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Montana Residential Energy Code Field Study

April 2019

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Y Xie

U.S. DEPARTMENT OF ENERGY

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

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

A research project in the state of Montana identified opportunities to reduce homeowner utility bills in residential single-family new construction by increasing compliance with the state energy code. The study was initiated in May 2018; data collection began in June 2018 and continued through September 2018. During this period, the project team visited 125 homes at various stages of construction, resulting in a data set based on observations made directly in the field. Analysis of the data has led to a better understanding of the energy features present in homes and identified nearly $192,000 in potential annual savings to Montana homeowners that could result from increased compliance with the Montana Residential Energy Code[1]. Public and private entities within the state can use this information to justify and catalyze future investments in energy code training and related energy efficiency programs.

Methodology

The project team was led by David Freelove, an independent energy code consultant, with support from Cadmus and the Northwest Energy Efficiency Alliance. The team applied a methodology prescribed by the U.S. Department of Energy (DOE), which was based on collecting information for the energy code-required building components with the largest direct impact on energy consumption. These *key items* are a focal point of the study and drive the analysis and savings estimates. The project team implemented a customized sampling plan representative of new construction within the state; the sampling plan was developed by Pacific Northwest National Laboratory (PNNL) and vetted through meetings with Montana Energy Code Collaborative.

Following data collection, PNNL conducted three stages of analysis on the resulting data set (Figure ES.1). The first stage identified compliance trends within the state based on the distributions observed in the field for each key item. The second stage modeled energy consumption of the homes observed in the field relative to what would be expected if sampled homes just met minimum code requirements. The third stage then calculated the potential energy savings, consumer cost savings, and avoided carbon emissions associated with increased code compliance. Together, these findings provide valuable insight on challenges facing energy code implementation and enforcement, and are intended to inform future energy code education, training, and outreach activities.

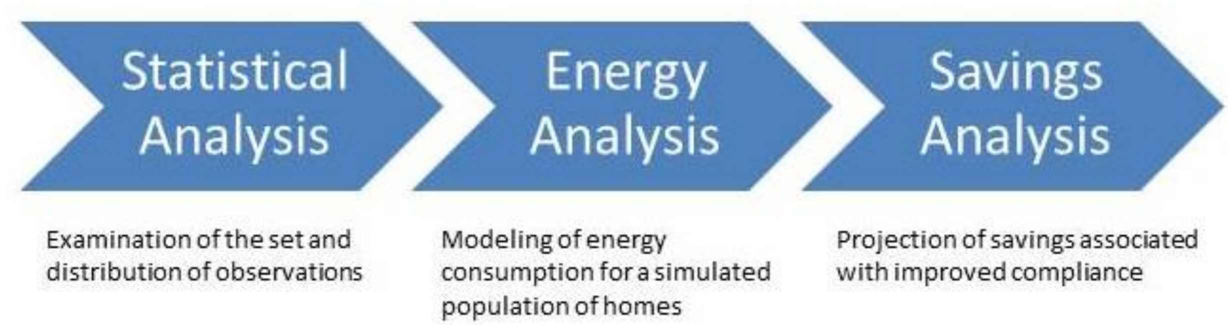

Figure ES.1. Stages of Analysis Applied in the Study

[1] On November 7, 2014, Montana adopted the 2012 International Energy Conservation Code (IECC) with several amendments.

Results

Table ES.1 shows the key items with the greatest saving potentials that could be achieved through increased code compliance in Montana. The estimates represent the savings associated with each measure and are extrapolated based on projected new construction. These items should be considered a focal point for compliance enhancement programs within the state, including energy code education, training, and outreach initiatives.

Table ES.1. Estimated Annual Statewide Savings Potential in Montana

Measure	**Total Energy Savings** (MMBtu)	**Total Energy Cost Savings** ($)	**Total State Emissions Reduction** (MT CO2e)
Duct Leakage	10,302	97,836	1,195
Exterior Wall Insulation	8,212	75,123	787
Envelope Air Leakage	1,516	11,721	21
Foundation Insulation	1,141	7,051	-86
TOTAL	**21,171 MMBtu**	**$191,731**	**1,783 MT CO2e**

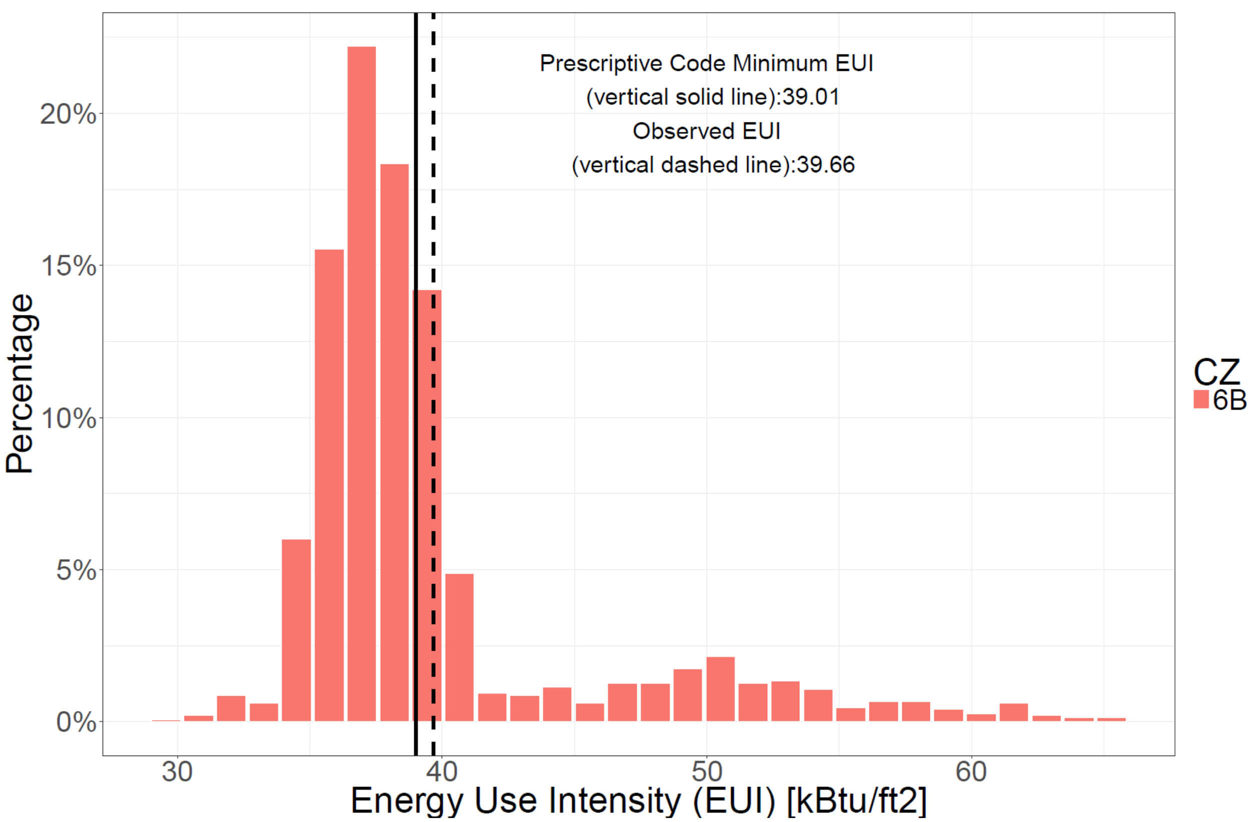

Figure ES.2. Modeled distribution of regulated EUI (kBtu/ft^2/year) in Montana

In terms of overall energy consumption, the analysis shows that homes within the state use *more* energy than would be expected relative to homes built to the current minimum state code requirements (Figure ES.2). Analysis of the collected field data indicates average regulated energy use intensity (EUI) of 39.66

kBtu/ft^2-yr statewide compared to 39.01 kBtu/ft^2-yr for homes exactly meeting minimum *prescriptive* energy code requirements. This suggests that, on average, the typical home in the state is about 2% worse than code.

Note that in an EUI analysis, items found to be better than code offset savings from items found to be worse than code. These below-code items represent a savings opportunity regardless of the above-code items. In this study, a significant portion of homes were found to not meet code in several key areas impacting energy use, durability, and comfort. Thus, there is an energy savings opportunity of nearly $192,000 annually from energy code compliance enhancement activities in Montana.

Acknowledgments

The following members comprised the Montana project team:

- David Freelove, *Energy Code Consultant*
- Jerica Stacey, and Jolyn Green, *Cadmus*

The Montana project team wishes to acknowledge the Northwest Energy Efficiency Alliance (NEEA) for providing the funding for this project. The team would also like to thank Steve Phoutrides, Senior Project Manager of Market Research and Evaluation at NEEA, for managing the project and Bing Liu, Senior Codes and Standards Manager at NEEA, for providing an insightful review of the report.

Additionally, the team extends its gratitude to the following peer reviewers and the Montana Energy Code Collaborative for their continued support throughout the project:

- Bonnie Rouse and Paul Tschida, Montana Department of Environmental Quality, and
- Dale Horton, Senior Energy Specialist at the National Center for Appropriate Technology

Northwest Energy Efficiency Alliance

The Northwest Energy Efficiency Alliance (NEEA) is a non-profit organization working to effect market transformation through the acceleration and adoption of energy-efficient products, services and practices. NEEA is an alliance of more than 140 Northwest utilities and energy efficiency organizations working on behalf of more than 13 million energy consumers. For more information, visit neea.org.

