still moderate room for improvement in both the amount of insulation and the installation quality.

Unvented Crawlspace Wall Insulation

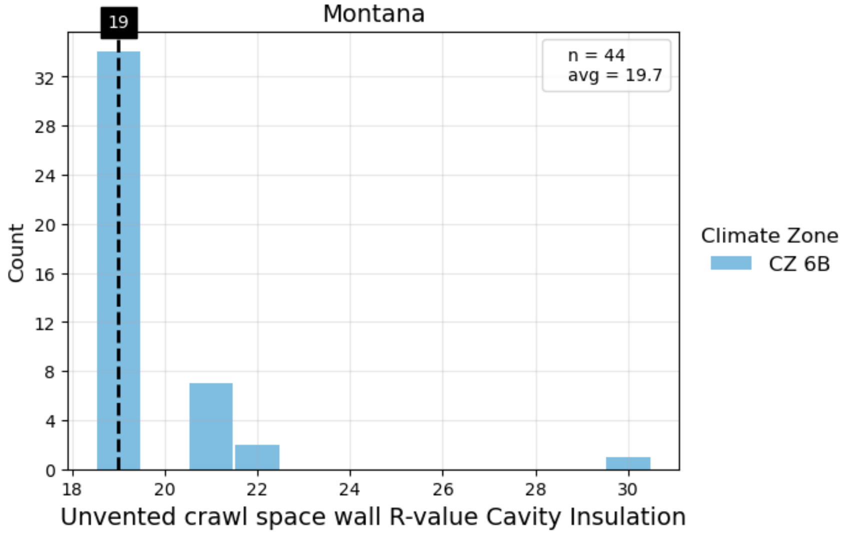

Figure 13. Unvented crawlspace wall R-value

Table 17. Unvented crawlspace wall R-value

Climate Zone	CZ6
Number	44
Range	19 to 30
Average	19.7
Requirement	19
Compliance Rate	44 of 44 (100%)

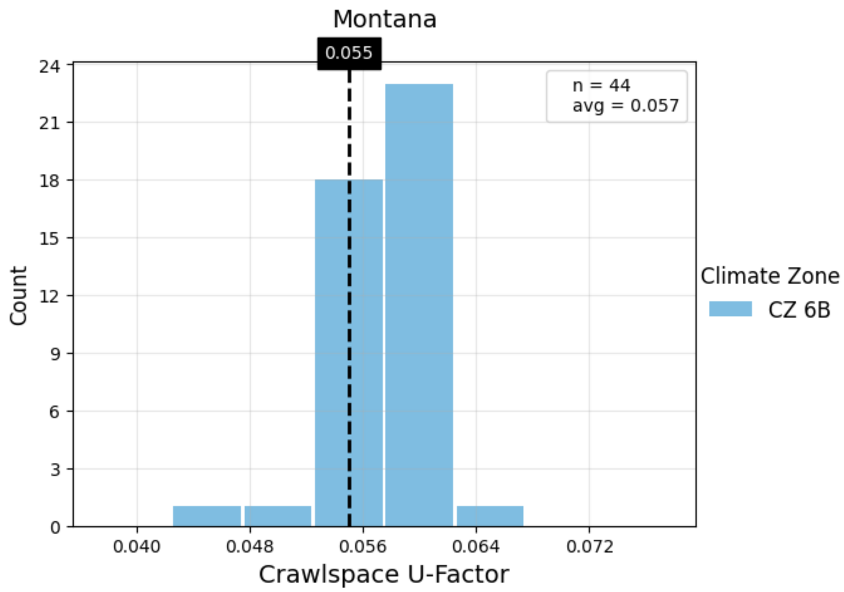

Figure 14. Unvented crawlspace wall U-factor

Table 18. Unvented crawlspace wall U-factor

Climate Zone	CZ6
Number	44
Range	0.047 to 0.067
Average	0.057
Assembly U-Factor (expected)	0.055
Compliance Rate	20 of 44 (45%)

Interpretations:

- All of the unvented crawlspace insulation R-values met or exceeded the prescriptive code requirement, with an average of R-19.7. However, only 45% of the U-factors observations did. This is because more than half of the observations were Grade II or III IIQ. So, the amount of insulation is sufficient, but installation quality is an area for improvement.
- In the previous study of the 2012 IECC with Montana amendments, all of the R-value observations exceeded the prescriptive code requirement and had the same average R-value of 19.7. All of the observations were continuous insulation and IIQ grade was not reported.

Slabs

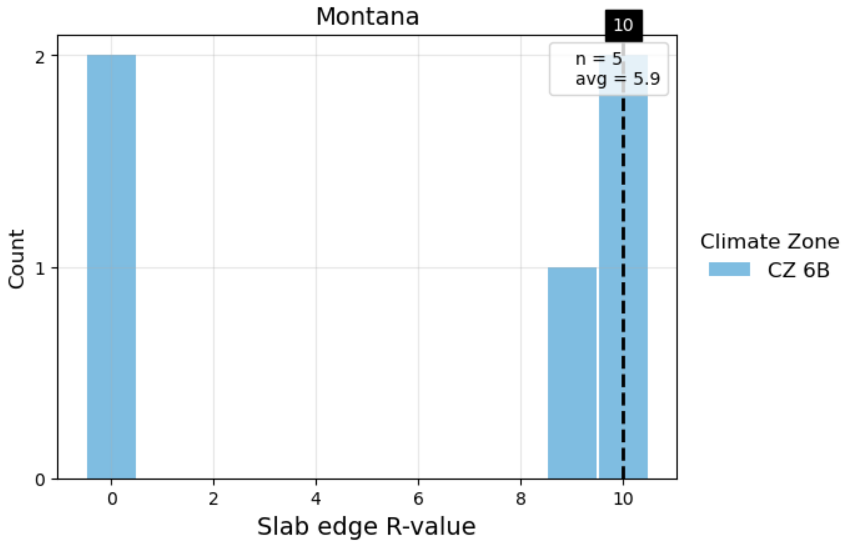

Figure 15. Slab edge R-value

Table 19. Slab edge R-value

Climate Zone	CZ6
Number	5
Range	0.0 to 10.0
Average	5.9
Requirement	10
Compliance Rate	2 of 5 (40%)

Interpretations:

- Forty percent of the slab edge R-value observations were compliant. The values ranged from R-0 to R-10 with an average of R-5.9.
- These results are similar to the previous study of the 2012 IECC with Montana amendments where only half of the six observations were compliant. The slab edge R-values ranged from R-0 to R-10 with an average of R-5.
- The amount of slab edge insulation continues to be an area for improvement.

Duct Leakage

This section summarizes the duct leakage results for both raw duct leakage and adjusted duct leakage. The raw duct leakage is the value observed on-site. Adjusted duct leakage accounts for ducts in conditioned spaces. For ducts entirely in conditioned space, the adjusted duct leakage is set to zero, regardless of the observed on-site value. Tests are not required if the ducts are entirely in conditioned space, so the adjusted duct leakage is the more accurate metric for compliance rates.

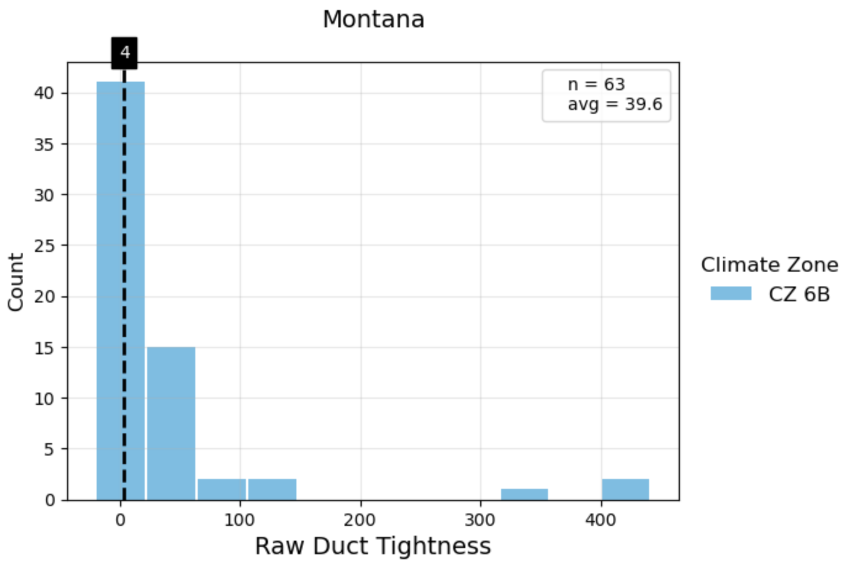

Figure 16. Raw duct tightness

Table 20. Raw duct tightness

Climate Zone	CZ6
Number	63
Range	0 to 418
Average	39.6
Requirement	4
Compliance Rate	6 of 63 (10%)

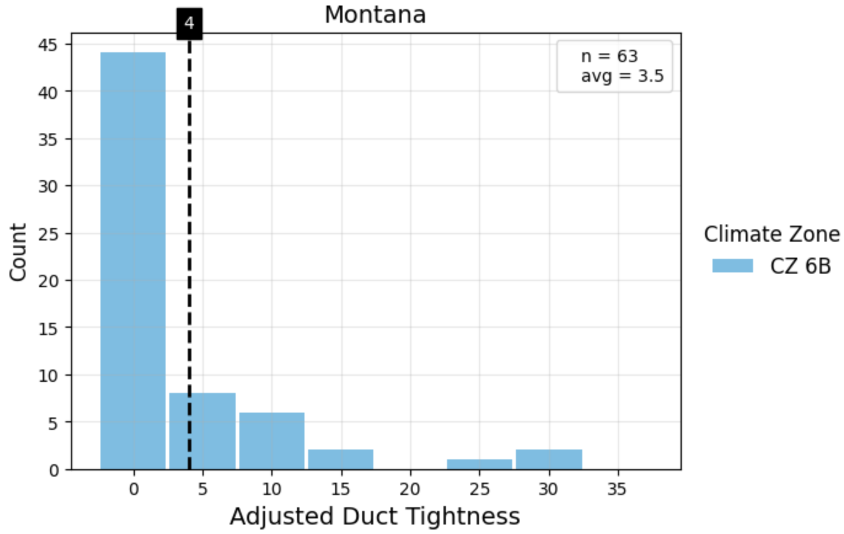

Figure 17. Adjusted duct tightness

Table 21. Adjusted duct tightness

Climate Zone	CZ6
Number	63
Range	0 to 30
Average	3.5
Requirement	4
Compliance Rate	46 of 63 (73%)

Interpretations:

- Seventy-three percent of the adjusted duct tightness observations met or exceeded the prescriptive code requirement. The average was 3.5 and ranged from 0 to 30 CFM 25/100 ft^2. Eight of the observations were completely in unconditioned space and 17 were partially located in unconditioned space.
- In the previous study of the 2012 IECC with Montana amendments, 84% of the adjusted duct tightness observations were compliant. The average was 2.79 and ranged from 0 to 29.2 CFM 25/100 ft^2. Ten of the observations were in unconditioned space.
- Reducing duct leakage in unconditioned spaces continues to be an area for improvement in Montana.

Impact of Insulation Installation Quality

The DOE *Residential Building Energy Code Field Study: Data Collection & Analysis Methodology* states that:

> At the start of the project, IIQ was noted as a particular concern among project teams and stakeholders as it plays an important role in the energy performance of envelope assemblies. However, insulation installation is not a requirement in the model energy codes and is not a key item by itself. Data on cavity IIQ was collected in the field and used in the analyses to modify the energy contribution from ceiling, wall, and foundation insulation.

Table 22 shows the IIQ for the observed envelope assemblies. Forty-five percent of the observations (83 out of 184) are Grade I. Forty-eight percent are Grade II and 7% are Grade III. Based on these results, improved insulation quality is generally an area for improvement in Montana, especially for ceilings, external walls, and unvented crawlspace walls.

Table 22. Insulation installation quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Ceiling	35	25	3	63
External wall	17	38	8	63
Floor over unconditioned space	0	0	0	0
Basement wall	11	2	1	14
Unvented crawlspace wall	20	23	1	44

Energy Analysis Results

The results of the statistical analysis were used as inputs into a large-scale Monte Carlo energy modeling analysis. This task compared the weighted average regulated energy consumption of the observed data set (on-site data) to the expected weighted average regulated consumption based on homes that exactly met the prescriptive code requirements. From the modeling results, regulated end uses include heating, cooling, lighting (interior + exterior), fans, and domestic hot water.

The results are shown in the histograms below, which estimate that the average home in Montana uses *more* energy than would be expected relative to a home built to the current minimum state code requirements under both code cycles. Based on the observed data set:

- **2018 IECC with** Montana **amendments:** The average observed regulated EUI is 52.2 kBtu/ft^2-yr (dashed blue line). In comparison, homes exactly meeting minimum prescriptive energy code requirements have an average EUI of 47.2 kBtu/ft^2-yr (solid blue line). The EUI for a “typical” home in the state uses about 10.6% more regulated energy than a code-compliant home.
- **2021 IECC with** Montana **amendments:** The average observed regulated EUI is 50.9 kBtu/ft^2-yr, while the code-compliant EUI is 45.5 kBtu/ft^2-yr.[7] The EUI for a “typical” home in the state uses about 12% more regulated energy than a code-compliant home.

Each of the models generated in the modeling analysis was compared to a minimally code-compliant model with the same heating and foundation type. In this comparison, 86.1% of the simulated population had a regulated EUI less than or equal to the 2018 IECC with Montana amendments code compliant model. This means that the analysis predicts 86.1% compliance and 13.9% non-compliance statewide. For the 2021 IECC with Montana amendments, which has stricter requirements for ceilings and lights, there was 84.7% compliance.

Note, the simulated population includes homes with above-code measures, which improves the average performance statewide. This is why the *average* home underperforms the code-compliant average by 10.6%, but there is still 13.9% non-compliance for the 2018 IECC with Montana amendments based on the individual models.

There is a substantial difference between the compliant and non-compliant home populations under both the 2018 and 2021 IECC with Montana amendments. When including above-code performance, on average the compliant population uses about 10% less energy than a code-compliant baseline while the non-compliant population uses about 20% more.