Cadmus

The Cadmus Group LLC was founded in 1983 in Watertown, MA. They provide services in the areas of energy, climate, water, public health, international development, transportation, and safety, security, and resiliency. See more information on Cadmus at https://www.cadmusgroup.com/.

Acronyms and Abbreviations

AC	air conditioning
ACCA	Air Conditioning Contractors of America
ACH	air changes per hour
AFUE	annual fuel utilization efficiency
AIA	American Institute of Architects
Btu	British thermal unit
cfm	cubic feet per minute
CO2e	carbon dioxide equivalent
CZ	climate zone
DOE	U.S. Department of Energy
EDC	electric distribution company
EERE	Office of Energy Efficiency and Renewable Energy
EUI	energy use intensity
FOA	funding opportunity announcement
HERS	home energy rating system
HSPF	heating season performance factor
ICC	International Code Council
IECC	International Energy Conservation Code
kBtu	thousand British thermal units
MMBtu	million British thermal units
MT	Montana
NA	not applicable
NEEA	Northwest Energy Efficiency Alliance
PNNL	Pacific Northwest National Laboratory
RESNET	Residential Energy Services Network
RFI	request for information
SHGC	solar heat gain coefficient

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1.0 Introduction

A research project in the state of Montana investigated the energy code-related aspects of unoccupied, newly constructed, single-family homes across the state. The study followed a methodology prescribed by the U.S. Department of Energy (DOE), which allowed the project team to build an empirical data set based on observations made directly in the field. The data was then analyzed by Pacific Northwest National Laboratory (PNNL) to identify compliance trends, determine the impact of such trends on statewide energy consumption, and calculate savings that could be achieved through increased code compliance. Study findings can help to justify additional support for energy code education, training, and outreach activities, as well as catalyze future investments in compliance enhancement programs.

The Montana field study was initiated in May 2018; data collection began in June 2018 and continued through September 2018. During this period, the project team visited 125 homes across the state at various stages of construction. At the time of the study, the state energy code was the 2012 International Energy Conservation Code (IECC) with Montana amendments, effective November 2014. The study methodology, data analysis, and findings are presented throughout this report.

1.1 Background

Energy codes for residential buildings have advanced significantly in recent years; today's model codes are approximately 30% more efficient than codes adopted by the majority of U.S. states. [1,2] As such, there is a growing need to ensure code-intended energy savings are achieved and that consumers reap the benefits of improved codes— outcomes that will happen only through high levels of compliance.

The purpose of the Montana field study is to gather field data on energy code measures as installed and observed in actual homes and identify trends and issues that can inform energy code training and other compliance enhancement programs. This study was modeled after DOE's field study, "Strategies to Increase Residential Energy Code Compliance Rates and Measure Results".[3] More information on DOE's interest in compliance is available on the DOE Building Energy Codes Program website.[4]

1.2 Project Team

David Freelove, an independent energy code consultant, led the Montana project team and collected the field data; Cadmus and the Northwest Energy Efficiency Alliance (NEEA) provided support to Mr. Freelove throughout the project. DOE and PNNL defined the methodology, conducted data analysis, and provided technical assistance to the project team. Funding for the data collection by the project team was provided by NEEA. More information on the organizations comprising the project team is included in the Acknowledgements section of this report.

[1] *National Energy and Cost Savings for New Single- and Multifamily Homes: A Comparison of the 2006, 2009, and 2012 Editions of the IECC*, available at http://www.energycodes.gov/development

[2] Available at http://www.energycodes.gov/adoption/states

[3] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study

[4] Available at https://www.energycodes.gov/compliance

1.3 Stakeholder Interests

Throughout the duration of the Montana field study, the project team actively engaged with the Montana Energy Code Collaborative, a stakeholder group comprising interested and affected parties within the state. Stakeholders represented the following groups:

- Building officials
- Homebuilders
- Energy efficiency advocates
- University professors
- Residential appraisal experts
- Utilities

A description of the stakeholders that participated in the project kickoff meeting is included in Appendix A.

Members of these and other groups are critical to the success of the project, as their buy-in to the results is necessary for future activities. Such stakeholders hold important information (e.g., building officials have the lists of homes under construction and are therefore key to the sampling process), control access to homes needed for site visits, are targets for training, or, as is often the case with government agencies, have oversight responsibilities for code adoption and implementation.

Utilities are also crucial stakeholders and often have direction from state regulatory bodies (e.g., the public utility commission) to achieve energy savings. Many utilities have expressed an increasing interest in energy code investments and are looking at energy code compliance as a means to provide assistance and generate additional savings. The field study is aimed specifically at providing a strong, empirically-based case for such utility investment.

2.0 Methodology

2.1 Overview

The Montana field study was based on a methodology developed by DOE to identify savings opportunities associated with increased energy code compliance. This methodology involves gathering field data on energy code measures as they are installed and observed in actual homes. The subsequent analysis identifies trends and issues with code compliance and can be used to inform energy code training and other compliance enhancement programs.

Highlights of the methodology:

- Focuses on **individual code requirements** within **new single-family homes**
- Based on a **single site visit** to reduce burden and minimize bias
- Prioritizes **key items** with the greatest impact on energy consumption
- Designed to produce **statistically significant results**
- **Data confidentiality** built into the study—no occupied homes were visited, and no personal data shared
- Results based on an **energy metric** and reported at the **state level**

PNNL identified the code-requirements (and associated energy efficiency measures) with the greatest direct impact on residential energy consumption. [1] These *key items* drive sampling, data analysis, and eventual savings projections:

1. Envelope tightness (ACH at 50 Pascals)
2. Windows (U-factor & SHGC)
3. Wall insulation (assembly U-factor)
4. Ceiling insulation (R-value)
5. Lighting (% high-efficacy)
6. Foundation insulation (R-value)[2]
7. Duct tightness (expressed in cfm per 100 ft^2 of conditioned floor area at 25 Pascals)

PNNL evaluated the variability associated with each key item and concluded that a minimum of 63 observations would be needed for each one to produce statistically significant results at the state level. Both the key items themselves and the required number of observations were prescribed in the DOE methodology.

The following sections describe how the methodology was implemented as part of the Montana study, including sampling, data collection, and data analysis. More information on the full DOE protocol and

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[1] Based on the *mandatory* and *prescriptive* requirements of the International Energy Conservation Code (IECC).

[2] Floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation were combined into a single category of foundation insulation.

PNNL analysis is published separately from this report (DOE/PNNL 2018) and is available on the DOE Building Energy Codes Program website.[3]

2.2 State Study

The prescribed methodology was customized for Montana to reflect circumstances unique to the state, such as state-level code requirements and regional construction practices. Customization also ensured that the results of the study would have credibility with stakeholders.

2.2.1 Sampling

PNNL developed a statewide sampling plan statistically representative of recent construction activity within the state. The samples were apportioned to jurisdictions across the state in proportion to their average level of construction compared to the overall construction activity statewide. This approach is a proportional random sample, which PNNL based on the average of the three most recent years of Census Bureau permit data.[4] The plan specified the number of key item observations required in each selected jurisdiction (totaling 63 of each key item across the entire project coverage area). The sampling plan was vetted with the Montana Energy Code Collaborative.

2.2.2 Data Collection

Following confirmation of the sample plan, the project team began contacting local building departments to identify homes currently in the permitting process. Code officials responded by providing lists of homes at various stages of construction within their jurisdiction. These lists were then sorted using a random number generator and utilized by the project team to contact builders to gain site access. As prescribed by the methodology, each home was visited only once to avoid any bias associated with multiple site visits. Only installed items directly observed by the field team during site visits were recorded. If access was denied for a particular home on the list, field personnel moved onto the next home on the list.

2.2.2.1 Data Collection Form

The field teams relied on a data collection form customized to the *mandatory* and *prescriptive* requirements of the state energy code, the 2012 IECC with Montana amendments.[5] The final data collection form is available in spreadsheet format on the DOE website.[6] The form included all energy code requirements (i.e., not just the eight key items), as well as additional items required under the prescribed methodology. For example, the field teams were required to conduct a blower door test and duct leakage test using RESNET[7] protocols on every home where such tests could be conducted.

The information beyond the key items was used during various phases of the analysis, or to supplement the overall study findings. For example, insulation installation quality impacts the energy-efficiency of insulation was used to modify that key item during the energy modeling and savings calculation.

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[3] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study.

[4] Available at http://censtats.census.gov/ (select the “Building Permits” data).

[5] Information about the Montana energy code is available at http://deq.mt.gov/Energy/eec/EnergyCode.

[6] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study and based on the forms typically used by the RES*check* compliance software.

[7] See http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf.

Equipment, including fuel type and efficiency rating, and basic home characteristics (e.g., foundation type) helped validate the prototype models applied during energy simulation. Other questions, such as whether the home participated in an above-code program, can assist in understanding whether other influencing factors are at play beyond the code requirements.

The data collected were the energy values observed, rather than the compliance status. For insulation, for example, the R-value was collected; for windows, the U-factor. The alternative, such as was used in DOE's older work, simply stated whether an item did or did not comply. The current approach provides an improved understanding of how compliance equates to energy consumption and gives more flexibility during analysis since the field data can be compared to any energy code.