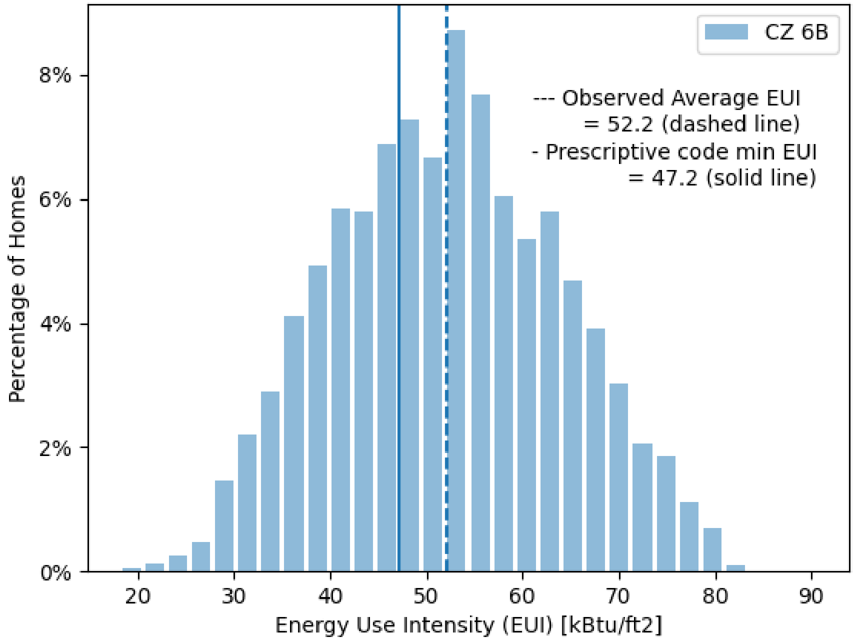

Figure 18. Statewide EUI analysis for the 2018 IECC with Montana amendments

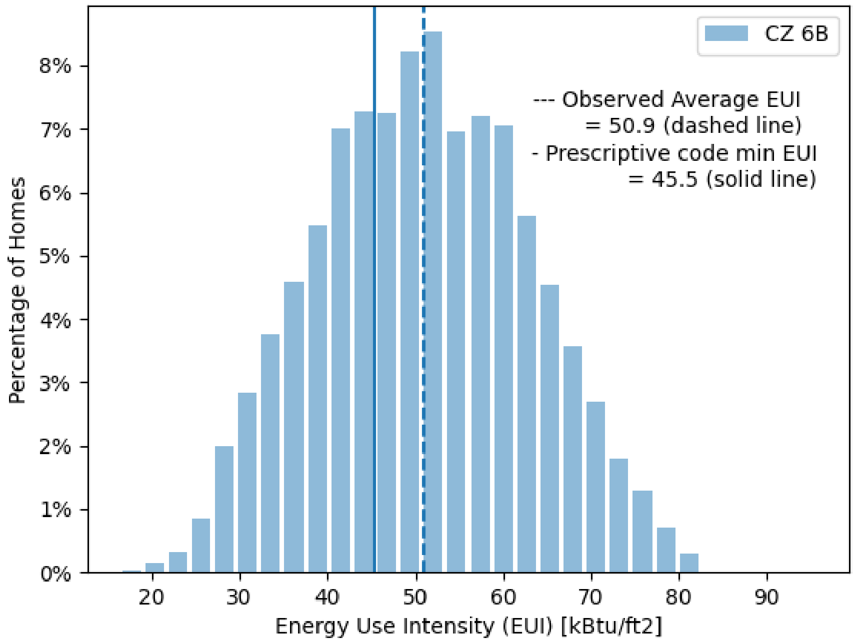

Figure 19. Statewide EUI analysis for the 2021 IECC with Montana amendments

Savings Analysis Results

The following section summarizes the potential energy, energy cost, and emissions savings for key measures with below-code observations. Potential savings (from bringing individual measures up to code) were calculated for the following key measures:[20]

Table 23. Key measures with savings potential from improved compliance

	2018 Montana Code (% compliant)	2021 Montana Code (% compliant)
Envelope Tightness	**84%**	**84%**
Wall Insulation U-factor	**2%**	**2%**
Ceiling Insulation U-factor	**35%**	**35%**
Basement Wall U-factor	**64%**	**64%**
Unvented Crawl U-factor	**45%**	**45%**
Slab Edge R-value	**40%**	**40%**
Adjusted Duct Tightness	**73%**	**73%**

[20] Savings potential was calculated for key measures with more than 5% of observations not meeting the prescriptive code requirement statewide. For insulated assemblies, the U-factor observations are used. Potential savings were calculated for each of these measures individually. A set of models was analyzed to compare the code-compliant EUI to that of a building where all measures are compliant except for the individual measure being studied. The difference in energy use represents the savings potential of increased compliance for that measure. The savings methodology can be found in the **Savings Analysis** section.

The estimated savings from improved compliance for the 2018 IECC with Montana amendments are shown in **Table 24**. The estimated savings for the 2021 IECC with Montana amendments are shown in **Table 25**. Energy savings are shown both per home and statewide, while energy cost and emissions saving are statewide only.[21] The results are shown in order of highest to lowest total savings**. Table 26** and **Table 27** show the savings breakdown by foundation type. **Table 28** and **Table 29** show the total statewide savings that would accumulate over 5, 10, and 30 years of construction.

Table 24. Statewide annual measure-level savings under the 2018 IECC with MT amendments

Measure	Climate Zone	Electricity Savings (kWh/ home)	Natural Gas Savings (Therms/ home)	Energy Savings (kBtu/ home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Associated Emissions (MT CO2e)
Duct Leakage	6B	107	23	2,628	3,213	8,442	125,521	477
External Wall Insulation	6B	84	22	2,490	3,213	7,999	113,502	447
Ceiling Insulation	6B	53	13	1,520	3,213	4,882	69,613	273
Envelope Tightness	6B	21	9	980	3,213	3,150	40,983	173
Foundation Insulation	6B	2.2	0.4	51	3,213	162	2,446	9
TOTAL		**268**	**68**	**7,668**	**3,213**	**24,636**	**352,064**	**1,380**

Notes: Negative values mean that savings or reductions decrease if the measure is brought up to code. See Table 27 below for annual measure-level savings results by foundation type.

Table 25. Statewide annual measure-level savings under the 2021 IECC with MT amendments

Measure	Climate Zone	Electricity Savings (kWh/ home)	Natural Gas Savings (Therms/ home)	Energy Savings (kBtu/ home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Associated Emissions (MT CO2e)
Duct Leakage	6B	108	23	2,716	3,169	8,608	127,159	486
External Wall Insulation	6B	85	22	2,501	3,169	7,925	112,645	443
Ceiling Insulation	6B	79	19	2,181	3,169	6,913	99,662	388
Envelope Tightness	6B	22	9	991	3,169	3,141	40,972	173
Foundation Insulation	6B	2.3	0.4	51	3,169	162	2,469	9
TOTAL		**297**	**74**	**8,440**	**3,169**	**26,747**	**382,906**	**1,499**

Notes: Negative values mean that savings or reductions decrease if the measure is brought up to code. See Table 27 below for annual measure-level savings results by foundation type.

[21] Energy cost and emissions assumptions are documented in the **Montana Fuel Prices and Emission Factors** Appendix.

Table 26. Statewide annual measure-level savings by foundation type under the 2018 IECC with MT amendments

Measure	Climate Zone	Electricity Savings (kWh/ home)	Natural Gas Savings (Therms/ home)	Energy Savings (kBtu/ home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Associated Emissions (MT CO2e)
Basement Wall Insulation	6B	0.7	0.5	53	568	30	367	1.6
Slab Edge Insulation	6B	10	1.5	183	618	113	1,837	7
Crawlspace Wall Insulation	6B	0.2	0.1	10	2,027	19	242	1.1
FOUNDATION TOTAL		**2.2**	**0.4**	**51**	**3,213**	**162**	**2,446**	**9**

Notes: Increased insulation results in lower natural gas usage in the winter but higher electricity usage in the summer. For foundation measures, the total number of homes is multiplied by the foundation share for each foundation type and is therefore smaller than the total number of homes shown for other measures.

Table 27. Statewide annual measure-level savings by foundation type under the 2021 IECC with MT amendments

Measure	Climate Zone	Electricity Savings (kWh/ home)	Natural Gas Savings (Therms/ home)	Energy Savings (kBtu/ home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Associated Emissions (MT CO2e)
Basement Wall Insulation	6B	0.7	0.5	53	561	30	361	1.6
Slab Edge Insulation	6B	11	1.5	188	609	115	1,877	7
Crawlspace Wall Insulation	6B	0.2	0.1	9	1,999	18	231	1.0
FOUNDATION TOTAL		**2.3**	**0.4**	**51**	**3,169**	**162**	**2,469**	**9**

Table 28. Five-, ten-, and thirty-year cumulative annual statewide savings under the 2018 IECC with MT amendments

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Associated Emissions (MTCO2e)		
	5yr	10yr	30yr	5yr	10yr	30yr	5yr	10yr	30yr
Duct Leakage	126,636	464,332	3,925,712	1,882,812	6,903,643	58,367,166	7,153	26,227	221,734
External Wall Insulation	119,982	439,935	3,719,455	1,702,527	6,242,599	52,778,340	6,712	24,610	208,062
Ceiling Insulation	73,235	268,529	2,270,291	1,044,188	3,828,688	32,369,814	4,101	15,036	127,122
Envelope Tightness	47,247	173,241	1,464,671	614,750	2,254,084	19,057,254	2,598	9,527	80,549
Foundation Insulation	2,435	8,928	75,478	36,684	134,509	1,137,212	138	506	4,275
Total	**369,536**	**1,354,964**	**11,455,607**	**5,280,961**	**19,363,523**	**163,709,786**	**20,701**	**75,905**	**641,741**

Table 29. Five-, ten-, and thirty-year cumulative annual statewide savings under the 2021 IECC with MT amendments

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Associated Emissions (MTCO2e)		
	5yr	10yr	30yr	5yr	10yr	30yr	5yr	10yr	30yr
Duct Leakage	129,114	473,416	4,002,519	1,907,382	6,993,734	59,128,843	7,283	26,704	225,767
External Wall Insulation	118,871	435,861	3,685,006	1,689,675	6,195,477	52,379,939	6,652	24,390	206,208
Ceiling Insulation	103,690	380,197	3,214,396	1,494,923	5,481,385	46,342,619	5,819	21,337	180,396
Envelope Tightness	47,111	172,740	1,460,440	614,579	2,253,456	19,051,948	2,592	9,504	80,356
Foundation Insulation	2,426	8,895	75,200	37,033	135,789	1,148,031	138	505	4,271
Total	**401,212**	**1,471,109**	**12,437,560**	**5,743,593**	**21,059,841**	**178,051,381**	**22,484**	**82,441**	**696,998**

Above-Code Observations

Overall, about a third of the individual observations exceeded the prescriptive code requirements. **Table 30** summarizes the percentage of above-code observations for each key measure. Of particular note, 84% of the envelope tightness, 79% of the window U-factor, and 73% of the adjusted duct tightness observations exceeded the prescriptive code requirements statewide.

Table 30. Summary of above-code observations

	% of above-code observations
Envelope Tightness (ACH50)	84%
Window U-factor	79%
External wall R-value	13%
External wall U-Factor	2%
Ceiling R-value (2018)	5%
Ceiling R-value (2021)	0%
Ceiling U-factor	5%
High-efficacy lighting (2018)	90%
High-efficacy lighting (2021)	0%
Basement R-value	50%
Basement U-Factor	50%
Unvented crawlspace R-value	23%
Unvented crawlspace U-Factor	11%
Slab edge R-value	0%
Adjusted Duct Tightness	73%

Comparison to the 2012 IECC with Montana Amendments

Compliance Rates

The results of the current study are also compared to the previous study of 2012 IECC with Montana amendments to track how compliance rates have changed since the last code cycle. **Table 31** summarizes the measure-level compliance rates for the previous study and the current results. Red text indicates a lower compliance rate, and green text indicates a higher compliance rate for the current study as compared to the previous study. Window U-factor, wall insulation U-factor, lighting, and ceiling insulation have more stringent requirements.

Table 31. Comparison of measure level compliance rates under the 2012, 2018, and 2021 IECC with Montana Amendments

	IECC 2012 w/ MT	IECC 2018 w/ MT	IECC 2021 w/ MT	Stringency
		% compliant		
Envelope Tightness	73%	84%	84%	Same
Window SHGC	N/A	N/A	N/A	N/A
Window U-factor	96%	97%	97%	2018 and 2021 more stringent
Wall Insulation R-value	98%	95%	95%	2018 and 2021 more stringent
Wall Insulation U-factor	3%	2%	2%	2018 and 2021 more stringent
Ceiling Insulation R-Value	100%	38%	5%	2021 more stringent
Ceiling Insulation U-factor	NR	35%	35%	Same
Lighting	91%	98%	90%	Each more stringent
Floor Insulation R-value	N/A	N/A	N/A	Same
Floor Insulation U-factor	N/A	N/A	N/A	Same
Basement wall R-value	81%	79%	79%	Same
Basement wall U-factor	8%	64%	64%	Same
Unvented Crawl R-value	100%	100%	100%	Same
Unvented Crawl U-factor	100%	45%	45%	Same
Slab Edge R	50%	40%	40%	Same
Raw Duct Tightness	0%	10%	10%	Same
Adjusted Duct Tightness	84%	73%	73%	Same

Table 32 provides an overall comparison of the results in both studies. The key measures that had lower compliance rates in the current study were ceiling R-value, unvented crawl U-factor, and adjusted duct tightness. Compliance remained high for window U-factor, wall R-value, lighting, and unvented crawl R-value. Compliance rates increased for envelope tightness and basement wall U-factor. When looking at the individual on-site observations for each, most measures had similar efficiency levels. However, efficiency levels increased for lighting and decreased for ceiling insulation R-values and duct tightness.

Table 32. Summary of the previous study and the current study results

Key measure	Current vs. previous		Statewide average efficiency			Stringency
	Compliance	Efficiency	Prev.	Current	Units	
Envelope leakage	Increased	Increased	3.5	2.9	ACH at 50 Pa	Same
Window SHGC	N/A	Same	0.27	0.27	N/A	N/A
Window U-factor	Both high	Similar	0.29	0.28	Btu/h-ft2-F	2018 and 2021 more stringent
Wall insulation R-Value	Both high	Similar	21	21.6	h-ft2-F/Btu	2018 and 2021 more stringent
Wall insulation U-factor	Both very low	Similar	0.063	0.064	Btu/h-ft2-F	2018 and 2021 more stringent
Ceiling insulation R-Value	Decreased	Decreased	49.3	41.8	h-ft2-F/Btu	2021 more stringent
Ceiling Insulation U-factor	N/A	N/A	NR	0.031	Btu/h-ft2-F	Same
Lighting	Increased/ Similar	Increased	91	98.8	% high efficacy	Each more stringent than previous
Floor insulation R-value	N/A	N/A	NR	NR	h-ft2-F/Btu	Same
Floor insulation U-factor	N/A	N/A	NR	NR	Btu/h-ft2-F	Same
Basement wall R-value	Similar	Similar	18	19.2	h-ft2-F/Btu	Same
Basement wall U-factor	Increased	Increased	0.06	0.052	Btu/h-ft2-F	Same
Unvented crawl wall R-value	Both 100%	Similar	19	19.7	h-ft2-F/Btu	Same
Unvented crawl U-factor	Decreased	N/A	NR[22]	0.057	Btu/h-ft2-F	Same
Slab Edge R	Both low	Similar	5	5.9	h-ft2-F/Btu	Same
Raw duct tightness	Both low	Decreased	18.7	39.6	cfm per 100 ft2 of CFA at 25 Pa	Same
Adjusted duct tightness	Decreased	Decreased	2.79	3.5	cfm per 100 ft2 of CFA at 25 Pa	Same

[22] In the previous study, all of the observations had continuous insulation. This assumes the equivalent of Grade I IIQ in the EnergyPlus models, but the report did not include a histogram of the U-factors.

Energy Analysis

The EUI for a "typical" home under the 2018 IECC with Montana amendments uses about 10.6% more regulated energy than a code compliant home. Under the 2021 IECC with Montana amendments, the average home uses about 12% more energy than a code-compliant home. In comparison, the previous study of the 2012 IECC with Montana amendments found that typical homes used about 2% more regulated energy than a code compliant home.

It should also be noted that the average and range of EUIs in the current study are higher than the previous study. There are two driving factors for this:

Updated PNNL prototypes increased the average EUI: The weighted average code-compliant EUI in the previous study was 39 kBtu/ft^2-yr. In the current study, this is 47.2 kBtu/ft^2-yr under the 2018 IECC with Montana amendments and EUI is 45.5 kBtu/ft^2-yr under the 2021 IECC with Montana amendments. Since each code cycle has been more stringent than the last, this increase was unexpected. However, the team believes that the driving difference here is a shift in the PNNL prototypes themselves.[23] The PNNL prototypes are designed to be used in comparative analyses (like this methodology) as opposed to being predictive of exact performance. So, the percent compliance and savings analysis should be comparable between the studies, even though there is a difference in the original prototypes.

As an additional check, the team also compared the current PNNL 2018 IECC and 2021 IECC prototypes to the code-compliant results in the previous study and found that EUIs were also higher. This means that average EUIs were higher *before* the files were adjusted for the Montana amendments. Once the 2018 and 2021 IECC files were adjusted for the Montana amendments (worse infiltration and wall insulation), the regulated EUI increased by 11-14% depending on the prototype, which seemed within reason given Montana's heating dominated climate.

- **Decreased efficiency levels increased the range in EUI:** In the previous study the 2012 IECC with Montana amendments, the highest individual model EUI was about 65 kBtu/ft^2-yr. In the current study, the highest individual EUI was about 87 kBtu/ft^2-yr. Separate from prototype model differences, as noted above three key measures had lower compliance rates in the current study (ceiling R-value, unvented crawl U-factor, and adjusted duct tightness) and observed efficiency levels decreased for ceiling insulation R-values and duct tightness. In the Monte Carlo analysis, high envelope leakage combined with poor insulation resulted in higher maximum EUIs. In the previous study, envelope tightness ranged from 1.4 to 4.6 ACH50. In the current study, this range was 1 to 6 ACH50. As noted with the ceiling histograms, it was unexpected that the average ceiling insulation R-value decreased, but it is unclear if this is due to a difference in the R-value per inch on-site observation assumptions or whether a shift from batt to blown-in insulation resulted in lower installation performance.