2.2.2.2 Data Management and Availability

Once the data collection effort was complete, the project team conducted a thorough quality assurance review. This included an independent check of raw data compared to the information provided to PNNL for analysis, and helped to ensure completeness, accuracy, and consistency across the inputs. Prior to submitting the data to PNNL, the team also removed all personally identifiable information, such as project site locations and contact information. The final dataset is available in spreadsheet format on the DOE website.[8]

2.3 Data Analysis

PNNL conducted all data analysis in the study through three basic stages:

1. **Statistical Analysis:** Examination of the data set and distribution of observations for individual measures
2. **Energy Analysis:** Modeling of energy consumption for a simulated population of homes
3. **Savings Analysis:** Projection of savings associated with improved compliance

The first stage identified compliance trends within the state based on what was observed in the field for each key item. The second stage modeled energy consumption (of the homes observed in the field) relative to what would be expected if sampled homes just met minimum code requirements. The third stage then calculated the potential energy savings, consumer cost savings, and avoided carbon emissions associated with increased code compliance. Together, these findings provide valuable insight on challenges facing energy code implementation and enforcement, and are intended to inform future energy code education, training, and outreach activities.

The following sections provide an overview of the analysis methods applied to the field study data, with the resulting state-level findings presented in Section 3.0, State Results.

2.3.1 Statistical Analysis

Standard statistical analysis was performed with distributions of each key item plotted by climate zone. This approach enables a better understanding of the range of data and provides insight on what energy-efficiency measures are most commonly installed in the field. It also allows for a comparison of installed values to the applicable code requirement, and for identification of any problem areas where potential for

[8] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study.

improvement exists. The graph below represents a sample key item distribution, and is further explained in the following paragraph.

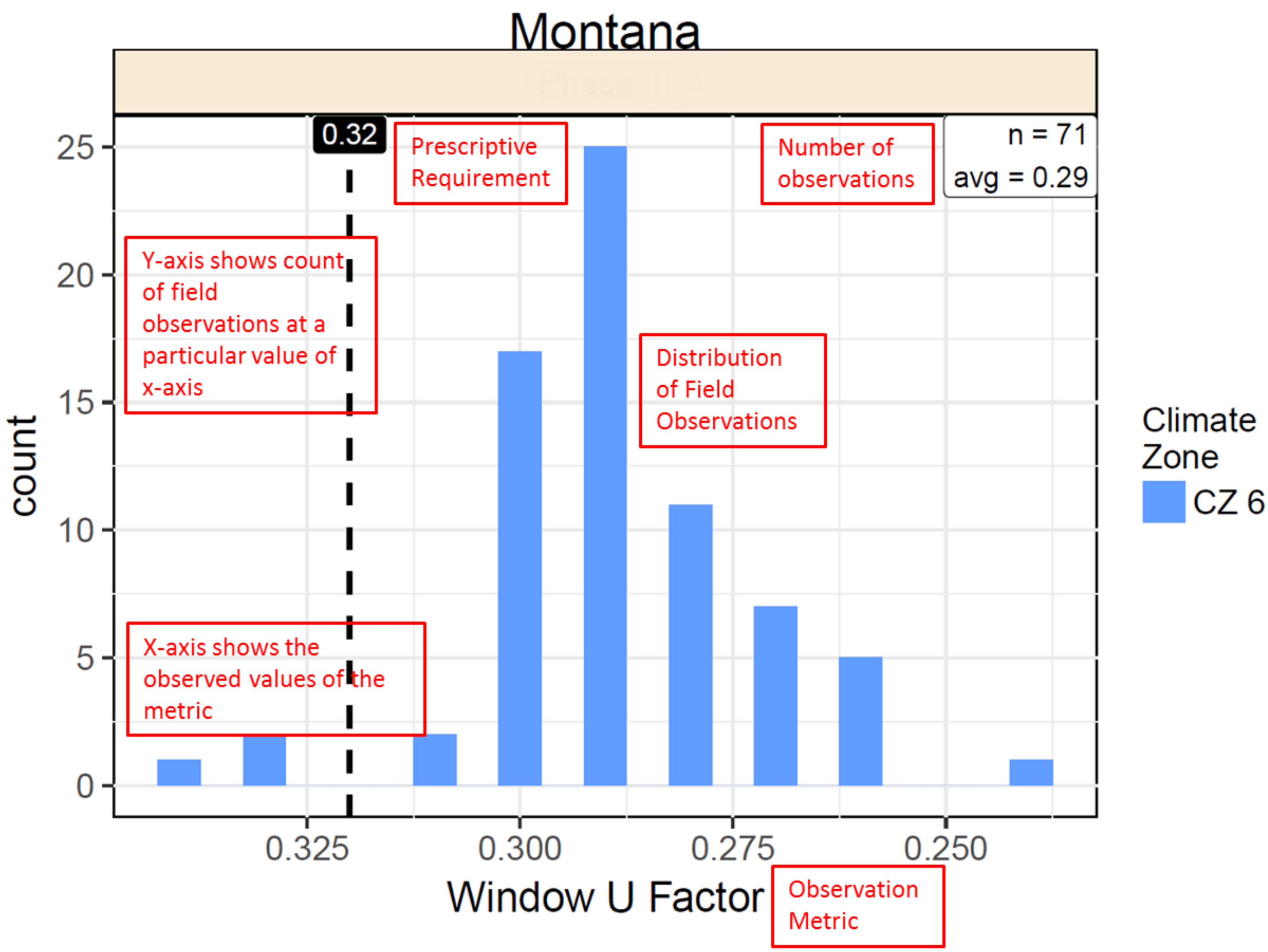

Figure 2.1. Sample Graph

Each graph is set up in a similar fashion, identifying the *state*, *climate zone*, and specific item being analyzed. The total *sample size* (n) is displayed in the top left or right corner of the graph, along with the distribution *average*. The *metric* associated with the item is measured along the horizontal axis (e.g., window U-factor is measured in Btu/ft^2-hr-F), and a *count* of the number of observations is measured along the vertical axis. A vertical line is imposed on the graph representing the applicable code requirement (e.g., the prescriptive requirement in climate zone 6 is 0.32)—values to the right-hand side of this line are *better than code*. Values to the left-hand side represent areas for improvement.

For walls and foundations, two graphs are included – one for R-value observations and another for U-factor observations. The R-value graphs show whether or not homes are being constructed with the required amount of insulation for the climate zone. The U-factor graphs indicate whether or not the combination of installed R-value and insulation installation quality meets the U-factor requirements in the climate zone. The combination of these two graphs can be used to determine if there is an issue with the amount of insulation, insulation installation quality, or both.

2.3.2 Energy Analysis

The next phase of the analysis leveraged the statistical analysis results to model average statewide energy consumption. A consequence of the field study methodology allowing only one site visit per home to minimize bias is that a full set of data cannot be gathered on any single home, as not all energy-efficiency measures are in place or visible at any given point during the home construction process. This lack of complete data for individual homes creates an analytical challenge because energy modeling and simulation protocols require a complete set of inputs to generate reliable results. To address this challenge, a series of "pseudo homes" were created, composed of over 1,500 models encompassing most of the possible combinations of key item values found in the observed field data. In aggregate, the models provide a statistical representation of the state's population of newly constructed homes. This approach is known in statistics as a Monte Carlo analysis.

Energy simulation was then conducted using the EnergyPlus™ software.[9] Each of the 1,500 models was run multiple times to represent each combination of heating systems and foundation types commonly found in the state. This resulted in upwards of 30,000 simulation runs for climate zone 6. An EUI was calculated for each simulation run and these results were then weighted by the frequency with which the heating system/foundation type combinations were observed in the field data. Average EUI was calculated based on regulated end uses (heating, cooling, lighting, and domestic hot water) for two sets of homes—one *as-built* set based on the data collected in the field, and a second *code-minimum* set (i.e., exactly meeting minimum code requirements). Comparing these values shows whether the population of newly constructed homes in the state is using more or less energy than would be expected based on minimum code requirements. Further specifics of the energy analysis are available in the methodology report (DOE/PNNL 2018).

2.3.3 Savings Analysis

To begin the third phase, each of the key items was examined individually to determine which had a significant number of observed values that did not meet the associated code requirement.[10] For these items, additional models were created to assess the savings potential, comparing what was observed in the field to a scenario of full compliance (i.e., where all worse-than-code observations for a particular item exactly met the corresponding code requirement).[11] This was done by individually upgrading each worse-than-code observation to the corresponding *prescriptive* code requirement, resulting in a second set of models (*full compliance*) that could be compared to the first (*as-built*). All other components were maintained at the corresponding prescriptive code value, allowing for the savings potential associated with a key item to be evaluated in isolation.

All variations of observed heating systems and foundation types were included, and annual electric, gas, and total EUIs were extracted for each building. To calculate savings, the differences in energy use calculated for each case were weighted by the corresponding frequency of each observation to arrive at an average energy savings potential for each climate zone. Potential energy savings for each climate zone were further weighted using construction starts in that zone to obtain the average statewide energy savings potential. State-specific construction volumes and fuel prices were used to calculate the maximum

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[9] *See* https://energyplus.net/

[10] "Significant" was defined as 15% or more of the observed values not meeting the associated code requirement. Only the items above this threshold were analyzed.

[11] Better-than-code items were not included in this analysis because the intent was to identify the maximum savings potential for each measure. The preceding energy analysis included both better-than-code and worse-than-code results, allowing them to offset each other.

energy savings potential for the state in terms of *energy* (MMBtu), *energy cost* ($), and avoided *carbon emissions* (MT CO2e).

Note that this approach results in the maximum theoretical savings potential for each measure as it does not take “interaction effects” into account, such as the increased amount of heating needed in the winter when energy efficient lights are installed. A building’s energy consumption is a dynamic and interactive process that includes all the building components present within a given home. 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.

2.4 Limitations

The following sections address limitations of the project, some of which are inherent to the methodology itself, and other issues as identified in the field.

2.4.1 Applicability of Results

An inherent limitation of the study design is that the results can be considered statistically significant only at the state level. Other results of interest, such as analysis based on climate zone level, or reporting of non-key items, were identified. While some of these items are visible in the publicly available data set, they should not be considered statistically representative.

2.4.2 Determination of Compliance

The field study protocol is based on a single site visit, which makes it impossible to know whether a particular home complies with the energy code as not enough information can be gathered in a single visit to know whether all code requirements have been met. For example, homes observed during the earlier stages of construction often lack key features (e.g., walls with insulation), and in the later stages, many of these items may be covered and therefore unobservable. To gather all the data required in the sampling plan, field teams therefore needed to visit homes in various stages of construction. The analytical implications of this are described above in Section 2.3.2.

2.4.3 Sampling Substitutions

As is often the case with field-based research, substitutions to the state sampling plan were sometimes needed to fulfill the complete data set. If the required number of observations in a jurisdiction could not be met because of a lack of access to homes or an insufficient number of homes (as can be the case in rural areas), substitute jurisdictions were selected by the project team. In all cases, the alternative selection was comparable to the original in terms of characteristics such as the level of construction activity and general demographics. More information on the sampling plan and any state-specific substitutions are discussed in Appendix B.

2.4.4 Site Access

Site access was purely voluntary and data was collected only in homes where access was granted, which can be characterized as a self-selection bias. While every effort was made to limit this bias (i.e., sampling randomization, outreach to builders, reducing the burden of site visits, etc.), it is inherent due to the voluntary nature of the study. The impacts of this bias on the overall results are not known.

2.4.5 Analysis Methods

All energy analysis was conducted using prototype models; no individually visited homes were modeled, as the self-imposed, one-visit-per-home limitation meant that not all necessary modeling inputs could be collected from a single home. Thus, the impact of certain field-observable factors such as size, height, orientation, window area, floor-to-ceiling height, equipment sizing, and equipment efficiency were not included in the analysis. In addition, duct leakage was modeled separately from the other key items due to limitations in the EnergyPlus™ software used for analysis. It should also be noted that the resulting energy consumption and savings projections are based on modeled data, and not on utility bills or actual home energy usage.

2.4.6 Presence of Tradeoffs

The field team was able to gather only a minimal amount of data regarding which code compliance paths were being pursued for homes included in the study; all analyses therefore assumed that the prescriptive path was used. The project team agreed that this was a reasonable approach. The overall data set was reviewed in an attempt to determine if common tradeoffs were present, but the ability to do this was severely limited by the single site-visit principle which did not yield complete data sets for a given home. To the extent it could be determined, it did not appear that there was a systematic presence of tradeoffs.

3.0 State Results

3.1 Field Observations

The eight key items form the basis of the study and are therefore the focus of this section. However, discussion of other findings is covered in this section as well, including a description of how certain observations, such as insulation installation quality, are used to modify key items. (See Section 2.3.1 for a sample graph and explanation of how they should be interpreted.) Montana has one climate zone, zone 6 (CZ 6), and it is represented in the sampling, data collection, resulting analysis, and statewide savings calculations.

3.1.1 Key Items

The field study and underlying methodology are driven by *key items* that have a significant direct impact on residential energy efficiency. The graphs presented in this section represent the key item results for the state based on the measures observed in the field. Note that these key items are also the basis of the results presented in the subsequent *energy* and *savings* phases of analysis.

The following key items were found to be applicable within the state:

1. Envelope tightness (ACH at 50 Pascals)
2. Window SHGC
3. Window U-factor
4. Exterior wall insulation (assembly U-factor)
5. Ceiling insulation (R-value)
6. Lighting (% high-efficacy)
7. Foundations – basement walls, crawlspace and floors (assembly U-factor)
8. Duct tightness (expressed in cfm per 100 ft^2 of conditioned floor area at 25 Pascals)

3.1.1.1 Envelope Tightness

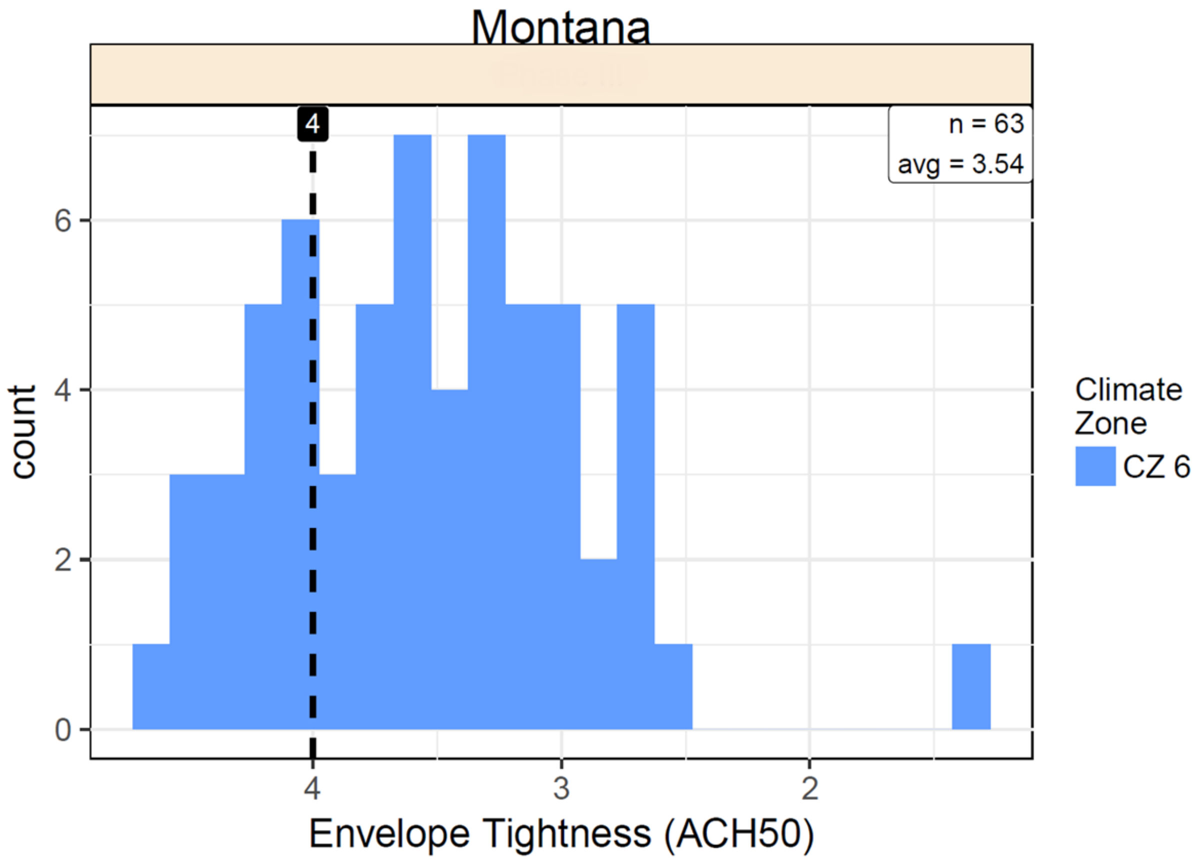

Figure 3.1. Envelope Tightness (ACH50)

Table 3.1. Envelope Tightness (ACH50)

Climate Zone	CZ6	Statewide
Number	63	63
Range	1.4 to 4.6	1.4 to 4.6
Average	3.5	3.5
Requirement	4	4
Compliance Rate	46 of 63 (73%)	46 of 63 (73%)

- **Interpretations:**
  - Overall, the distribution exhibits lower air leakage than expected based on the current code requirement.
  - Almost two-thirds of the observations met or exceeded the prescriptive code requirement.

3.1.1.2 Window SHGC

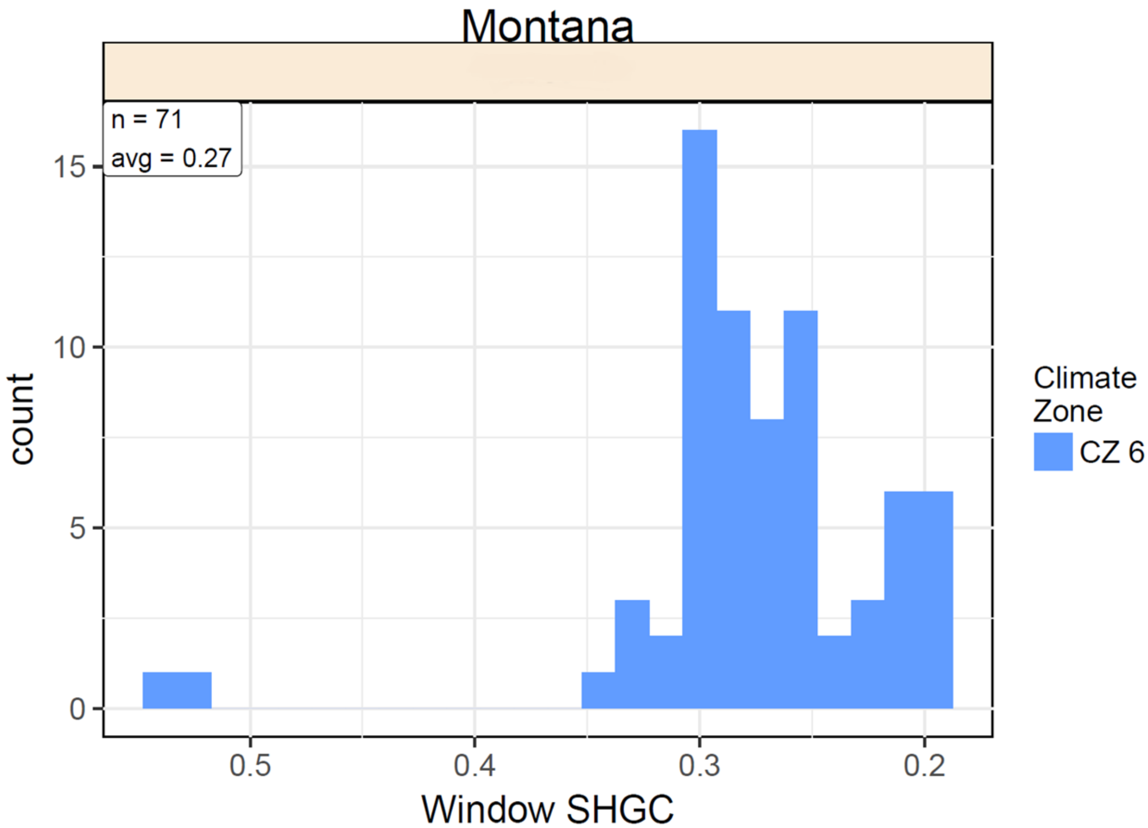

Figure 3.2. Window SHGC

Table 3.2. Window SHGC

Climate Zone	CZ6	Statewide
Number	71	71
Range	0.19 to 0.54	0.19 to 0.54
Average	0.27	0.27
Requirement	NA	NA
Compliance Rate	NA	NA