[23] As noted on the PNNL website, "The single-family prototypes are now complete EnergyPlus files utilizing the airflow network for duct leakage modeling. Previous single family prototype models posted on the Energy Codes website did not contain duct leakage specifications. Calculating loads for duct leakage required multiple EnergyPlus simulations with and without duct leakage and post processing the results for both single family and multifamily buildings. **As a result, there may be large differences in energy consumption when comparing the latest single family prototypes results to older prototype results downloaded from this website**."

4 Interview Results

The team conducted interviews with five code officials and five builders. This section provides the interview findings, including results pertaining to builder and code-official reported levels of compliance with key measures.

Compliance with Key Measures

Code officials were asked to rate the level of difficulty that builders in their jurisdictions face in complying with each of the seven key measures. Builders were asked to rate the level of difficulty they experience complying with these code elements. Respondents provided ratings using a scale of 1 to 5, where 1 meant high compliance/little trouble meeting the code requirement and 5 meant low compliance/significant difficulty in complying. **Figure 20** shows the average ratings for each building/code component.[24]

Overall, neither code officials nor builders reported substantial difficulty in complying with any of the code components, as none of the average ratings exceeded a 3 on the 1 to 5 scale. Both builders (2.7 average rating) and code officials (1.5) provided the highest (most difficult to comply) ratings to the duct tightness requirements.

While builders and code officials had similar average ratings across most components, builders provided slightly higher average ratings for wall installation (1.8 versus 1.2), ceiling insulation (2.0 versus 1.3), and duct tightness (2.7 versus 1.5) than code officials. While builders providing higher ratings may be a function of the respondents interpreting the scale differently, it could also mean that builders are having some challenges complying with these specific measures that code officials are not aware of.

Both code officials and builders reported that window U-factor and solar heat gain coefficient and percent high efficiency for lighting were the components with the highest compliance/least difficulty in complying. Average ratings for windows and lighting were both 1.0. This was generally due to market availability, as most windows on the market meet the code requirements, and almost all lighting available is now LED, and aligns with what was observed on-site (high compliance for these measures). Most code officials and interviewees noted that it is difficult to find non-compliant windows or non-LED bulbs, which aligns with the high compliance rates for those measures observed in the field study. Builders and code officials attributed the more difficult measures to a lack of skilled labor, especially highlighting the challenges of finding qualified contractors who understood duct and envelope tightness requirements.

[24] Some builders and code officials did not provide a rating for all of the code components. The foundation insulation rating is averaged across four out of the five builders and three out of the five code officials. Ceiling insulation and duct tightness code official ratings are averaged across four out of the five code officials. Code officials, but not builders, were asked to rate the level of difficulty in complying with envelope tightness.

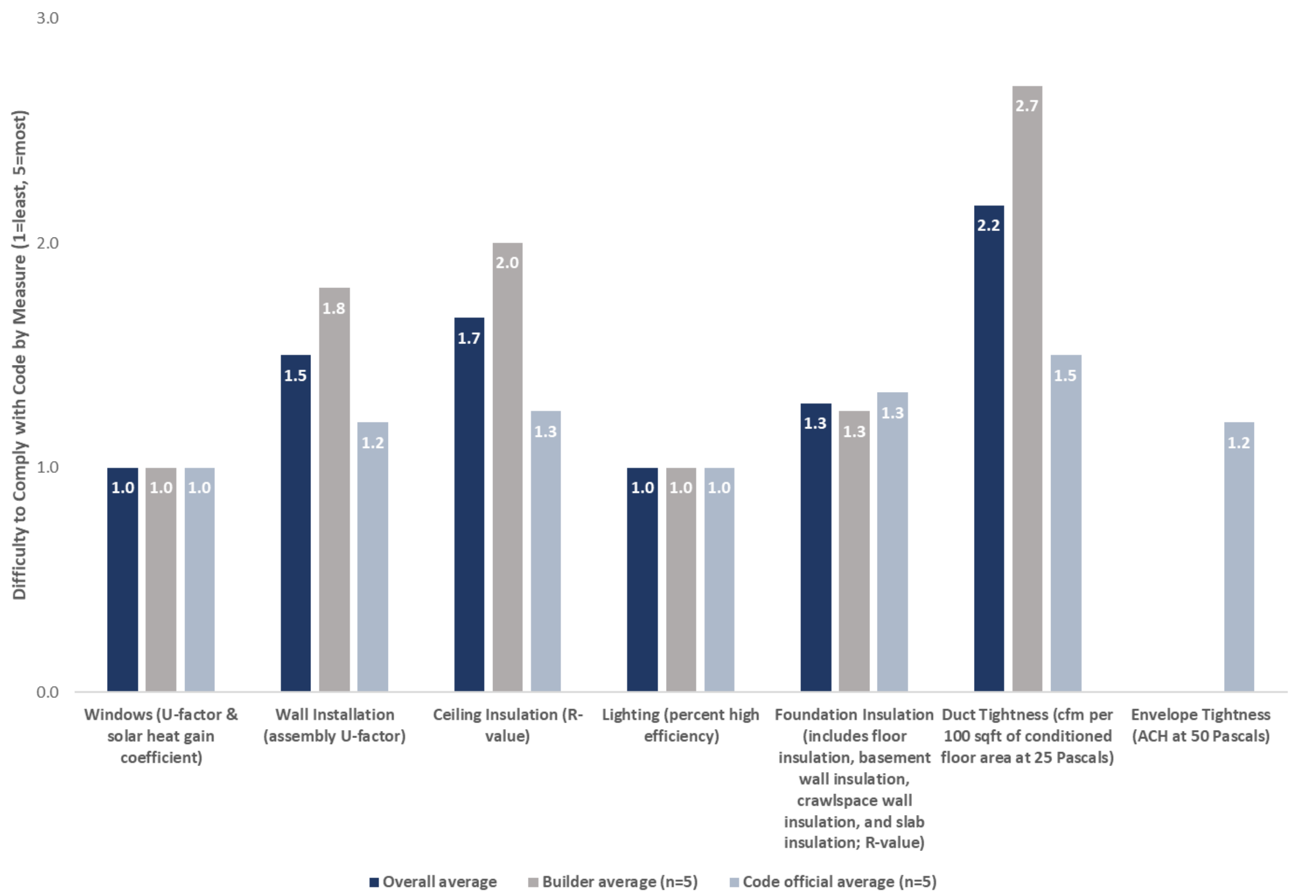

Figure 20. Interviewee ratings for difficulty complying with Montana building/code components

Two builders noted challenges with complying with the wall insulation requirements when building custom designs for higher-end homes. Builders and code officials attributed some difficulty in adjusting to new code requirements for ceiling insulation (the key measure with the most substantive change from 2018 to 2021 IECC), leading to slightly higher ratings there. Additionally, two builders mentioned frustration with increased costs associated with ceiling insulation as well as problems with mold in attics due to insulation and envelope tightness requirements.

Multiple builders said that duct tightness was the most difficult measure to comply with. One builder rated the level of difficulty complying with duct tightness as a 4 and said it is difficult to get contractors up to speed on conducting blower door tests. A code official, who did not provide a rating for duct tightness, was concerned that the requirement for all bathroom and kitchen fans to be duct blasted would slow many projects due to a lack of blower door testers in the area. One code official in the eastern part of the state who the team spoke to during the initial permit outreach echoed this sentiment saying that the nearest company with duct blaster capability was over three hours from his jurisdiction.

Additional Interview Findings

In addition to answering questions about their experience and challenges in complying with the key measures, builders provided insight into their experiences with the compliance/permitting process across different jurisdictions. Code officials shared details on resources they have seen or provided to builders to help with compliance and the level of effort required to conduct their enforcement activities. The key takeaways from these elements of the interviews include:

Builders and code officials reported varying levels of code enforcement across different jurisdictions. All five of the builders interviewed noted that code enforcement is weaker in unincorporated areas. While some said they build to the same standards regardless of jurisdiction, others said they prefer to build outside of city limits because of the less stringent code enforcement. These builders still expressed a desire to meet the energy code in their homes but emphasized that they enjoyed the reduced burden of completing paperwork involved in the permitting process and waiting for inspections to be conducted in these rural areas. One builder from the Bozeman area explained, "In rural areas, you stick to best practices but you're kind of on your own." Another builder from near Bozeman said that although they are working on one home in city limits, they typically "avoid the city like the plague." A builder based in Whitefish said that they prioritize efficiency in all their projects, but that it is in everyone's best interest to have more inspections in rural areas so that all homes are in compliance. Code officials shared similar observations around code enforcement. One code official noted, "There are some builders who do things the same in or out of city jurisdiction, others do it differently if they're in the city," while another said it is the "wild west" when it comes to code enforcement outside of city limits.

Builders expressed concerns with building homes to meet the 2021 IECC with Montana amendments. Multiple builders explained that although it is not necessarily difficult to comply with code requirements, some of the new requirements under 2021 IECC with Montana amendments have created new challenges for them. Two of the five builders said that the envelope tightness and insulation requirements have led to mold in recently built homes. One builder said they have had "instant mold" because they are required to make "everything so tight and can't vent it." The other builder said that home inspections revealed mold in the attics of two of their recently built homes that went up for resale. Builders also discussed how the envelope tightness requirements can lead to more condensation on windows, leading homeowners to think the builder did something wrong. In addition to these concerns, some builders discussed their perception that the additional requirements were driving up building costs and expressed doubts that homeowners would be willing to accept these increased costs. One builder noted that increased costs may not be a problem for clients building higher-end homes, but that the added costs are very difficult for the average homeowner to bear—especially when they are not seeing substantial energy bill savings from the new measures. A builder and a code official both mentioned that they believed the increased costs of materials needed to achieve these measures may negate the energy saving benefits.

Code officials interviewed for this study generally dedicate one to two staff members to energy code compliance. This level of staffing was consistent across all interviews, although two of the jurisdictions reported having additional staff available to help as needed. Two code officials discussed how long it takes to certify a home for energy components. One official said that they complete two inspections per home build, each lasting 30 minutes to one hour, while the other official said it takes them 10-12 hours per home to complete all phases of the plan review and inspection process.

Additional feedback from code officials. In addition, individual code officials provided the following feedback:

- One code official noted the difficulty of meeting the ceiling insulation value of R60 as required in the 2021 IECC with Montana amendments. According to the code official, this increased insulation adds costs which are not outweighed by energy savings. This code official said that they received permission from the state to revert to the 2018 requirement of R49, and that the state is considering amending the R60 insulation requirement. The code official would like to see an official amendment, so they are consistent with the state requirements.
    - Multiple code officials in rural areas expressed frustration at blower door test requirements, saying that there are few people qualified and available to conduct these tests. This difficulty leads to delays for new construction projects.
    - One code official said they would like to see more continuing education opportunities, such as a class that walks through code standards and enforcement.
    - One code official commented that DEQ should highlight changes from the previous code cycle when they send out new pamphlets or flyers on energy codes.

5 Radon Mitigation Results

Montana ranks among the top states in the nation in terms of elevated levels of in-home radon, leading to this increased focus for the Montana Department of Environmental Quality (DEQ).[25] As part of this study, DEQ, which partners with NEEA on codes-related work, asked the team to collect data on radon mitigation systems during the home inspections. The inspection forms contained six fields regarding radon mitigation:

- Does the home have a radon mitigation system?
- Is the system active (with a fan) or passive?
- Location of fan
- Is there an electrical outlet in the attic for radon fans?
- Size of radon pipe
- Does the radon pipe extend through the roof?

The results are summarized in the tables and text below.

Table 33. Does home have a radon system?

Does home have a radon mitigation system?		
Response	**%**	**Count**
Yes	48%	63
No	52%	69

Table 33 shows that roughly half the homes inspected had a radon mitigation system (%).[26] Almost two-thirds of homes with radon mitigation had passive systems (**Table 34**). For homes that had an active system with a fan, 100%were located in the home's attic. Seventy percent of homes had attic electrical outlets that could accommodate radon fans. The majority of radon pipes (84%) were 3 inches, and nearly all (98%) radon pipes extended through homes' roofs.

Table 34. Summary of Radon Data

Measure	Response		
	Yes	**No**	**# of responses**
Is there an electrical outlet in the attic for radon fans?	70%	30%	47
Does the radon pipe extend through the roof?	98%	2%	61
	Active	Passive	
Is the system active (with fan) or passive?	38%	62%	58
	Attic	Other	
Location of Fan	100%	0%	19
	3 inches	4 inches	
Size of Radon Pipe	84%	16%	62

[25] For information on Montana's radon levels, see: https://apps.msuextension.org/magazine/assets/docs/Radon.pdf, https://deq.mt.gov/files/Energy/Radon/Radon_Brochure_2019.pdf, and https://www.cascadecountymt.gov/DocumentCenter/View/756/City-County-Health-Department-Radon-Fact-Sheet-PDF#:~:text=Radon%20Levels%20in%20Montana%3A,greater%20than%2020%20pCi%2FL.. Information on Montana DEQ's mitigation efforts can be found at: https://deq.mt.gov/energy/programs/radon.

[26] Each of the radon mitigation measures had incomplete responses. The team collected radon mitigation data for 132 of the 143 site visits, but did not provide data for all the measures at each home.

Looking at the results by jurisdiction, homes in incorporated jurisdictions were more likely to have radon mitigation systems than homes in unincorporated jurisdictions (**Table 35**). Fifty-three percent of observed homes in incorporated jurisdictions had radon mitigation systems, while 40% of homes in unincorporated areas had systems. Homes in the greater Bozeman and Missoula areas often had systems in place. This includes the cities of Belgrade (83%), and Bozeman (71%) in Gallatin County (52% in unincorporated county areas), and 75% of homes in the city of Missoula along with 71% in unincorporated Missoula County. Conversely, homes in Yellowstone County typically did not have systems in place. This includes 30% of the 23 homes observed in Billings and none of the 11 homes in unincorporated Yellowstone County.

Table 35. Radon mitigation data by jurisdiction

Does home have a radon mitigation system?			
Jurisdiction	**Yes**	**No**	**# of responses**
Butte	100%	0%	1
Belgrade	83%	17%	6
Missoula	75%	25%	8
Unincorporated Missoula County	71%	29%	7
Bozeman	71%	29%	24
Unincorporated Flathead County	67%	33%	3
Kalispell	57%	43%	7
Unincorporated Gallatin County	52%	48%	23
Helena	50%	50%	2
Whitefish	33%	67%	3
Billings	30%	70%	23
Unincorporated Cascade County	22%	78%	9
Red Lodge	0%	100%	5
Unincorporated Yellowstone County	0%	100%	11

6 Conclusions

This study provides insight into code compliance both at a measure and whole-home level under 2018 and 2021 IECC with Montana amendments.

Statewide, under the 2018 IECC with Montana amendments, the average home uses about 10.6% more energy than a baseline home that exactly meets code requirements. Statewide, 13.9% of the population was non-compliant. As noted above, about a third of the individual observations exceeded the prescriptive code requirements, which improved the average performance statewide. This is why the *average* home underperforms the code-compliant average by 10.6%, but there is still 13.9% non-compliance for the 2018 IECC with Montana amendments based on the individual models.

Under the 2021 IECC with Montana amendments, the average home uses about 12% more regulated energy than a code-compliant home and 15.3% of the population was non-compliant.

There is a substantial difference between the compliant and non-compliant home populations under both the 2018 and 2021 IECC with Montana amendments. When including above-code performance, on average the compliant population uses about 10% less energy than a code-compliant baseline while the non-compliant population uses about 20% more.

Table 36 and **Table 37** below summarize the potential measure-level savings that could be the target for future education, training, and outreach activities. Under the 2018 IECC with Montana amendments, potential statewide annual energy savings are 24,636 MMBtu, which results in $352,064 in energy cost savings and 1,380 MT CO_{2e} in emission reductions. Over a 30-year period, this would save 11.5 million MMBtu, $164 million, and 641,741 MT CO_{2e}. Under the 2021 IECC with Montana amendments, potential statewide annual energy savings are 26,747 MMBtu, which results in $382,906 in energy cost savings and 1,499 MT CO_{2e} in emission reductions. Over a 30-year period, this would save 12.4 million MMBtu, $178 million, and 696,998 MT CO_{2e}.

The highest potential for savings is in duct leakage and external wall insulation, which represent 67% of the potential savings under the 2018 IECC with Montana amendments and 62% of the savings under the 2021 IECC with Montana amendments. About 40% of the observed homes had ducts completely or partially in unconditioned space. While 95% of the observations met or exceeded the prescriptive code requirements for wall insulation R-value, nearly three quarters of the wall IIQ observations were Grade II or III, which resulted in lower U-factors.[27] So, wall insulation installation quality and duct sealing are two potential areas of focus for education and outreach.

There are also potential savings for ceiling insulation, envelope tightness, and foundation insulation. Here, education and outreach focus areas include ceiling insulation amount and IIQ,

[27] As noted above, wood-frame wall U-factors became more stringent under the 2018 code updates and remained that way under the 2021 updates (0.057 to 0.045 Btu/h-ft^2-°F). For wood-framed walls, IECC requires either R-20+5 or R-13+10, both with a U-factor of 0.045. In both versions of the code, Montana amended this to allow R-21 but kept the U-factor at 0.045. Based on IECC's "Table RF102.1 Assembly U-Factors for Wood Frame Walls" no R-21 construction would meet the U-factor requirement. Estimated savings are based on an R-21 construction (0.058 U-factor), which would meet the R-value requirement, but not the U-factor requirement.

envelope sealing, basement wall insulation amount and IIQ, unvented crawl wall IIQ, and slab insulation amount.

Table 36. Annual statewide savings potential under the 2018 IECC with MT amendments

Key Measure	Annual Savings		
	Energy (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
Duct Leakage	8,442	125,521	477
External Wall Insulation	7,999	113,502	447
Ceiling Insulation	4,882	69,613	273
Envelope Tightness	3,150	40,983	173
Foundation Insulation	162	2,446	9
TOTAL	**24,636 MMBtu**	**$352,064**	**1,380 MT CO2e**

Table 37. Annual statewide savings potential under the 2021 IECC with MT amendments

Key Measure	Annual Savings		
	Energy (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
Duct Leakage	8,608	127,159	486
External Wall Insulation	7,925	112,645	443
Ceiling Insulation	6,913	99,662	388
Envelope Tightness	3,141	40,972	173
Foundation Insulation	162	2,469	9
TOTAL	**26,747 MMBtu**	**$382,906**	**1,499 MT CO2e**

7 Recommendations

Recommendations to Improve Code Compliance

Education and outreach efforts can focus on the key variables with potential savings. From highest to lowest, the majority of the potential savings are in duct leakage, external wall insulation, ceiling insulation, and envelope tightness. There is also room for improvement in foundation insulation compliance, however the potential savings are comparatively small.

Reduce duct leakage by relocating ducts to conditioned spaces or enhancing duct sealing in unconditioned spaces. Duct leakage has the highest potential savings from improved compliance under the 2018 and 2021 IECC with Montana amendments, representing 34% and 32% of the potential annual energy savings, respectively. This measure also had the highest potential savings (49%) in the previous study of the 2012 IECC with Montana amendments. Of the 63 on-site visits, 8 of the observations were completely in unconditioned space and 17 were partially located in unconditioned space. Education and outreach efforts can focus on either moving ducts to conditioned spaces or improving duct sealing in unconditioned spaces.

Improve the quality of external wall insulation installation. The potential savings for external wall insulation is a close second, representing 32% of the 2018 IECC with Montana annual energy savings from improved compliance and 29% of the 2021 IECC with Montana amendment savings. External wall insulation also had the second highest potential savings (39%) in the previous study of the 2012 IECC with Montana amendments. Nearly all of the observations met or exceeded the R-21 insulation requirement, but about three quarters of the observations had Grade II or III IIQ. So, the amount of insulation is generally sufficient, but education and outreach efforts could focus on installation quality.

Improve both the quantity and quality of ceiling insulation, including compliance with increased R-value requirements. Ceiling insulation represents 20% of the 2018 IECC with Montana amendments annual energy savings from improved compliance and 25% of the 2021 IECC with Montana amendment savings. Ceiling R-value requirements increased from R-49 to R-60 under the 2021 IECC with Montana amendments. In contrast to the wall insulation, for ceiling insulation, both the amount of ceiling insulation and the installation quality are areas for improvement. Observed R-values were 38% compliant under the 2018 IECC with Montana amendments and 5% compliant under the 2021 IECC with Montana amendments. Forty-four percent of the IIQ observations were Grade II and III.

Enhance envelope tightness, aiming for increased compliance and tighter average envelopes. There is room for modest savings in improved envelope tightness, which represents 13% and 12% of the 2018 and 2021 IECC with Montana amendment savings, respectively. Compared to the previous study of the 2012 IECC with Montana amendments, the rate of compliance increased (73% to 84%) and the average envelope is tighter (3.5 to 2.9 ACH).

Improve foundation insulation compliance, particularly in basement wall insulation, unvented crawlspace wall insulation, and slab insulation. There is room for improvement in foundation insulation compliance, but this is unlikely to result in substantial savings. Foundation insulation represents 1% of the potential annual savings under both the 2018 and 2021 IECC with

Montana amendments. Areas for improvement include basement wall insulation amount and IIQ, unvented crawlspace wall IIQ, and slab insulation amount.

Recommendations for Future Studies & Education Opportunities

Future studies and education can focus on key areas to enhance code compliance and building performance.

Reevaluate the feasibility of using permit data for future compliance assessments. Based on the team's experience in attempting to use permit data to assess compliance, this does not seem like a feasible approach with Montana's current enforcement landscape. If a greater number of counties begin to issue building permits outside of incorporated city limits, a future study may want to reassess the feasibility of using permit data.

Investigate whether building code compliance rates differ between urban and rural areas and between enforced and unenforced areas. Although the sample sizes of homes observed during this study were too small to statistically test the differences in compliance levels between rural and urban areas, feedback from the interviews and anecdotal evidence from the field team and other study participants suggested that there may be lower rates of compliance and/or less awareness of aspects of the building code in rural areas (especially rural, unenforced areas).[28] The team assessed differences between urban and rural homes for envelope tightness and found compliance rates to be slightly higher in urban areas (88%) than rural (76%), although the average ACH values were similar in both urban and rural areas. Future studies may want to further study whether code compliance rates differ in urban versus rural areas. NEEA may also want to further study code compliance in enforced versus unenforced areas to see if code compliance is lower in the areas of the state that do not issue building permits.

Enhance education and training to improve builders' understanding of air tightness, proper ventilation practices, and the value of building higher performing homes. During the interviews, two of the five builders expressed a concern that building homes to meet the current envelope tightness requirements had caused mold to grow in attics of their homes where moisture was able to enter but air was not able to escape. They also noted that there was increased window condensation in these homes. These builders suggested that there may be some benefits to building homes with slightly lower envelope tightness levels. One also expressed a concern that the added costs of building a home to the current code did not add value to the homeowner. This feedback suggests that there are training opportunities to improve builders' understanding of air tightness and proper ventilation practices to ensure they meet code without negative effects and to explain the value proposition of building higher performing homes with proper practices.

Additionally, the field team identified two educational opportunities to address awareness:

- **Increase heat recovery ventilation (HRV) and energy recovery ventilators (ERV) system awareness:** HRV and ERV systems are whole-home ventilation systems that maintain sufficient fresh air while reducing energy usage through a heat exchanger on the exhaust air.[29] Installing these systems can mitigate the negative impacts that builders associated with tighter homes (mold and window condensation), while improving home comfort and performance. The field team noted that awareness of these systems and their benefits was low across the builder community and could be improved with additional outreach. Further, as the 2024 IECC

[28] For the purposes of this study, NEEA and the team define "rural" areas as all unincorporated parts of the state and define "urban" areas as all incorporated parts of the state.

[29] The heat exchanger in an HRV system only transfers heat, while an ERV system transfers both moisture and heat.

requires an HRV or ERV system to be installed, increased education in the near term can help prepare builders for potential code changes.

- **Address Regional Building Practices affecting home performance:** The field team observed some regional building trends that may have been associated with the common practices of area-specific subcontractors. For example, the team found that insulation installations varied across the state. The team typically only found spray foam insulation in Bozeman and in higher end builds, whereas most of the rest of the state used fiberglass batt insulation. In Billings, the team found a lack of caulking to seal cracks and improve insulation quality. The team also noted differences in the performance of HVAC systems being installed across the state, which may be driven by builder preferences. Identifying areas where insulation practices could be improved, and/or HVAC equipment is less efficient, and providing educational resources to local subcontractors in those areas could improve statewide building performance.

Appendix A – State Sampling Plan

Table 38 shows the final sample plan that the team used to conduct the on-site inspections. As described in Section 2, this plan was selected from ten options provided by DOE/PNNL by the team in conjunction with the Montana TAG. The team was able to follow the sample plan exactly, with only two deviations, replacing homes in Cascade County and the City of Butte, respectively, with homes in Gallatin County and the city of Missoula due to a lack of new construction in those areas. The team coordinated with NEEA and PNNL to determine that these counties were demographically similar and suitable for substitution.

Table 38. On Site Inspection Sample Plan

Location	Number of Measures
City of Bozeman	13
City of Billings	12
Gallatin County[1]	10
Yellowstone County	5
Cascade County[1]	4
City of Missoula[2]	5
City of Belgrade	3
Missoula County	3
City of Kalispell	3
City of Whitefish	2
City of Red Lodge	2
City of Helena	1
City of Butte[2]	0

[1]The original target in Cascade County was five. Per discussion with PNNL, the team replaced one observation with an additional from Gallatin County, moving the Gallatin County total from nine to ten.
[2] The original target in Butte was five. Per discussion with PNNL, the team replaced the one observation with an additional from the city of Missoula, moving the Missoula total from four to five.

Appendix B – 2018 vs. 2021 Montana Code Requirements

To understand the potential difference between homes built to the 2018 and 2021 code in Montana, the team reviewed both codes, as shown below.

Table 39. Comparison of code requirements

IECC Code Section	Component	CZ	2012 IECC with Montana amendments	2018 IECC	2018 IECC with Montana amendments	2021 IECC	2021 IECC with Montana amendments	Units
R402.4.1.2	Envelope Tightness	6B	4	3	4	3	4	ACH at 50 Pa
R402.1	Fenestration U-factor	6B	0.32	0.3	0.3	0.3	0.3	Btu/h-ft2-F
	Fenestration SHGC	6B	NR	NR	NR	NR	NR	
	Wood-framed R-value (U-factor)	6B	20 or 13+5 (0.057)	20+5 or 13+10 (0.045)	21 or 13+10 (0.045)	20+5ci or 13+10ci or 0+20ci (0.045)	21 or 20+5ci or 13+10ci or 0+15ci (0.045)	h-ft2-F/Btu (Btu/h-ft2-F)
	Mass wall R-value (U-factor)	6B	15/20 (0.060)	15/20 (0.060)	15/20 (0.060)	15/20 (0.060)	15/20 (0.060)	h-ft2-F/Btu (Btu/h-ft2-F)
	Ceiling R value (U-factor)	6B	49 (0.026)	49 (0.026)	49 (0.026)	60 (0.024)	60 (0.026)	h-ft2-F/Btu (Btu/h-ft2-F)
R404.1	Lighting equipment	6B	75	90	90	100	100	% high-efficacy
R402.1	Floor R-value (U-factor)	6B	30 (0.033)	30 (0.033)	30 (0.033)	30 (0.033)	30 (0.033)	h-ft2-F/Btu (Btu/h-ft2-F)
	Basement wall R-value (U-factor)	6B	15/19 (0.050)	15/19 (0.050)	15/19 (0.050)	15ci or 19 or 13+5ci (0.050)	15ci or 19 or 13+5ci (0.050)	h-ft2-F/Btu (Btu/h-ft2-F)
	Slab R-value and depth	6B	10, 4 ft	10, 4 ft	10, 4 ft	10ci, 4 ft	10ci, 4 ft	h-ft2-F/Btu
	Crawlspace wall R-value (U-factor)	6B	15/19 (0.055)	15/19 (0.055)	15/19 (0.055)	15ci or 19 or 13+5ci (0.055)	15ci or 19 or 13+5ci (0.055)	h-ft2-F/Btu (Btu/h-ft2-F)
R403.3.4	Duct leakage (prescriptive)	6B	4	4	4	4	4	ft3/min per 100 ft2 of CFA at 25 Pa

Notes:

- The 2021 IECC with Montana amendments went into effect on June 10, 2022.
- Montana does not require continuous insulation for wood frame walls, so R-21 is compliant in both 2018 and 2021 IECC with Montana amendments.
- The 2018 IECC with Montana amendments ceiling R-value is R-49, while the 2021 IECC with Montana amendments is R-60. However, the ceiling U-factor is the same in both codes.

For the key variables, the only differences in the 2018 and 2021 IECC with Montana amendments are the ceiling insulation and high-efficacy lighting. In the 2019 field study of the 2012 IECC with Montana amendments, these both had very high compliance. The 2019 results were:

- Ceiling R-Value: 100% compliance
  - All ceiling R-value observations met or exceeded the code requirement.
  - Almost all (97%) of the roof cavity insulation installation quality observations were Grade I, indicating that roofs are well insulated in Montana.
- High-efficacy Lighting: 91% compliance
  - Nearly all (91%) of the field observations met the code requirement.

Modeling Scenarios: 2018 vs. 2021 IECC with Montana amendments

To study performance differences between the 2018 and 2021 IECC with Montana amendments, the team ran three scenarios in *EnergyPlus*, which are described below.

Scenario 1 vs. 2 illustrates the effect of the 2021 IECC with Montana amendments compared to 2018 IECC with Montana amendments *for the key variables only*. In these models, only the ceiling and lighting are updated. If the energy impacts of 1. vs. 2. are minimal, then grouping 2018 and 2021 site data would be sufficient for a 2018 savings analysis. Since the 2021IECC with Montana amendments changes the ceiling R-value, but not the U-value, the team thinks this would be a worst-case impact difference for the key variables in the study.

Scenario 3 vs 1 illustrates the effect of the 2021 IECC with Montana amendments requirements compared to the 2018 IECC with Montana amendments *from a whole house perspective*. This difference shows the magnitude in difference of the baselines used in a 2018 vs. a 2021 compliance study to estimate savings potential.

1. **PNNL IECC 2018 prototypes modified to include** Montana **2018 amendments**
   - Key variable changes in 2018 IECC vs. Montana 2018 amendments:
     - Air leakage input changed from 3 ACH to 4 ACH
     - Change from R20+5 to R21
   - This is the original model to be used as the baseline in the 2018 analysis

2. **PNNL IECC 2018 prototypes modified to include** Montana **2021 amendments for <u>only</u> the key variables**
   - Key variable changes in 2018 IECC vs. 2021 IECC:
     - Change ceiling R-value from R-49 to R-60
       - The U-factor equivalent for ceilings remains the same (0.026) in Montana 2021 and IECC 2018, but will change R-value to test impact
     - Change percent of high efficacy lighting from 90% to 100% (interior and exterior hardwired)
   - Key variable changes in Montana 2021 amendments:
     - Air leakage input changed from 3 ACH to 4 ACH
     - PNNL already models the wall as R-20+5, so no change needed

3. **PNNL IECC 2021 prototypes modified to include** Montana **2021 amendments**
   - Key variable changes in Montana 2021 amendments:
     - Air leakage input changed from 3 ACH to 4 ACH
     - PNNL already models the wall as R-20+5, so no change needed

- All modeling changes in PNNL 2021 IECC prototypes (compared to PNNL 2018 IECC prototypes):
  - Change ceiling R-value from R-49 to R-60
    - The U-factor equivalent for ceilings remains the same (0.026) in Montana 2021 and IECC 2018, but will change R-value to test impact
  - Change percent of high efficacy lighting from 90% to 100% (interior and exterior)
  - Increases whole-house mechanical ventilation system fan efficacy requirements for inline fans and bathroom/utility rooms
  - New section requiring choice of additional efficiency option - 2021 prototype opts for high efficiency water heating

Table 40. Water heating systems modeled for the 2018 IECC and for the additional efficiency option package for the 2021 IECC

Space Heating Type	2018 IECC Water Heating	2021 IECC Water Heating
Gas Furnace	Gas Storage, 0.58 EF, 40 gal	Gas Tankless, 0.82 EF
Oil Furnace	Oil Storage, 0.61 EF, 52 gal	HPWH, 2.0 EF, 50 gal
Electric Furnace	Electric Storage, 0.92 EF, 52 gal	HPWH, 2.0 EF, 50 gal
Heat Pump	Electric Storage, 0.92 EF, 52 gal	HPWH, 2.0 EF, 50 gal

Results

The 2019 field study of the 2012 IECC with Montana amendments used the following weights:

- Foundation shares -- heated basement: 35.58%; slab: 5.77%; unvented crawlspace: 58.65%
- Heating System shares -- heat pump 2.42% and gas furnace 97.58%.