- **Interpretations:**
  - SHGC values were very consistent, and nearly meet the prescriptive requirement for Climate Zones 1-3, even though there are no SHGC requirements in Climate Zone 6.
  - The vast majority of the observations were in the 0.25 to 0.32 SHGC range.

3.1.1.3 Window U-Factor

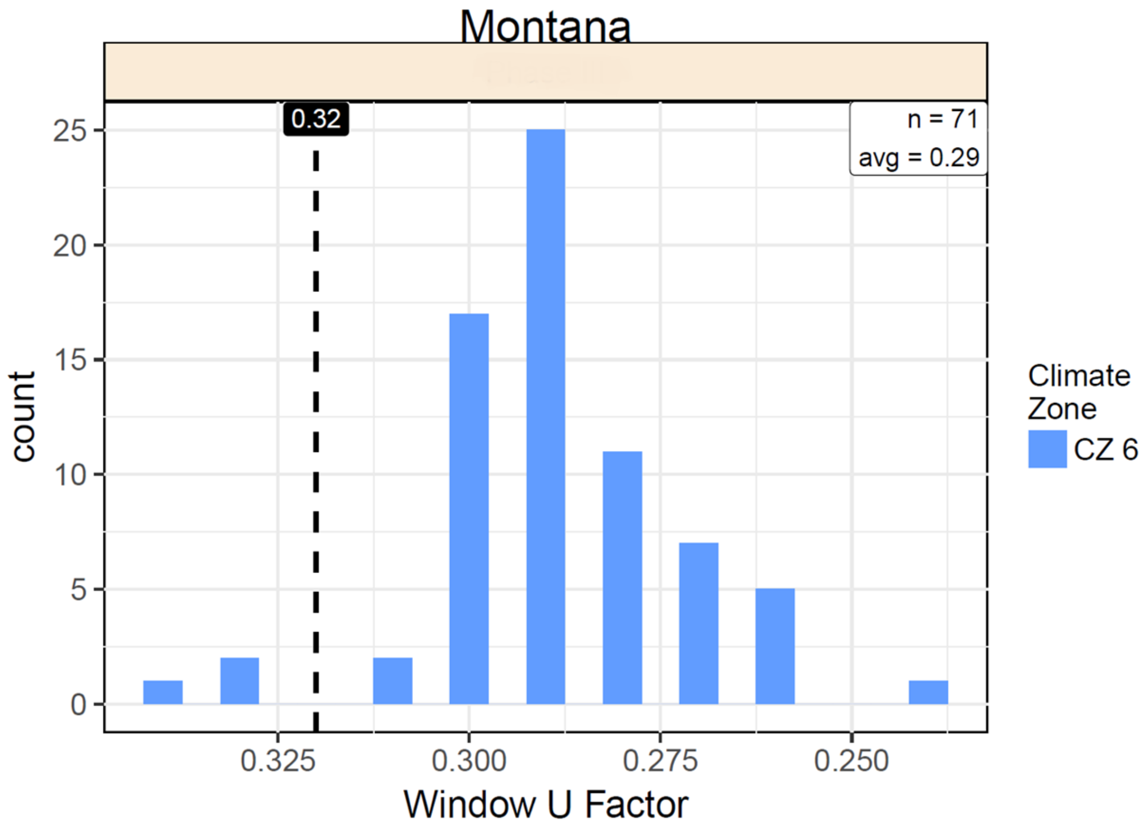

Figure 3.3. Window U-Factor

Table 3.3. Window U-Factor

Climate Zone	CZ6	Statewide
Number	71	71
Range	0.24 to 0.34	0.24 to 0.34
Average	0.29	0.29
Requirement	0.32	0.32
Compliance Rate	68 of 71 (96%)	68 of 71 (96%)

- **Interpretations:**
  - There is an extremely high rate of compliance for fenestration products.
  - This represents one of the most significant findings of the field study, with nearly all of the observations at or above the code requirement.
  - Window U-factor requirements appear to have been implemented with a high rate of success.

3.1.1.4 Wall Insulation

Two graphs are shown for walls, cavity and continuous insulation (R-value) and binned wall assembly (U-factor). The R-value graphs show both the cavity and continuous insulation R-values observed, sorted in order of increasing cavity insulation R-value. The binned U-factor graphs indicate the U-factor of the wall assembly, including cavity and continuous insulation layers and framing, and considering insulation installation quality, as observed in the field. The U-factors are binned to reduce the number of bars in the chart as individual U-factor observations may be only slightly different.

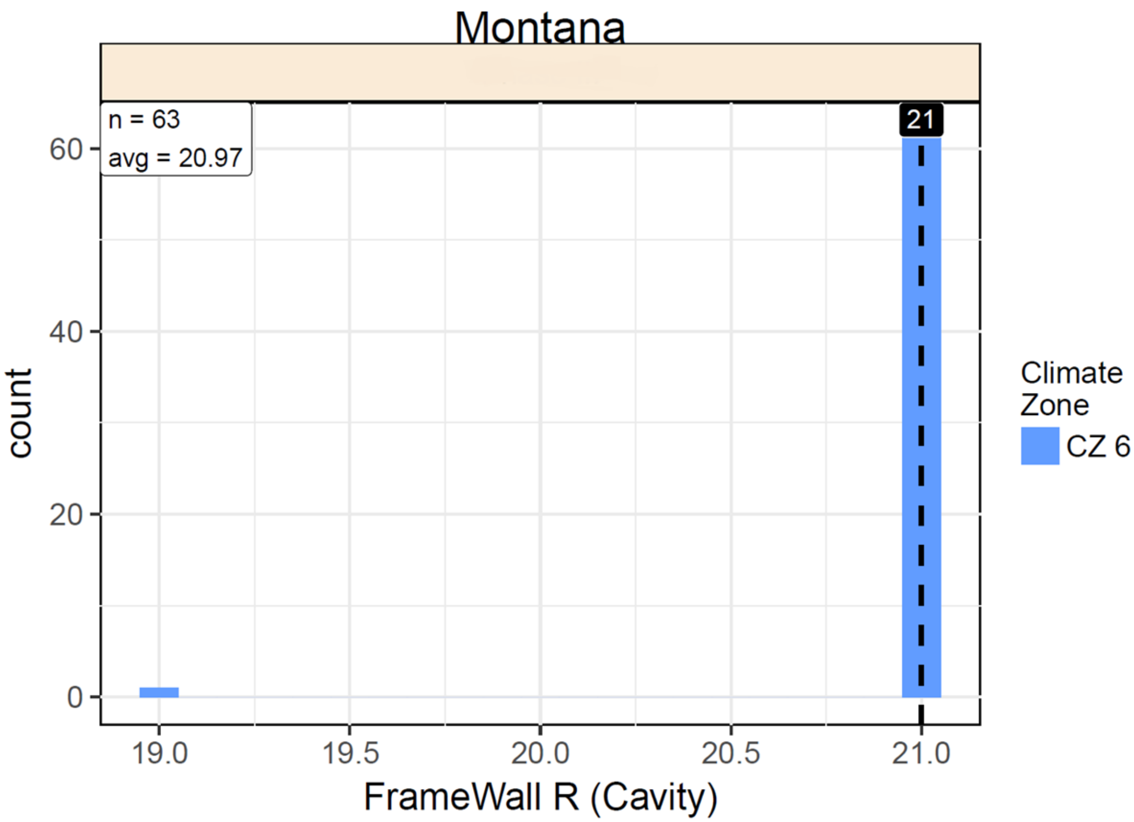

Figure 3.4. Wall R-Values

Table 3.4. Wall R-Value

Climate Zone	CZ6	Statewide
Number	63	63
Range	R-19 to R-21	R-19 to R-21
Average	R-21	R-21
Requirement	R-21	R-21
Compliance Rate	62 of 63 (98%)	62 of 63 (98%)