So, the prototypes of highest concern are likely to be:

- Gas furnace, heated basement
- Gas furnace, unvented crawlspace

The table below summarizes the results of the *EnergyPlus* runs for Scenarios 1, 2, and 3. The gas furnace results in red are the two building types that were the most common in the 2019 field study.

- **From Scenario 1 to Scenario 2,** energy use drops around 0.6%.
- **From Scenario 1 to Scenario 3**, energy use drops anywhere from around 2.5% to 5.7%.
  - The range of changes mostly stems from the different water heating options used in the 2018 and 2021 models. The heat pump models switch from electric resistance storage water heating in 2018 to HPWHs in 2021, while the gas models switch from gas storage water heating in 2018 to tankless water heating in 2021, leading to a reduction around 3%.
  - This shows that mechanical equipment type has a relatively large impact on energy use, so we will want to use the same mechanical equipment as in the baseline when analyzing the impact of the key variables

Recommended Methodology:

1. **Site visit data from buildings constructed under the 2021 IECC with Montana amendments can be used to conduct an analysis of the 2018 IECC with Montana Amendments.** Scenarios 1 and 2 generated very similar results, so the team concluded that data from 2018 and 2021 buildings can be used to complete the 2018 analysis.
2. **Conduct the Monte Carlo analysis with both a PNNL 2018 and 2021 protype baseline.** Scenario 3 vs. Scenario 1 showed differences up to 5.7%. To expand the project scope to include 2021, the analysis will run the Monte Carlo simulation twice with both a 2018 and 2021 baseline to calculate more accurate savings projections.

Table 41. Results of EnergyPlus runs for Scenarios 1, 2, and 3

		Scenario											
		1. IECC 2018 + MT 2018				2. IECC 2018 + MT 2021				3.IECC 2021 + MT 2021			
Heating System	**Foundation**	Total Energy (kBtu)	EUI (kBtu/ft²)	Conditioned Area EUI (kBtu/ft²)	-	Total Energy (kBtu)	EUI (kBtu/ft²)	Conditioned Area EUI (kBtu/ft²)	**% Change from 1**	Total Energy (kBtu)	EUI (kBtu/ft²)	Conditioned Area EUI (kBtu/ft²)	**% Change from 1**
Elec. Resistance	Crawlspace	122,123	25.69	51.37	-	121,369	25.53	51.06	-0.6%	118,880	25.01	50.01	-2.6%
Elec. Resistance	Heated Basement	131,975	27.76	37.01	-	131,189	27.59	36.79	-0.6%	128,953	27.12	36.17	-2.3%
Elec. Resistance	Slab	122,876	34.46	51.69	-	122,141	34.25	51.38	-0.6%	119,915	33.63	50.45	-2.4%
Elec. Resistance	Unheated Basement	119,029	25.04	50.07	-	118,276	24.88	49.76	-0.6%	115,969	24.39	48.79	-2.6%
Gas Furnace	*Crawlspace*	*148,536*	*31.24*	*62.49*	-	*147,673*	*31.06*	*62.12*	*-0.6%*	*143,925*	*30.27*	*60.55*	*-3.1%*
Gas Furnace	*Heated Basement*	*160,485*	*33.76*	*45.01*	-	*159,587*	*33.57*	*44.76*	*-0.6%*	*156,033*	*32.82*	*43.76*	*-2.8%*
Gas Furnace	Slab	149,874	42.03	63.05	-	149,035	41.8	62.7	-0.6%	145,475	40.8	61.2	-2.9%
Gas Furnace	Unheated Basement	144,641	30.42	60.85	-	143,788	30.24	60.49	-0.6%	140,135	29.48	58.95	-3.1%
Heat Pump	Crawlspace	102,061	21.47	42.94	-	101,520	21.35	42.71	-0.5%	96,254	20.25	40.49	-5.7%
Heat Pump	Heated Basement	109,649	23.06	30.75	-	109,035	22.93	30.58	-0.6%	104,269	21.93	29.24	-4.9%
Heat Pump	Slab	104,360	29.27	43.9	-	103,831	29.12	43.68	-0.5%	98,893	27.73	41.6	-5.2%
Heat Pump	Unheated Basement	99,966	21.03	42.05	-	99,437	20.92	41.83	-0.5%	94,345	19.84	39.69	-5.6%
Oil Furnace	Crawlspace	145,604	30.63	61.25	-	144,736	30.44	60.89	-0.6%	140,081	29.46	58.93	-3.8%
Oil Furnace	Heated Basement	157,047	33.03	44.04	-	156,177	32.85	43.8	-0.5%	152,001	31.97	42.63	-3.2%
Oil Furnace	Slab	146,733	41.15	61.73	-	145,889	40.92	61.37	-0.6%	141,670	39.73	59.6	-3.5%
Oil Furnace	Unheated Basement	141,812	29.83	59.66	-	140,956	29.65	59.3	-0.6%	136,600	28.73	57.47	-3.7%

Appendix C – Modeling Methodology

EnergyPlus and OpenStudio

For the energy modeling tasks, the study used the PNNL Single Family Residential Prototype building models based on the 2018 and 2021 versions of the IECC for climate zone 6B.

Note that since the previous field study, updates were made to the single family EnergyPlus prototype model files to directly use the airflow network for duct leakage modeling rather than relying on post processing.

The following modifications were made to the IECC 2018 and IECC 2021 prototype models to include Montana amendments:

- Wood-framed Wall R-value
  - 2018: 20+5 or 13+10 (0.045) --> 21 (0.058) or 13+5
  - 2021: 20+5ci or 13+10ci or 0+20ci (0.045) --> 21 (0.058) or 20+5ci or 13+10ci or 0+15ci (0.045)
    - Note: In consultation with NEEA, the baseline models incorporate the R21 option, which meets the prescriptive R-value, but not the U-factor.
- Envelope tightness, 2018 and 2021
  - 3 ACH50 --> 4 ACH50

Additionally, a model was created for an unvented crawlspace foundation. The existing PNNL crawlspace foundation assumes a vented crawlspace with foundation insulation placed in the floor. The newly created model for an unvented crawlspace assumes:

- Insulation is placed along the exterior crawlspace wall
  - R-19 cavity insulation
- Crawlspace ventilation matches the indoor ventilation:
  - 5 ACH50

Montana Fuel Prices and Emission Factors

The fuel prices used for calculating potential energy cost savings from improved compliance are derived from the U.S. Energy Information Administration's (EIA) Montana State Energy Profile, which shows a state average residential electricity price of $0.1343/kWh and residential gas price of $11.18/Mcf, which is equal to $1.0915/therm assuming a natural gas heat content of 1,023 Btu/cf.[30,31]

The emissions rates used to calculate potential greenhouse gas (GHG) emissions savings for electricity available from improved compliance are derived from the National Renewable Energy Laboratory's (NREL) Cambium database for forecasted grid carbon intensity. Using the Cambium 2023 Mid-Case scenario's average CO_2e emissions (which include CO_2, CH_4, and N_2O) rate for electric load in the NorthernGrid East region (Idaho, Montana, and part of Wyoming), the 2025 rate is

30 "Montana State Energy Profile." U.S. EIA. 2024. https://www.eia.gov/state/print.php?sid=MT

31 "Heat Content of Natural Gas Consumed.: U.S. EIA. 2024. https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm

projected to be 0.2597 kg CO_2e/kWh. In 2050, the average emissions rate is projected to be 0.0169 kg CO_2e/kWh due to more low-carbon generation in the grid region.[32,33]

The emissions rate used to calculate GHG emissions savings for natural gas is derived from the EPA's emission factors for combustion fuels, which shows an emissions rate of 5.330.533 kg CO_2e/therm of natural gas.[34]

[32] "Cambium 2023 Scenario Descriptions and Documentation." NREL. 2024. https://www.nrel.gov/docs/fy24osti/88507.pdf
[33] "Cambium 2023". NREL. 2024. https://scenarioviewer.nrel.gov/?project=0f92fe57-3365-428a-8fe8-0afc326b3b43&mode=download&layout=Default
[34] Natural Gas Combustion. AP 42, 5thEdition, Vol. 1, Chapter 1. EPA. 1998. https://www3.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf

Appendix D – Interview Guides

NEEA Residential Energy Code Evaluation

Draft Interview Guide for Code Officials in Montana

[IEc WILL POPULATE THE FOLLOWING FIELDS PRIOR TO CONDUCTING THE INTERVIEW. NOTE TO INTERVIEWERS: DO **NOT** USE PHRASES LIKE “CHECKING COMPLIANCE”, “VERIFYING COMPLIANCE”, etc. DURING THE INTERVIEW.]

Date of Interview: _______________

Interviewer Name: ______________

Interviewer Email: _______________

Respondent Name: _______________

Respondent Jurisdiction: ______________________________

Respondent Phone: __________________________

Respondent Email: ________________

[INTERVIEWER READ] Thank you for your participation in the Northwest Energy Efficiency Alliance (NEEA) Residential Energy Code Evaluation. Interviews with code officials like you are an important part of the study. I will be asking you some questions about your experience overseeing new single-family home construction projects within your jurisdiction [IF STATEWIDE OFFICIAL READ, “WITHIN THE STATE OF MONTANA”]. All responses will remain confidential, and no personal information will be shared. Do you have any questions before we begin?

1. Briefly, please describe your background.
   a. What is your current role?
   b. How many years have you been in this role?
   c. Do you have previous experience in the Montana residential new construction space? If yes, please explain.
2. [IF INTERVIEW IS WITH A LOCAL CODE OFFICIAL READ] In a typical year, how many new single-family homes are built in your jurisdiction?

   [IF INTERVIEW IS WITH STATE CODE OFFICIAL READ] In a typical year, how many new single-family homes are built across the State of Montana?
   a. What percentage of these homes are built within jurisdictions that do not have local building code enforcement (that is, jurisdictions where the State oversees permitting)?
   b. Has the number of new single-family homes built in a typical year in your jurisdiction [IF STATEWIDE OFFICIAL READ, “across the State”] changed over the past five years? If yes, please explain.

3. Now I will read a list of seven building components. For each component, what percentage of homebuilders [IN YOUR JURISDICTION/ACROSS THE STATE] typically succeed in meeting the requirement in the IECC 2021 Code with Montana amendments?
   Please consider the percentage of builders who achieve success at the final review/conclusion of construction, that is, after incorporating any fixes from earlier inspections.
   We are not asking you for a precise estimate; we are simply trying to understand which parts of the code are challenging to meet. Please provide a range if you are unsure of the exact percentage of builders who are able succeed in meeting these requirements.
   For each component, please list any challenges that builders typically face when working towards these requirements. These challenges may be indicated by your direct observation, inspection results, or frequent questions or pushback from homebuilders, among other factors. [INTERVIEWER READ LIST AND POPULATE RESPONSES FOR EACH]

Building Code Component	% Succeeding	Challenges
a. Envelope tightness (ACH at 50 Pascals)		
b. Windows (U-factor & solar hear gain coefficient)		
c. Wall Insulation (assembly U-factor)		
d. Ceiling Insulation (R-value) [IF RESPONDENT IS LOCATED IN CLIMATE ZONE 6, ASK IF THEY WOULD CHANGE THIS RESPONSE WHEN THINKING ABOUT THE 2018 IECC CODE AND RECORD RESPONSE FOR BOTH YEARS]		
e. Lighting (percent high efficiency) [IF RESPONDENT IS LOCATED IN CLIMATE ZONE 6, ASK IF THEY WOULD CHANGE THIS RESPONSE WHEN THINKING ABOUT THE 2018 IECC CODE AND RECORD RESPONSE FOR BOTH YEARS]		
f. Foundation Insulation (includes floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation; R-value)		
g. Duct tightness (cfm per 100 ft^2 of conditioned floor area at 25 Pascals)		

4. Do any of these seven components have substantially lower success rates during pre-inspection/earlier reviews? If yes:
   a. Which components typically have these lower rates? [INTERVIEW REPEAT QUESTIONS 4b-4d FOR EACH COMPONENT LISTED IN 4a]
   b. What is the percentage success rate (or range) at which builders typically meet these requirements at the earlier stage review?

   c. Why do you think builders typically struggle initially to meet the requirements of this component?

   d. How are final success rates determined – for example, through a follow-up inspection, or builder's own self-certification?

5. Other than the seven components we just discussed, are there any other code components with requirements that are challenging to meet? If yes:
   a. What are they?
   b. Please explain why meeting the requirement(s) is (are) challenging.
   c. Approximately what percentage of builders succeed in meeting the requirements in the IECC 2021 Code with Montana amendments for this component?
      i. Does this percentage differ from those meeting the requirements in the IECC 2018 Code for that component?
6. Are there any components of the 2018 or 2021 IECC code with Montana amendments where homebuilders frequently ask questions (e.g., during code trainings) or tell you it is difficult to meet the code requirements? If yes:
   a. Which components and requirements?
   b. What questions or concerns do homebuilders raise about meeting these requirements?
7. Have you noticed any changes in the percentage of homebuilders who succeed in meeting the requirements from the previous code (the 2018 IECC with Montana amendments) to the current 2021 IECC with Montana amendments?
   a. If yes, for which components has the level of success changed? Why do you think it has changed?
   b. If you have reviewed the proposed changes for the 2024 IECC, do you anticipate any challenges for builders in complying with the new requirements?
8. [IF INTERVIEW IS WITH A LOCAL CODE OFFICIAL READ] How does the permitting process work in your jurisdiction? Specifically:

   [IF INTERVIEW IS WITH STATE CODE OFFICIAL READ] How does the permitting process work for homes permitted by the State? Specifically:

   a. Do builders self-certify?
   b. What portion of new homes receive an inspection? Is this announced or surprise?
   c. What happens if you find that a home does not meet energy code requirements?
   d. Can a home receive a permit without meeting all energy code requirements? If yes, is there a minimum set of requirements a home must meet to receive a permit?

   e. Is permitting done online of through a paper system? [IF DONE ONLINE READ] In what year did you switch to the online system and have you noticed any major changes to compliance and/or the permitting process as a result?

9. What is the typical level of resources used to verify energy code compliance for each new single-family home? Specifically: [INTERVIEWER READ EACH FOLLOW ITEM SEPARATELY AND RECORD THE RESPONSE]
   a. How many staff are in your department?
   b. How many staff are typically involved in plan review and issuing a permit for a new single-family site?
   c. What proportion of their work hours, per year, does each staff member spend reviewing energy code compliance at newly built homes, including reviewing documentation, conducting site visits, and/or completing any other similar activities? How does this compare to their time spent on other building code inspection components, and all other activities?
   d. Would your approach to energy code compliance reviews change with increased FTEs within your department? Why or why not?
10. Do you have any thoughts on additional support that would be helpful for improving code compliance (e.g., more frequent training, contract support, virtual inspection program, etc.)?
11. Are there any other thoughts you would like to share on the permitting process or the energy code?

NEEA Residential Energy Code Compliance Study

Draft Interview Guide – Builders

[POPULATE THE FOLLOWING FIELDS PRIOR TO CONDUCTING THE INTERVIEW.]

Date of Interview: ________________

Interviewer Name: _______________

Interviewer Email: ________________

Respondent Name: ________________

Respondent Organization Name: _______________________________

Respondent Phone: ____________________________

Respondent Email: _________________

Introduction

[INTERVIEWER READ] Thank you for your participation in the Northwest Energy Efficiency Alliance (NEEA) Residential Code Evaluations Study. Interviews with homebuilders like you are an important part of the study. I will be asking you some questions about your experience with new single-family home construction projects in Montana. When you answer these questions, please consider homes that you are building now and homes that you built within the last two years. All responses will remain confidential, and no personal information will be shared. May I begin?

12. Please briefly describe your background and your company. How many years have you been building homes in Montana? What part(s) of the State do you mostly work in and what types of homes (i.e., custom versus prescriptive) do you typically build?

13. In a typical year, how single-family new construction homes does your company build in Montana?

2A. Has the number of single-family new construction homes that your company builds in a typical year changed over the past decade? If so, please describe how this has changed.