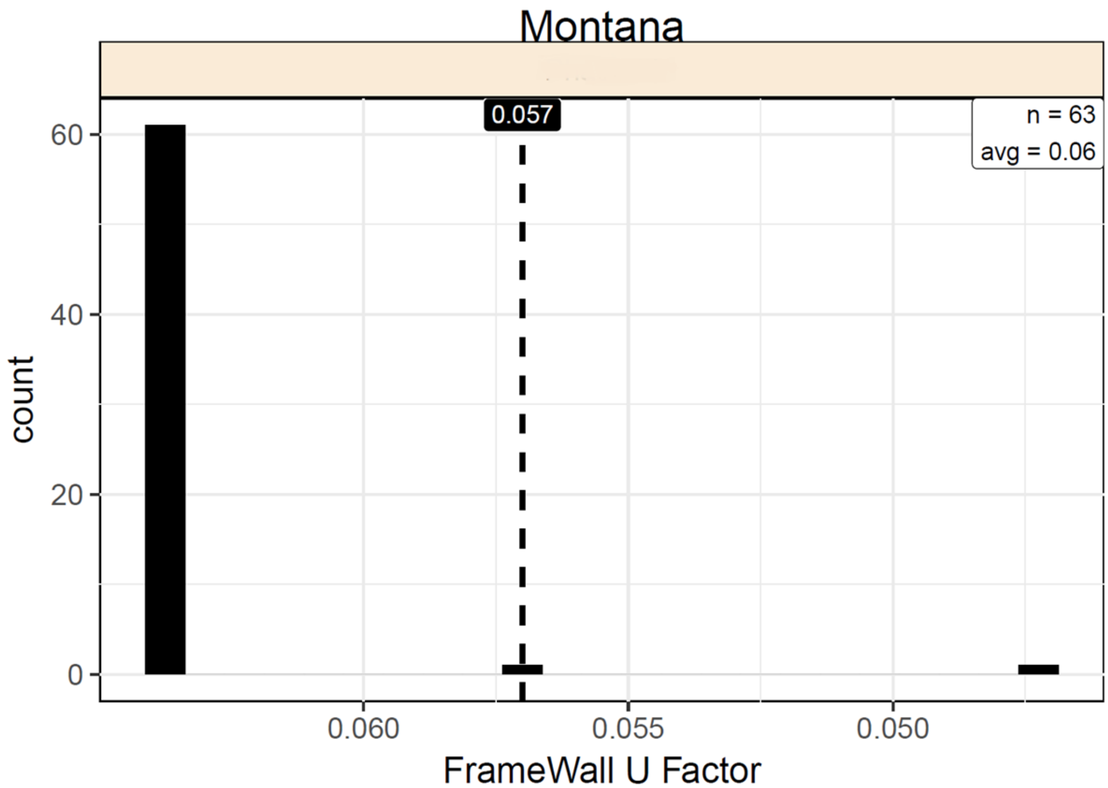

Figure 3.5. Wall Assembly Performance, including Wall Insulation Installation Quality

Table 3.5. Wall U-Factor, including Wall Insulation Installation Quality

Climate Zone	CZ6	Statewide
Number	63	63
Range	0.064 to 0.047	0.064 to 0.047
Average	0.063	0.063
Assembly U-Factor (expected)	0.057	0.057
Rate	2 of 63 (3%)	2 of 63 (3%)

- **Interpretations:**
  - Looking at the R-values, all the observations met or exceeded the prescriptive code requirement.
  - Looking at the U-factors, only two of the observations met or exceeded the prescriptive code requirement, indicating that insulation installation quality is a problem. In almost all observations (97%), the insulation installation quality was rated as Grade II, indicating an issue that should be addressed.

3.1.1.5 Ceilings

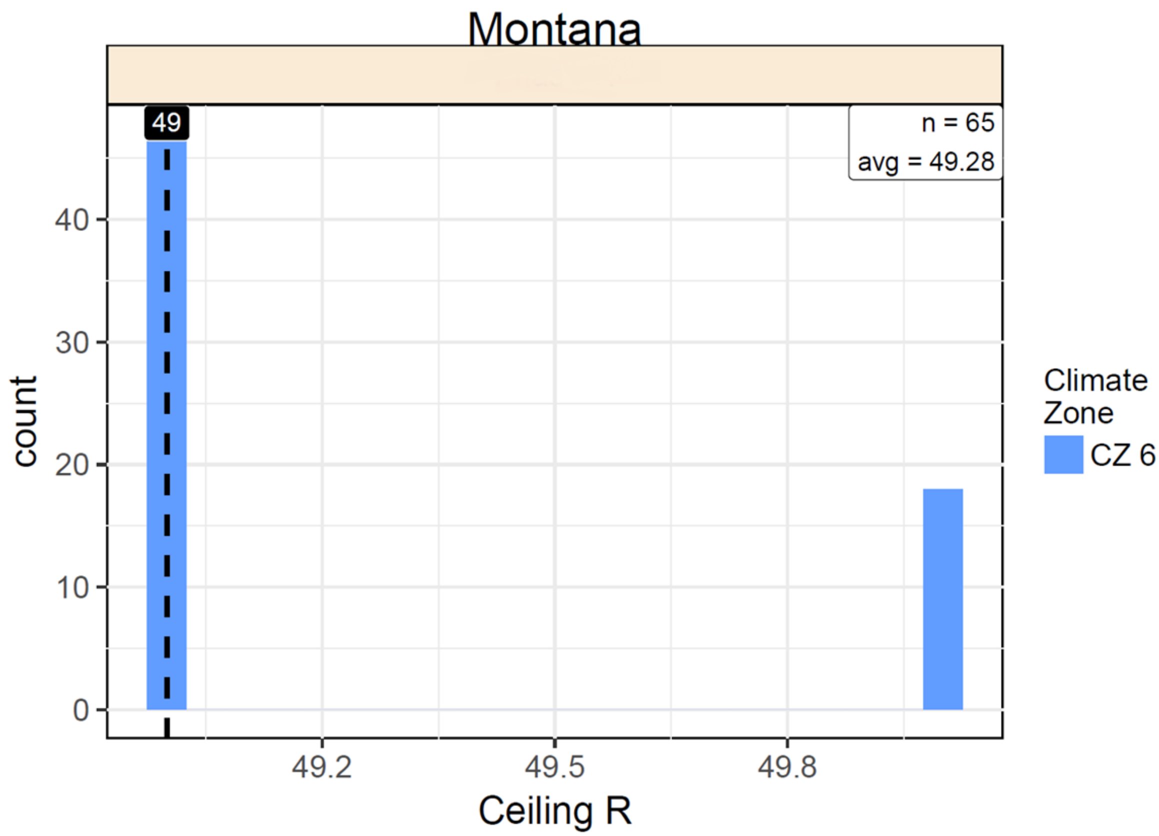

Figure 3.6. Ceiling R-Value

Table 3.6. Ceiling R-Value

Climate Zone	CZ6	Statewide
Number	65	65
Range	R-49 to R-50	R-49 to R-50
Average	R-49.3	R-49.3
Requirement	R-49	R-49
Compliance Rate	65 of 65 (100%)	65 of 65 (100%)

- **Interpretations:**
  - 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.

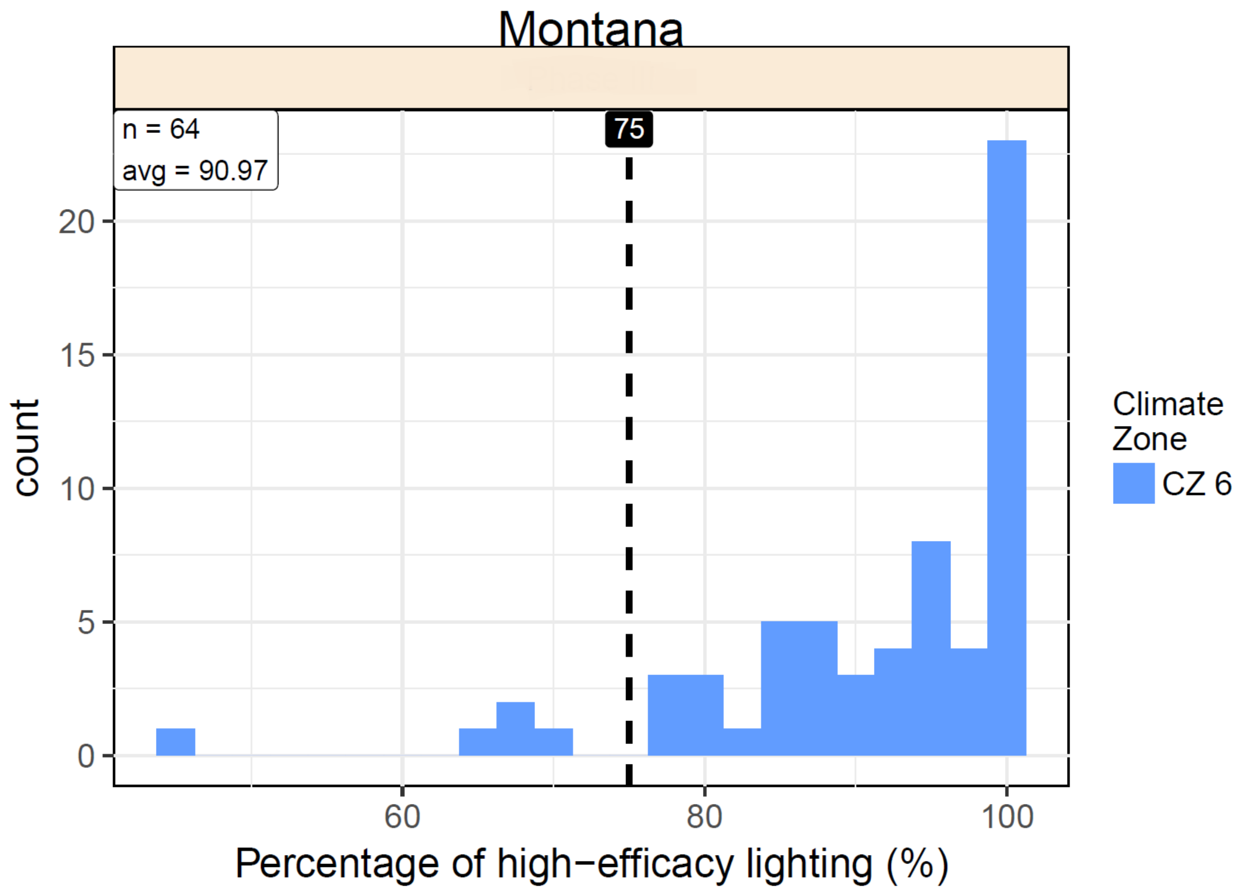

Figure 3.7. High-efficacy Lighting Percentage

Table 3.7. High-efficacy Lighting Percentage

Climate Zone	CZ6	Statewide
Number	64	64
Range	45 to 100	45 to 100
Average	91	91
Requirement	75	75
Compliance Rate	58 of 64 (91%)	58 of 64 (91%)

- **Interpretations:**
  - Nearly all (91%) of the field observations met the code requirement.

3.1.1.6 Foundation Assemblies

There were three predominant foundation types observed in Montana: heated basements, unvented crawlspaces, and slabs. Two graphs are shown for foundations, insulation (R-value), and binned assembly (U-factor).[1] The R-value graphs show the insulation R-values observed. The binned U-factor graphs

[1] No binned U-factor graph is provided for unvented crawlspace walls because all crawlspace wall insulation was continuous and therefore insulation installation quality does not come into play.

indicate the U-factor of the assembly, including cavity and continuous insulation layers and framing, and considering insulation installation quality, as observed in the field. The U-factors are binned to reduce the number of bars in the chart as individual U-factor observations may be only slightly different.

While initially combined into a single key item (i.e., foundation assemblies), the variety of observed foundation types are disaggregated in this section, as described above. This approach helps to portray the combinations of cavity and continuous insulation employed across each foundation type, which is anticipated to be of value for energy code training programs. From a savings perspective, results are calculated for both the aggregated perspective and for individual foundation types (presented later in Section 3.3); however, only the aggregated observations should be considered statistically representative at the statewide level.

Basement Wall Insulation (Conditioned Basements)

For basement wall R-values, the R-value plot shows only observations of cavity insulation, while the U-factor plots shows 5 additional observations of continuous insulation only.

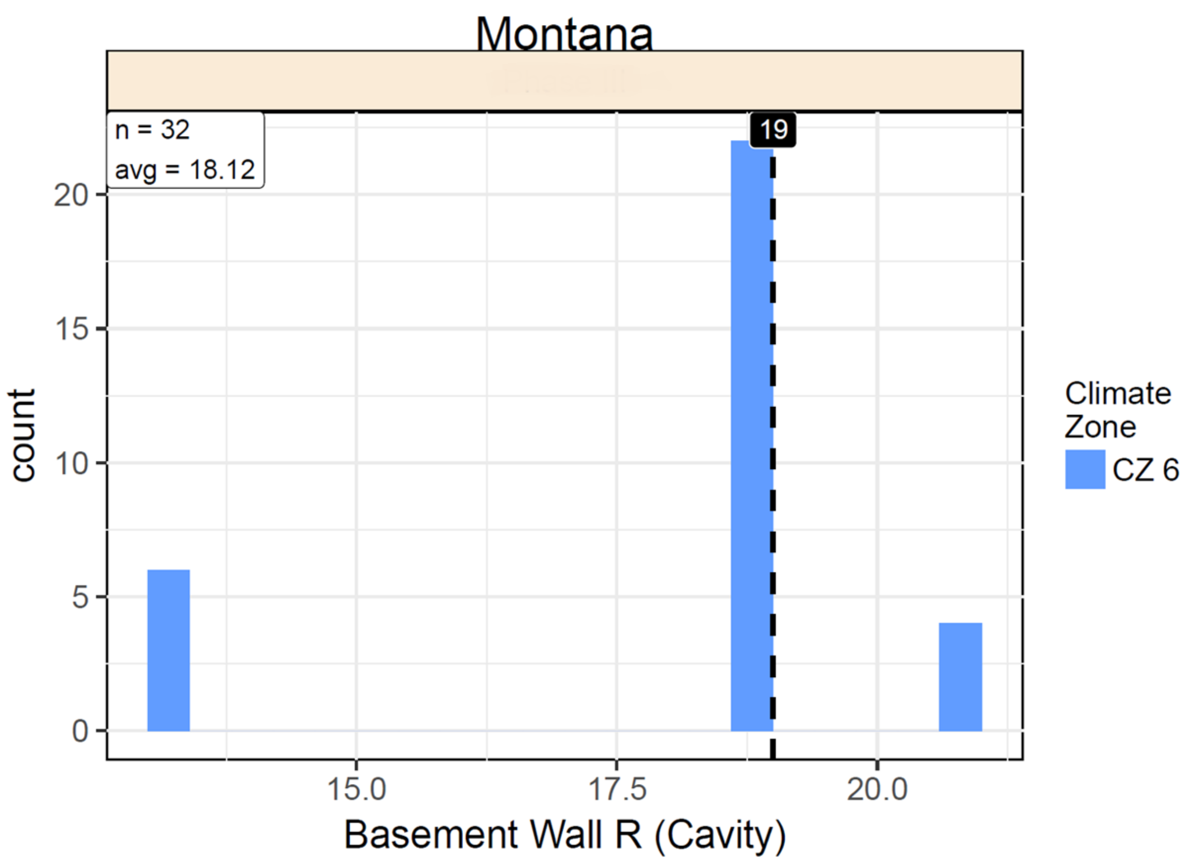

Figure 3.8. Basement Wall Cavity R-Values[2]

[2] Note that there are an additional 5 homes with continuous basement insulation that are not shown on this graph. These homes are shown in the basement insulation U-factor graph below.

Table 3.8. Basement Wall Cavity R-Values

Climate Zone	CZ6	Statewide
Number	32	32
Range	R-13 to R-21	R-13 to R-21
Average	R-18	R-18
Assembly U-Factor (expected)	R-19	R-19
Rate	26 of 32(81%)	26 of 32 (81%)

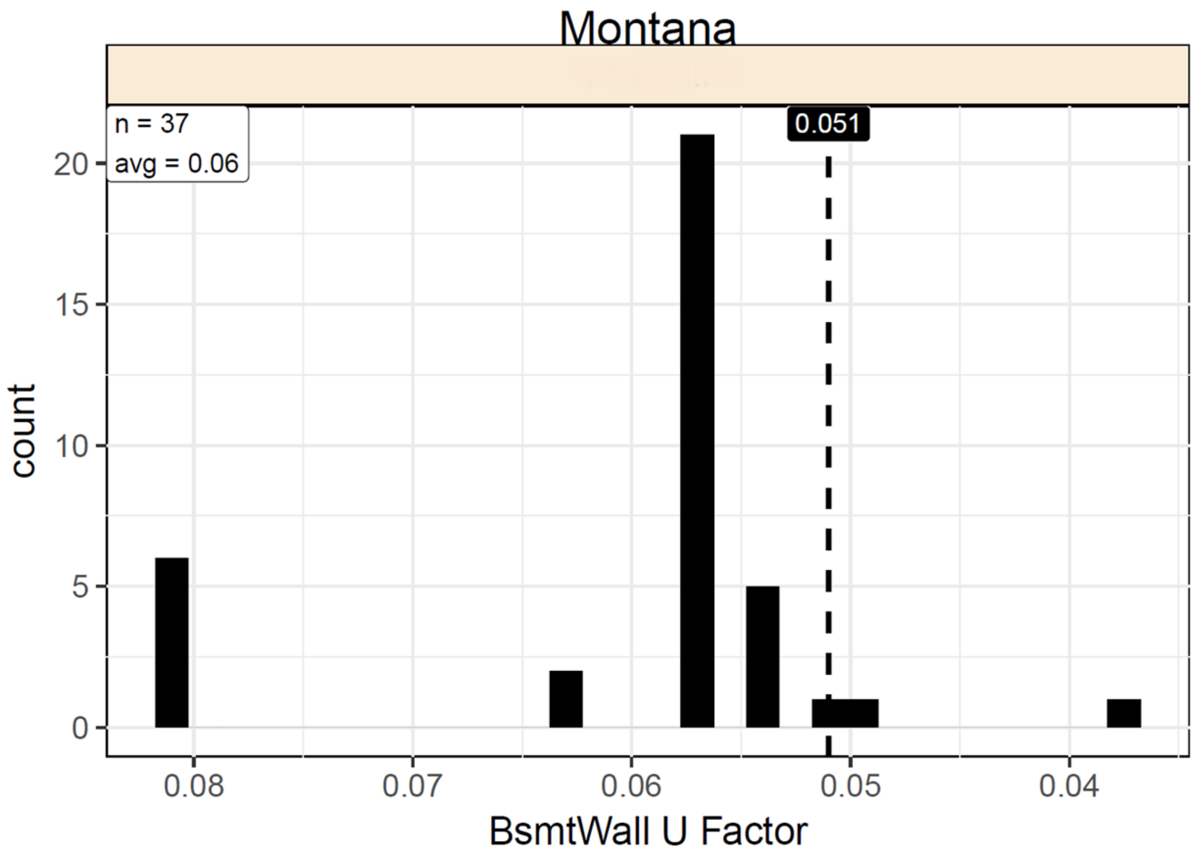

Figure 3.9. Basement Wall Assembly Performance, including Wall Insulation Installation Quality

Table 3.9. Basement Walls U-Factor

Climate Zone	CZ6	Statewide
Number	37	37
Range	0.081 to 0.038	0.081 to 0.038
Average	0.060	0.060
Assembly U-Factor (expected)	0.051	0.051
Rate	3 of 37 (8%)	3 of 37 (8%)

- **Interpretations:**
  - Note that there are five more basement wall U-factor observations than basement wall cavity R-value observations. This is because there are five homes with continuous insulation that are included in the U-factor plot. The continuous R-values range from R-11 to R-19, with only one of the observations meeting the basement wall continuous insulation requirement of R-15.
  - Comparison of the U-factor and R-value charts indicates that there are problems with both the insulation installation quality and the amount of insulation. Nearly all (94%) of the cavity basement wall insulation observations are Grade II. Couple this with the six cavity basement wall insulation observations that did not have enough insulation and the four continuous basement wall insulation observations that did not have enough insulation, and the overall result is that the U-factor observations fail at a high rate.