14. I am now going to read a list of six building components. For each, please rate the level of difficulty to comply with the *current* Montana Code (i.e., IECC 2021 with Montana amendments) using a scale of 1 (least difficult to comply with) to 5 (most difficult to comply with). Difficulty in complying may be driven by a number of factors including, but not limited to, costs of obtaining materials, installation costs, availability of skilled labor, rigor of enforcement of the building energy code, clarity of code requirements, pressure from homeowners, etc. For each component, please provide the reason why you provided this rating. [INTERVIEWER READ LIST AND POPULATE RESPONSES FOR EACH]

Building/Code Component	**Rating (1-5)**	**Reason for rating**
3A. Windows (U-factor & solar heat gain coefficient)		
3B. Wall Installation (assembly U-factor)		
3C. Ceiling Insulation (R-value)		
3D. Lighting (percent high efficiency)		
3E. Foundation Insulation (includes floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation; R-value)		
3F. Duct tightness (cfm per 100 ft^2 of conditioned floor area at 25 Pascals)		

4A. Has the difficulty in complying with any of the above components changed substantially with the shift from the previous code (2018 IECC w/ Montana amendments) to the current (2021 IECC w/ Montana amendments)? If yes, what elements have been the most challenging and why?

4B. Are there any elements of the previous or current Montana code that were not listed above where compliance is a challenge? If so, please explain why compliance is a challenge for this component. How difficult is compliance using the 1-5 scale that you used previously?

4C. How do you think your challenges with code compare with other new, single-family homebuilders in Montana?

5A. Have you built homes in multiple permit-issuing jurisdictions (i.e., have you had to apply for permits with multiple cities, towns, and/or counties) within the State? If yes, please briefly describe how permitting/compliance differs across these jurisdictions.

5B. [READ IF NOT ADDRESSED in 4A] Have you built homes in both areas of the State where permits are issued by the State of Montana, and in areas where the local jurisdiction provides the permits? If yes, please briefly describe how permitting/compliance differs between the Statewide process and local jurisdictions.

6. Are there any other thoughts you would like to share on the permitting/compliance process within the State of Montana?

Appendix E – Interview & Permit Data Request Outreach Email

Montana Builder Interview Outreach Email:
Hello ______,

I hope you are doing well! My name is [NAME], and I am reaching out on behalf of the Northwest Energy Efficiency Alliance (NEEA). My company, Industrial Economics inc. (IEc), is currently working with NEEA to conduct a Residential Energy Code Evaluation in the State of Montana. As part of this study, we are collecting and analyzing building permit data, conducting some targeted on-site visits with builder approval, and interviewing several Montana homebuilders such as yourself.

We are interested in asking you some questions about your experience building new single-family homes in Montana. There are no right or wrong answers, and your candor will help ensure that our study results are accurate and useful. All responses will remain confidential, and no personal information will be shared with NEEA. After we complete the interview, we will send you a $175 Visa gift card for participating.

Please let me know if you are interested in participating and provide a few dates and times when you would be available for a 30-minute virtual meeting over the next couple of weeks. Then, I will follow up by sending a meeting invitation.

Feel free to let me know if you have any questions about this study or the interview itself before deciding whether or not to participate. Thank you for your consideration!

Best,
[NAME]

Code Official Interview Outreach Email:

Hi ______,

I hope you're doing well! My name is [NAME], and I am reaching out on behalf of the Northwest Energy Efficiency Alliance (NEEA). My company, Industrial Economics, Inc. (IEc), is currently working with NEEA to conduct a Residential Energy Code Evaluation in the State of Montana. As part of this study, we are collecting and analyzing building permit data, conducting some targeted on-site visits with builder approval, and interviewing several Montana code officials such as yourself.

We are conducting brief interviews with code officials across the state to try to better understand local levels of compliance and areas where builders may be facing challenges. The interview should last 20-30 minutes.

Please let me know if you are interested in participating and provide a few dates and times when you would be available over the next couple of weeks. Then, I will follow up by sending a meeting invitation.

Feel free to let me know if you have any questions about this study or the interview itself before deciding whether or not to participate. Thank you for your consideration!

Best,
[NAME]

Permit Request Outreach Email:

Hi ______,

My name is [NAME], reaching out on behalf of the Northwest Energy Efficiency Alliance (NEEA). My company, Industrial Economics inc. (IEc), is currently working with NEEA to conduct a Residential Energy Code Compliance Study in the State of Montana. As part of this study, we are collecting and analyzing data to better understand how energy codes are being implemented in Montana.

We are interested in both the previous code cycle (IECC 2018 IECC with Amendments) and the current code cycle (2021 IECC with Amendments). Specifically, we are seeking to review permit data from a random selection of jurisdictions across the State. Through this methodology, we have selected Belgrade for part of our review.

If you are able to participate in the study, we are requesting access to the following permit data:

- All single-family new construction homes that are currently under construction.
- All single-family new construction homes have been constructed within the past six months but are not yet occupied.
- All single-family new construction homes that were permitted under the last six months of the previous code cycle (IECC 2018 with Amendments).

Study results will not contain any personally identifiable information about homeowners, builders, or compliance department staff. For more information about the study, please contact Meghan Bean at mbean@neea.org or 503-688-5413, or I would be happy to answer any additional questions via email or a brief phone call. For more information about NEEA, please visit: neea.org.

Thank you,
[NAME]

Appendix F – Outreach Letter for Site Visits

Study Notification Flyer

Residential Energy Code Compliance Study

The Northwest Energy Efficiency Alliance, Inc. ("NEEA"), part of an alliance with Northwest utilities, and its contractors are conducting a Residential Energy Code Compliance Study by collecting and analyzing data to better understand how energy codes are being implemented in Montana (the "Study"). Using protocols established by the Department of Energy, NEEA is collecting the following data points from a group of randomly selected residences: envelope tightness, window heat gain, window Ufactor, wall insulation, ceiling insulation, floor and foundation insulation, lighting efficacy, and duct leakage. Not all data points will be collected from each residence.

This residence has been randomly selected to contribute to this Study. By allowing the collection of data, you agree to participate in the Study and also understand and agree to the following terms:

NEEA and its contractors take your privacy seriously and will not disclose any information in a manner that could identify you or the location of the residence.

NEEA and its contractors are not providing advice, recommendations, or certification related to residential energy code compliance. Any advice, guidance, or services provided by NEEA and its contractors is provided "as is". NEEA DISCLAIMS ALL REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, ADVICE AND WARRANTIES, EXPRESS OR IMPLIED, REGARDING THE STUDY INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEEA AND ITS CONTRACTORS MAKE NO REPRESENTATION OR WARRANTY OF ANY KIND, AND ASSUME NO LIABILITY WITH RESPECT TO QUALITY, SAFETY, PERFORMANCE, OR ANY OTHER ASPECT OF ANY DESIGN, OF EQUIPMENT OR STRUCTURES INSPECTED PURSUANT TO THE STUDY, AND EXPRESSLY DISCLAIM ANY SUCH REPRESENTATION, WARRANTY OR LIABILITY.

For more information about the Study, please contact **Meghan Bean** at NEEA (**mbean@neea.org** or **503-688-5413**) or **Greg Englehart** at Industrial Economics (IEc) (**GEnglehart@indecon.com** or **617299-3660**). For more information about NEEA, please visit our website: **neea.org**.

Appendix G – Residential Building Type Comparison

Summary

Montana residential code includes detached one- and two-family dwellings and townhouses as well as Group R-2, R-3, and R-4[35] buildings three stories or less in height above grade plane.

As the team prepared to schedule site visits based on the sampling plan, it was noted that in some parts of the state, townhouses are being constructed at a greater rate than single-family detached homes. Based on discussions with NEEA and the TAG, the team included townhouses and duplexes in the site visits.

This section compares the observed key measures in single-family detached homes to those in townhouses and duplexes to understand whether there are any notable differences. The histograms below compare single-family detached homes to "other residential" which includes townhouses and duplexes. In total, there were 143 site visits, which include 125 single-family detached homes, 9 townhouses, and 9 duplexes. For the purposes of this exercise, all observations are included in the histograms. In the main report, histograms only include observations required to meet the sampling plan.

In general, the team did not observe any major differences between the single-family detached and other residential sets. As a result, the team recommends including single-family detached homes, townhouses, and duplexes in the modeling and savings analysis.

It should also be noted that the DOE Residential Building Energy Code Field Study: Data Collection & Analysis does consider this issue. Under the DOE methodology, observations from both townhouses and single-family detached homes are combined for areas with a large population of townhomes, which aligns with the team's recommendation based on the site observations.

> *7.3.1 Townhomes and Multi-unit Buildings*
>
> *The analysis was conducted using the PNNL detached single-family prototype building model which represents the most dominant configuration of homes across the country.* ***However, two states included in the pilot study exhibited a large population of townhomes (MD and PA). PNNL investigated the effect of including townhomes within the state's analysis and noted a few key differences relative to states without a significant multi-unit population.*** *Mainly, the EUI for townhomes tends to be lower than that for detached single-family homes because townhomes typically have lower exterior wall areas and lower window areas— both resulting in lower heat transfer through the building envelope.* ***The overall complexity of the analysis necessitated combining the observations from the townhomes with those from detached single-family homes.*** *The impact of this simplification on the results is that the statewide mean EUI and the measure-level savings in the affected states may be overstated. However, delta EUIs between the Phase I statewide*

[35] According to the International Code Council, residential Group-2 occupancies contain sleeping units or more than two dwelling units where the occupants are primarily permanent in nature, such as apartments. Group R-3 have occupancies that are primarily permanent in nature and not classified as R-1, R-2, or R-4, such as dormitories with 16 or fewer occupants. Group R-4 includes occupancies for 6-15 persons excluding staff who reside on a 24-hours basis in a supervised residential environment and receive custodial care, such as assisted living facilities.

mean and the baseline code-compliant EUI would likely remain unchanged because any changes are expected to affect both the baseline and the observed EUIs similarly.

Results

Envelope Tightness

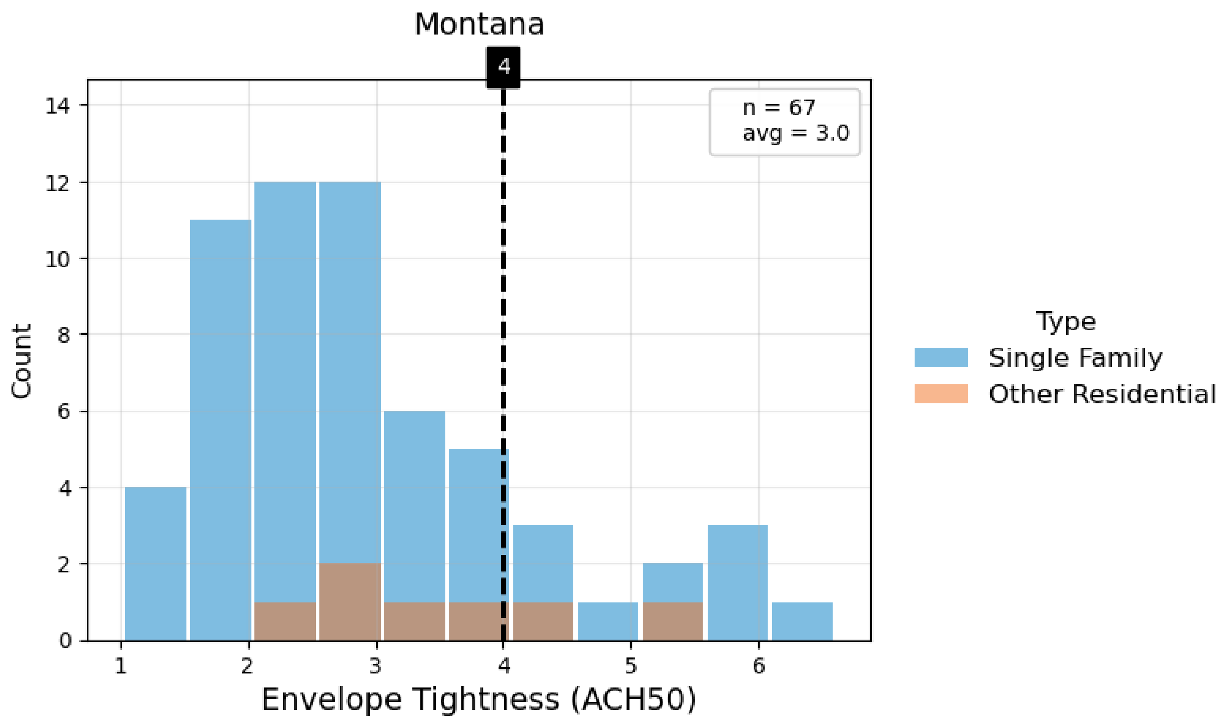

Figure 21. Envelope tightness (ACH50)

Table 42. Envelope tightness (ACH50)

Type	Single Family	Other Residential	Statewide
Number	60	7	67
Range	1.0 to 6.6	2.1 to 5.2	1.0 to 6.6
Average	2.9	3.5	3.0
Requirement	4	4	4
Compliance Rate	50 of 60 (83%)	5 of 7 (71%)	55 of 67 (82%)

Interpretations:

- The average air leakage rate is lower in single-family homes (2.9 verses 3.5). However, both averages outperform the 4ACH requirement and the other residential observations all fall within the single-family range.

Windows

U-factor

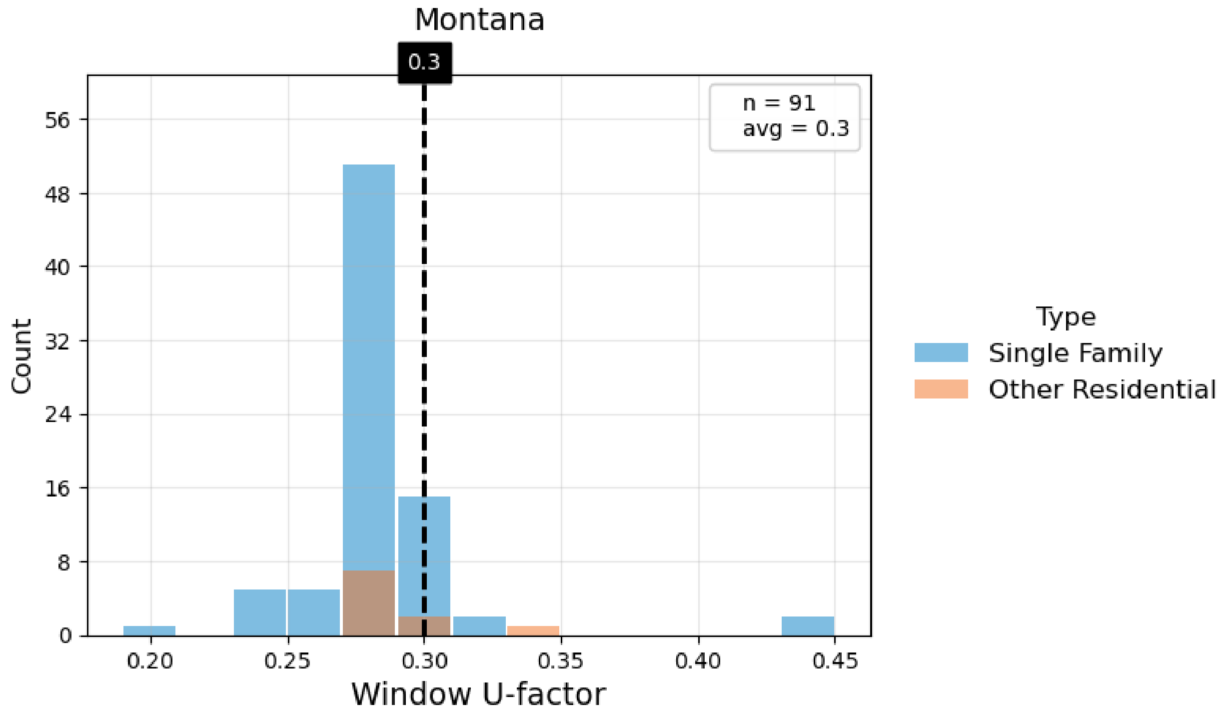

Figure 22. Window U-factor

Table 43. Window U-factor

Type	Single Family	Other Residential	Statewide
Number	81	10	91
Range	0.2 to 0.5	0.3 to 0.3	0.2 to 0.5
Average	0.3	0.3	0.3
Requirement	0.30	0.30	0.3
Compliance Rate	77 of 81 (95%)	9 of 10 (90%)	86 of 91 (95%)

Interpretations:

- Both categories have high compliance and an average of 0.30 for the window U-factor.

Solar Heat Gain Coefficient

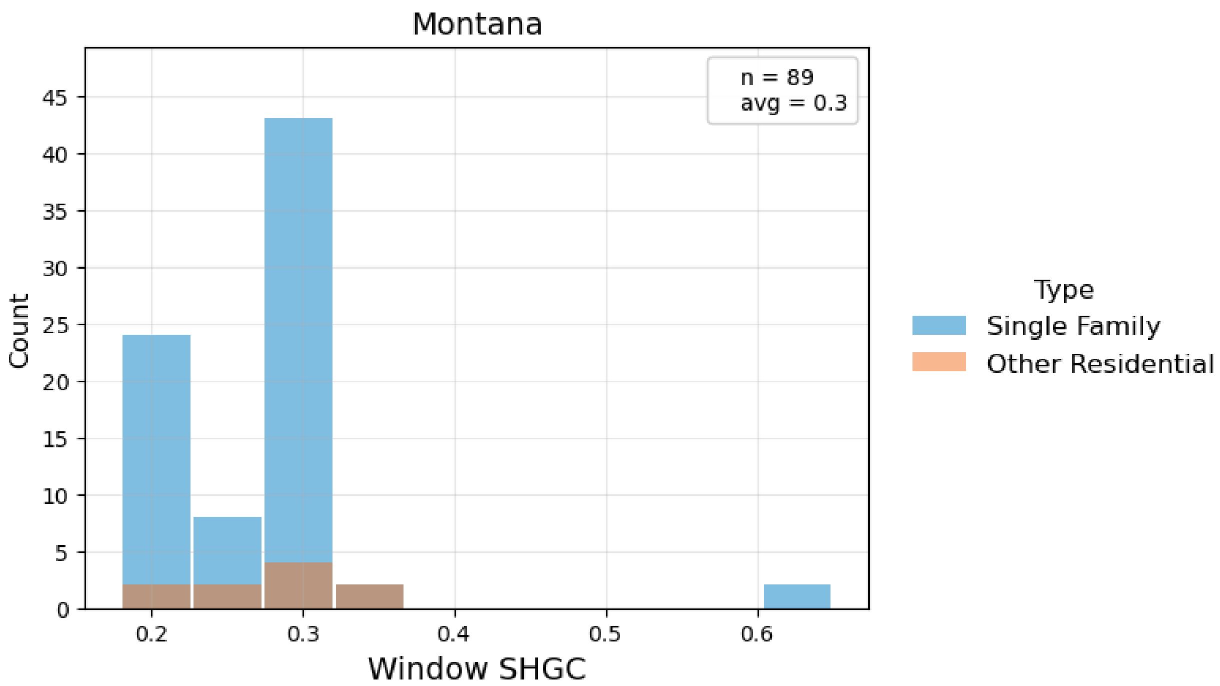

Figure 23. Window SHGC

Table 44. Window SHGC

Type	Single Family	Other Residential	Statewide
Number	79	10	89
Range	0.18 to 0.65	0.20 to 0.34	0.18 to 0.65
Average	0.3	0.3	0.3
Requirement	None	None	None
Compliance Rate	NA	NA	NA

Interpretations:

- With the exception of one single-family outlier, the observed window SHGC values are all very similar. The average in both categories is 0.30.

Wall Insulation

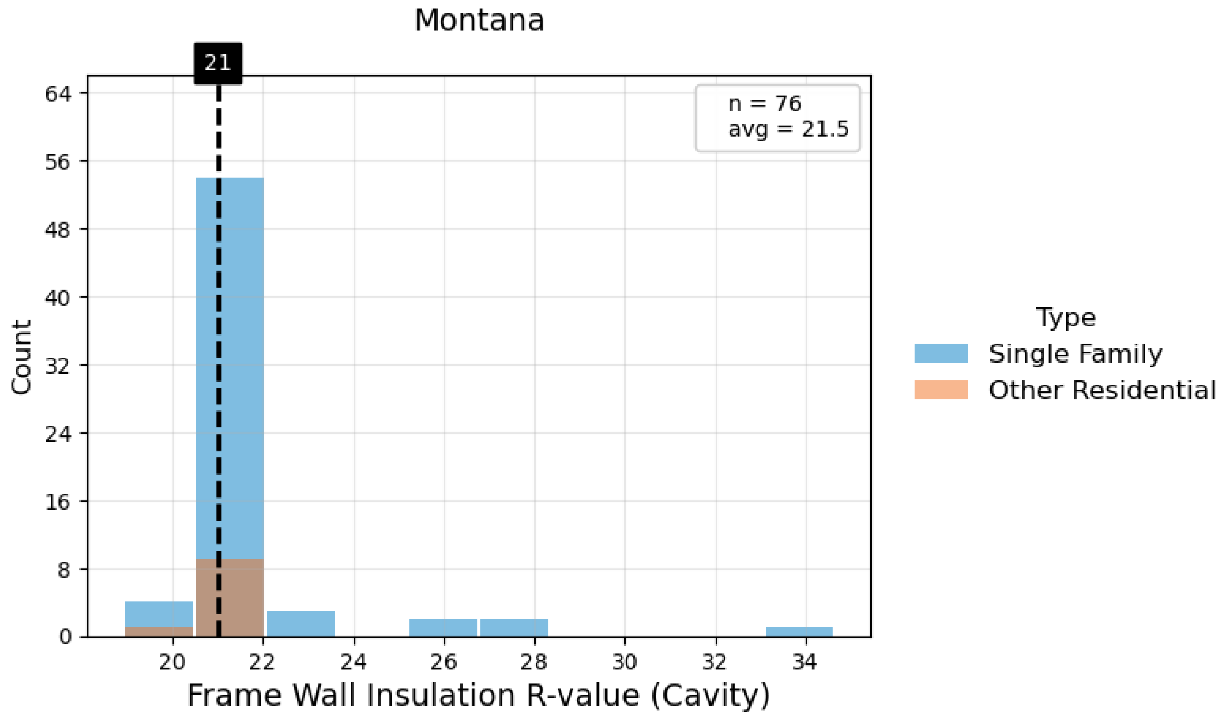

Figure 24. Wall R-values

Table 45. Wall R-values

Type	Single Family	Other Residential	Statewide
Number	66	10	76
Range	18.9 to 34.6	19.8 to 21.0	18.9 to 34.6
Average	21.6	20.9	21.5
Requirement	21	21	21
Compliance Rate	62 of 66 (94%)	9 of 10 (90%)	71 of 76 (93%)

Interpretations:

- The single-family detached homes have a wider range of wall insulation R-values, however both averages are very close to the R-21 prescriptive requirement.
- The single-family detached homes with higher R-value generally include spray foam in the cavity. This was not observed in the other residential set.

Ceiling Insulation

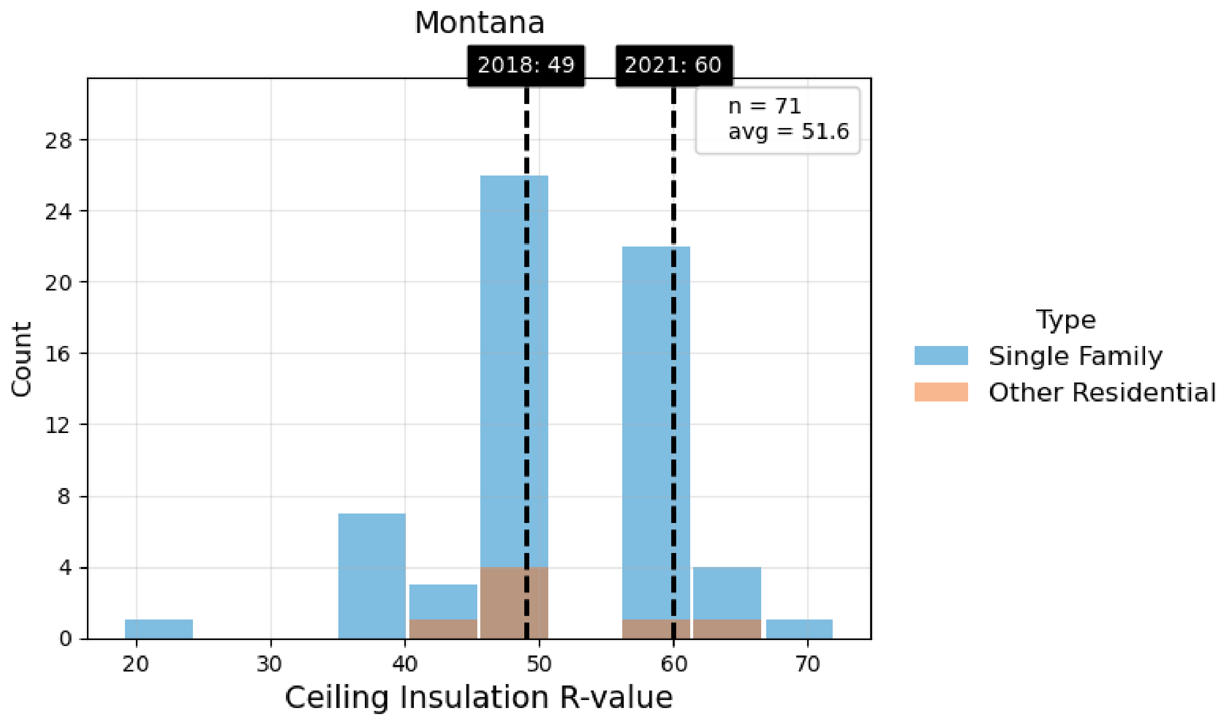

Figure 25. Ceiling R-value

Table 46. Ceiling R-value 2018 requirements

Type	Single Family	Other Residential	Statewide
Number	64	7	71
Range	19.0 to 72.0	42.0 to 64.8	19.0 to 72.0
Average	51.6	51.5	51.6
Requirement	49	49	49
Compliance Rate	53 of 64 (83%)	6 of 7 (86%)	59 of 71 (83%)

Table 47. Ceiling R-value 2021 requirements

Type	Single Family	Other Residential	Statewide
Number	64	7	71
Range	19.0 to 72.0	42.0 to 64.8	19.0 to 72.0
Average	51.6	51.5	51.6
Requirement	60	60	60
Compliance Rate	11 of 64 (17%)	1 of 7 (14%)	12 of 71 (17%)

Interpretations:

- Under IECC 2018 with Montana Amendments, the ceiling insulation requirement is R-49. This was increased to R-60 under IECC 2021 with Montana Amendments.
- Both categories have very similar average values and compliance levels.

- It should be noted that with a Statewide compliance of 17%, complying with the R-60 requirement is an area for improvement.

Lighting

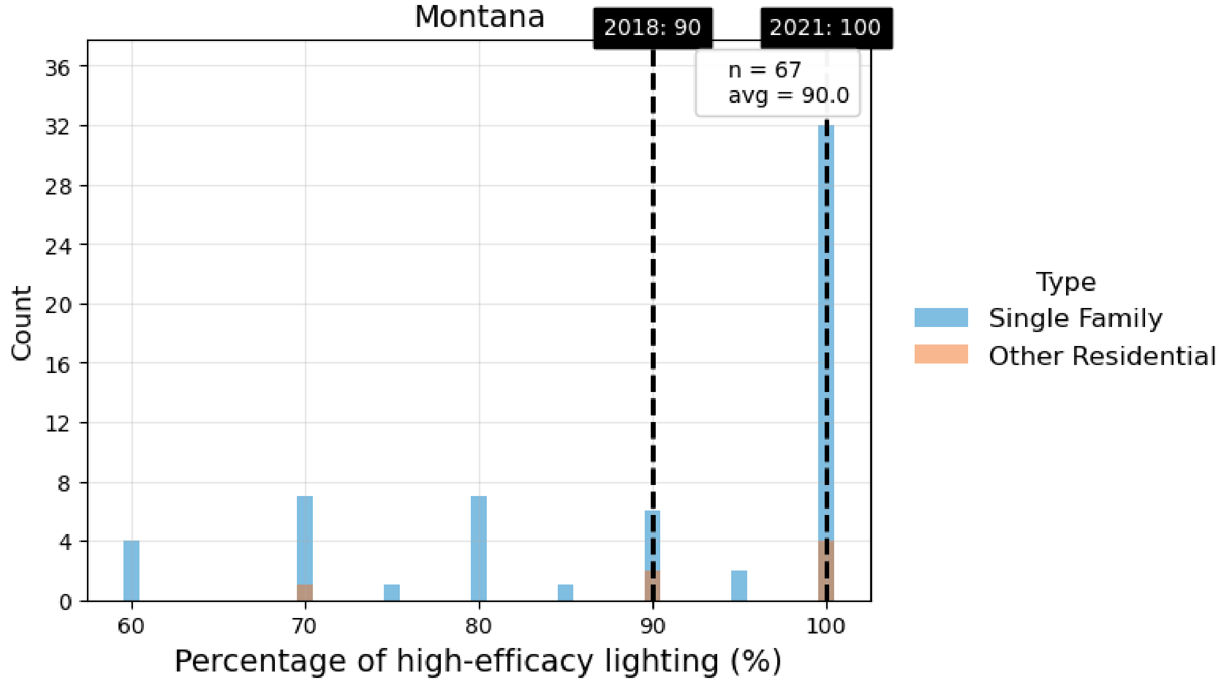

Figure 26. High-efficacy lighting percentage[36]

Table 48. High-efficacy lighting percentage 2018 requirements

Type	Single Family	Other Residential	Statewide
Number	60	7	67
Range	60.0 to 100.0	70.0 to 100.0	60.0 to 100.0
Average	89.7	92.9	90.0
Requirement	90	90	90
Compliance Rate	40 of 60 (67%)	6 of 7 (86%)	46 of 67 (69%)

Table 49. High-efficacy lighting percentage 2021 requirements

Type	Single Family	Other Residential	Statewide
Number	60	7	67
Range	60.0 to 100.0	70.0 to 100.0	60.0 to 100.0
Average	89.7	92.9	90.0
Requirement	100	100	100
Compliance Rate	32 of 60 (53%)	4 of 7 (57%)	36 of 67 (54%)

[36] An error was discovered in the on-site lighting observations after this portion of the analysis was complete. Once corrected, all but six observations had 100% high-efficacy lighting, resulting in 98% under 2018 and 90% under 2021. These values are corrected in the main body of the report.

Interpretations:

- The percent high-efficacy lighting average is similar in both categories (89.7% in single-family and 92.9 in other residential). In both categories, the most common observation is 100%.
- However, since the single-family average falls just below the 2018 requirement, compliance is lower (67% versus 86%).
- Other residential only has seven observations compared to 60 in the single-family category. All of the other residential observations fall well within the single-family range.

Foundation Insulation

Insulation in Floors Over Unconditioned Spaces

Following DOE's methodology, insulation in floors over unconditioned spaces includes both vented crawlspaces and unheated basements. There were no unheated basements observed and only one vented crawlspace, which was in a single-family home. The observed R-value was R-31, which exceeds the R-30 requirement.

Basement Wall Insulation (Conditioned Basements)

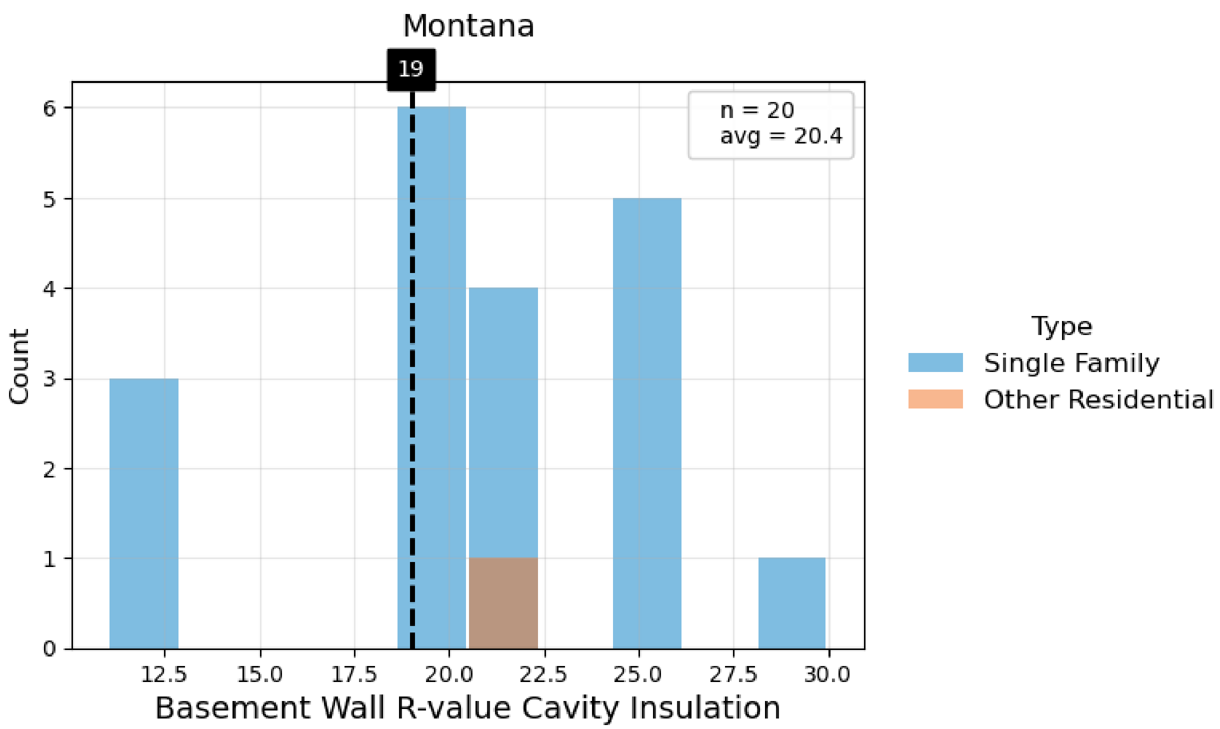

Figure 27. Basement wall R-value

Table 50. Basement wall R-value

Type	Single Family	Other Residential	Statewide
Number	19	1	20
Range	11.0 to 30.0	21.0 to 21.0	11.0 to 30.0
Average	20.4	21.0	20.4
Requirement	19	19	19
Compliance Rate	16 of 19 (84%)	1 of 1 (100%)	17 of 20 (85%)

Interpretation:

- The average basement wall R-value was similar in both categories, 20.4 in single-family and 21.0 in other residential. These exceed the R-19 prescriptive requirement.
- All of the other residential observations were R-21, while single-family ranged from 11.0 to 30.0. The three single-family observations with lower R-values were all 2x4 construction.

Unvented Crawlspace Wall Insulation

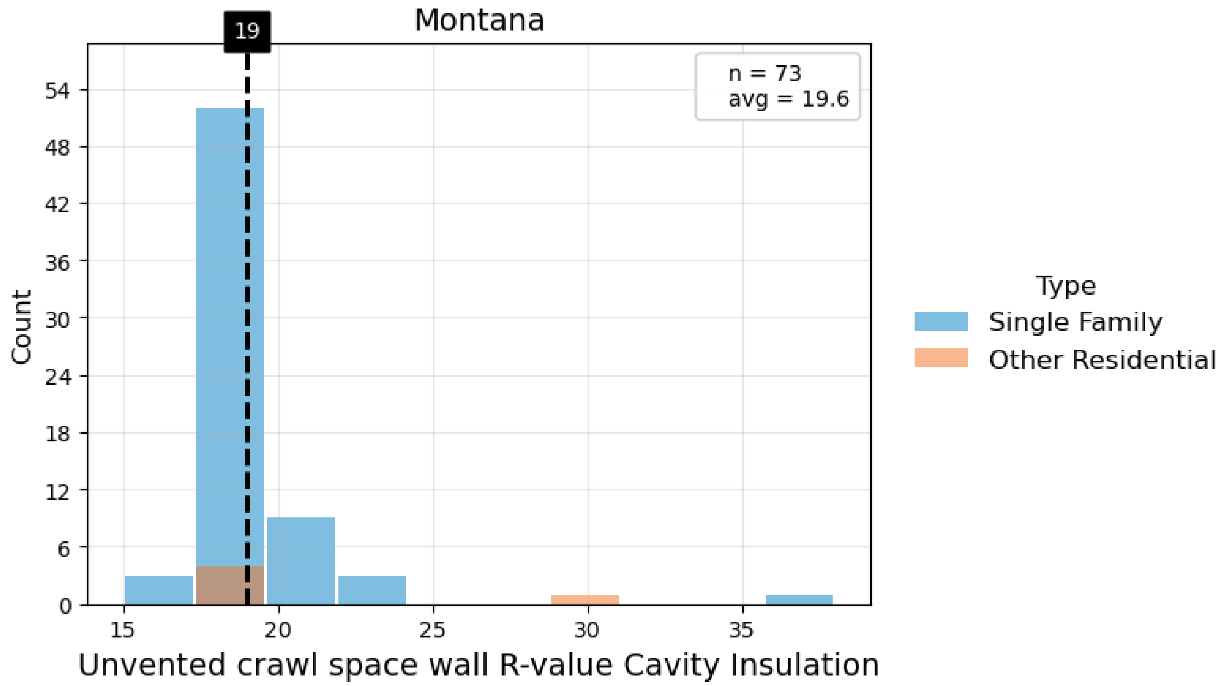

Figure 28. Unvented crawlspace wall R-value

Table 51. Unvented crawlspace wall R-value

Type	Single Family	Other Residential	Statewide
Number	68	5	73
Range	15.0 to 38.0	19.0 to 30.0	15.0 to 38.0
Average	19.5	21.2	19.6
Requirement	19	19	19
Compliance Rate	65 of 68 (96%)	5 of 5 (100%)	70 of 73 (96%)

Interpretation:

- The average unvented crawl wall R-value was similar in both categories, R-19.5 in single-family and R-21.2 in other residential. These exceed the R-19 prescriptive requirement.

Slabs

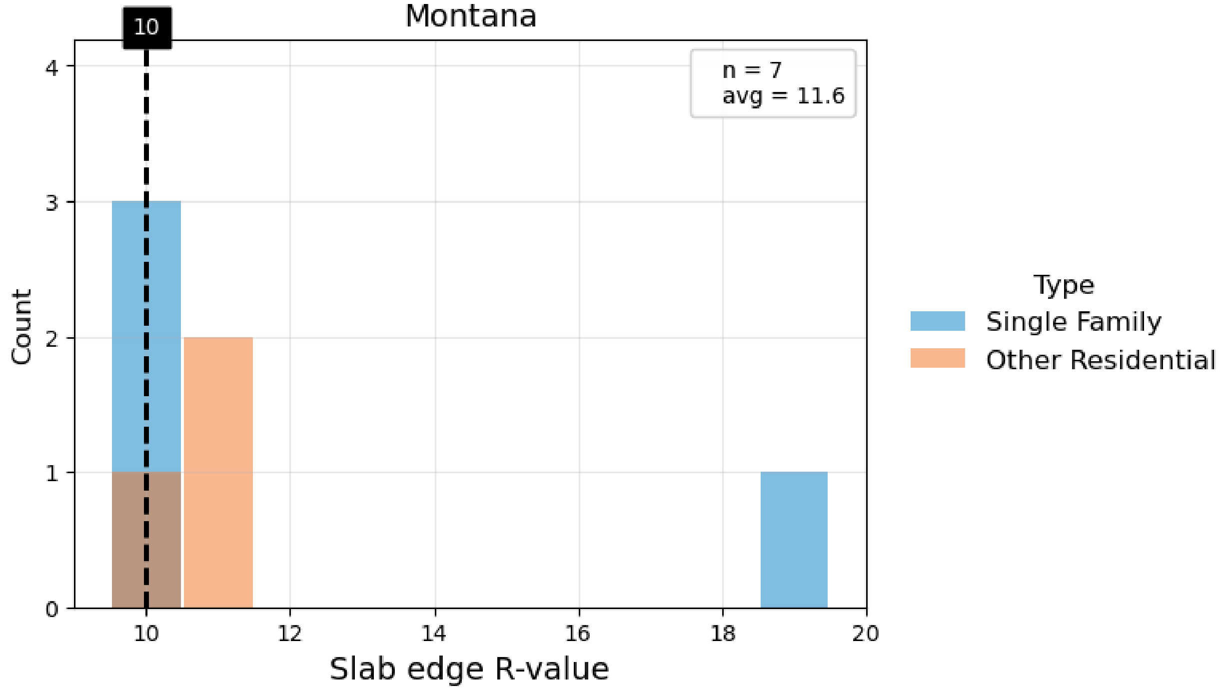

Figure 29. Slab edge R-value

Table 52. Slab edge R-value

Type	Single Family	Other Residential	Statewide
Number	4	3	7
Range	10.0 to 19.0	10.0 to 11.0	10.0 to 19.0
Average	12.2	10.7	11.6
Requirement	10	10	10
Compliance Rate	4 of 4 (100%)	3 of 3 (100%)	7 of 7 (100%)

Interpretations:

- There were only 7 slab edge R-value observations, but all of them met or exceeded the prescription requirement.

Duct Tightness

This section summarizes the duct tightness results for both raw duct leakage and adjusted duct leakage. The raw duct leakage is the value observed on-site. Adjusted duct leakage accounts for ducts in conditioned spaces. For ducts entirely in conditioned space, the adjusted duct leakage is set to zero, regardless of the observed on-site value. Tests are not required if the ducts are entirely in conditioned space, so the adjusted duct leakage is the more accurate metric for compliance rates.

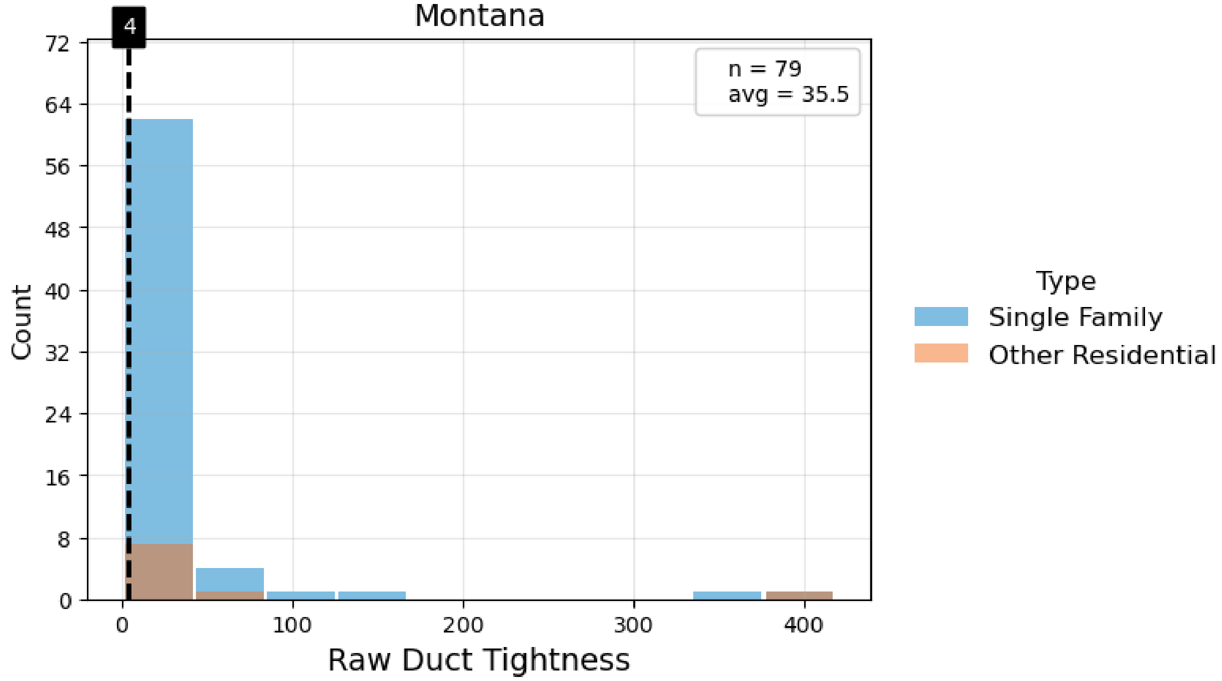

Figure 30. Raw duct tightness

Table 53. Raw duct tightness

Type	Single Family	Other Residential	Statewide
Number	70	9	79
Range	0.5 to 418.0	3.0 to 407.8	0.5 to 418.0
Average	32.4	59.8	35.5
Requirement	4	4	4
Compliance Rate	6 of 70 (9%)	1 of 9 (11%)	7 of 79 (9%)

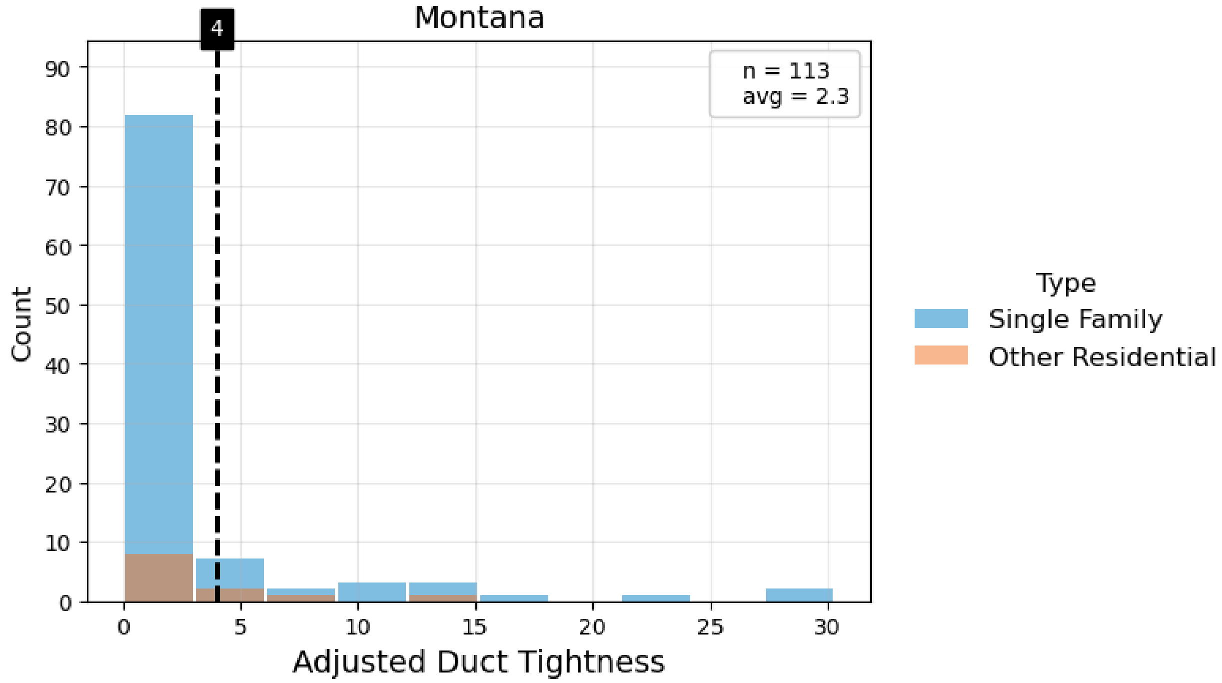

Figure 31. Adjusted duct tightness

Table 54. Adjusted duct tightness

Type	Single Family	Other Residential	Statewide
Number	101	12	113
Range	0.0 to 30.3	0.0 to 13.4	0.0 to 30.3
Average	2.3	2.7	2.3
Requirement	4	4	4
Compliance Rate	83 of 101 (82%)	9 of 12 (75%)	92 of 113 (81%)

Interpretations:

- In both categories, the vast majority of homes meet or exceed the 4 ft^3/min per 100 ft^2 of CFA at 25 Pa requirement for duct tightness.
- The adjusted duct tightness average is slightly lower in single-family (2.3 versus 2.7). However, there were 101 single-family duct tightness observations, but only 12 in the other residential category. All of the other residential observations fall within the single-family range.
- Note: There are more adjusted duct leakage observations than raw duct leakage observations. This is because there were 34 observations that noted 100% of the ducts were in conditioned space, but did not include a raw duct leakage measurement. Since all of these would be converted to 0 ft^3/min per 100 ft^2 of CFA at 25 Pa, regardless of the raw measurement, these observations were included in this exercise.