Insulation in Walls of Unvented Crawlspaces

For this assembly, all of the observations involved continuous insulation. The R-value plot shown is for vented crawlspace wall continuous R-value and therefore there is no U-factor graph required.

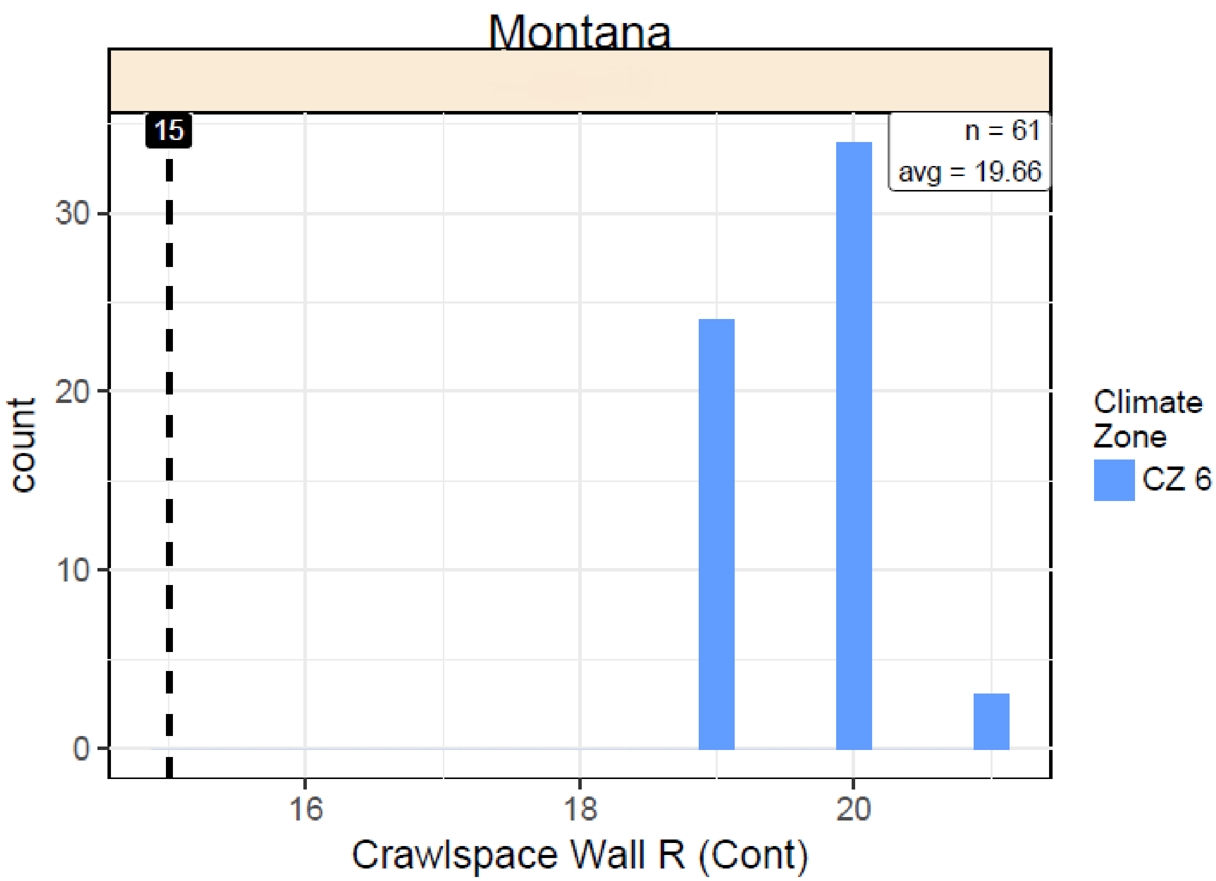

Figure 3.10.Unvented Crawlspace Wall Continuous Insulation R-Value for Montana

Table 3.10. Unvented Crawlspace Wall Continuous R-Value

Climate Zone	CZ6	Statewide
Number	61	61
Range	R-19 to R-21	R-19 to R-21
Average	R-19.7	R-19.7
Assembly U-Factor (expected)	R-15	R-15
Rate	61 of 61 (100%)	61 of 61 (100%)

- **Interpretations:**
  - Crawlspace insulation was fully compliant; in fact, the insulation exceeded the code requirement by nearly R-5.

Slabs

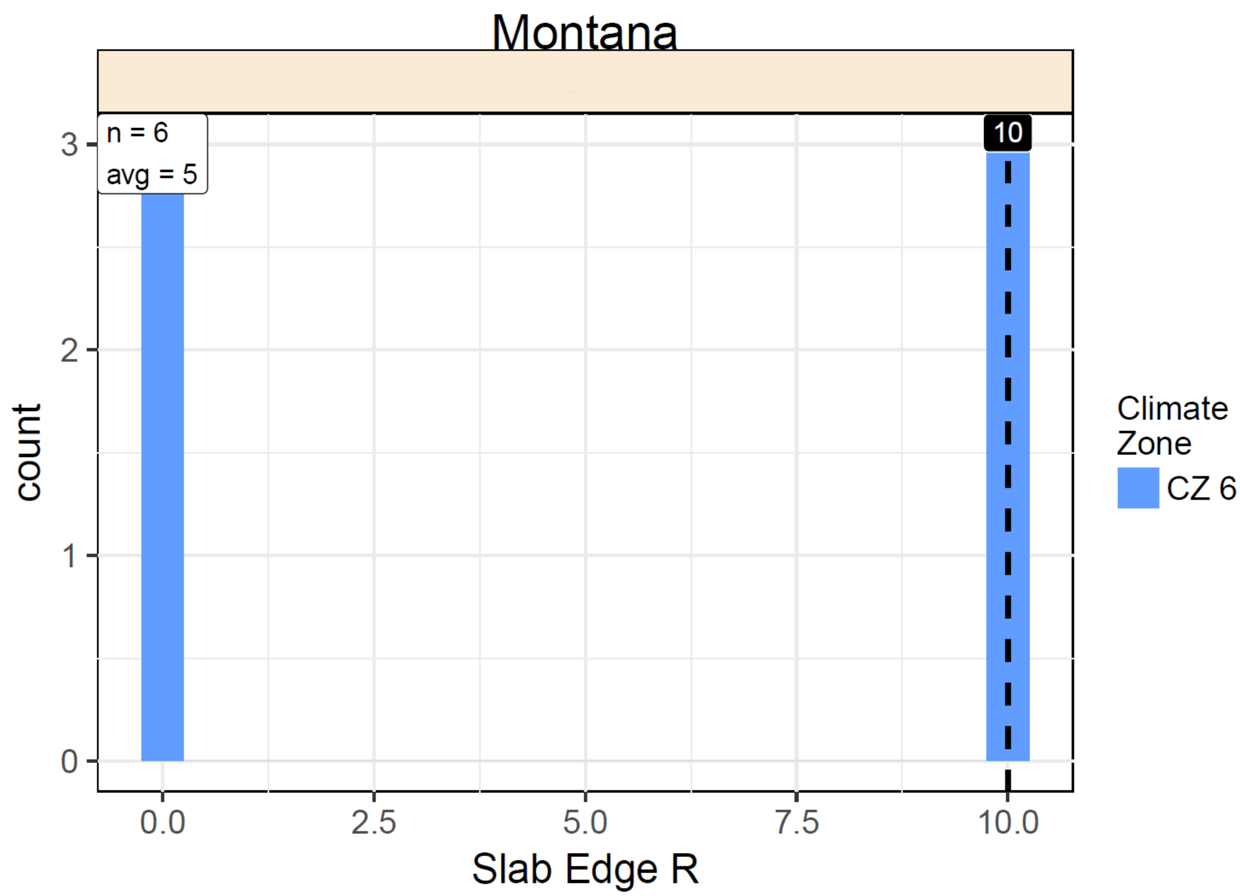

Figure 3.11. Slabs

Table 3.11. Slabs

Climate Zone	CZ6	Statewide
Number	6	6
Range	0 to 10	0 to 10
Average	5	5
Requirement	10	10
Rate	3 of 6 (50%)	3 of 6 (50%)

- **Interpretations:**
  - Half of the slab edge insulation observations met the code requirement.

3.1.1.7 Duct Tightness

For ducts, this report presents both raw duct leakage and adjusted duct leakage. Raw duct leakage is simply the values of duct leakage observed in the field. Adjusted duct leakage looks at the location of the ducts and adjusts the leakage values for any ducts which are entirely in conditioned space by setting the leakage of those ducts to zero (0). The adjustment reflects the fact that duct leakage tests are not required if the ducts are entirely in conditioned space.

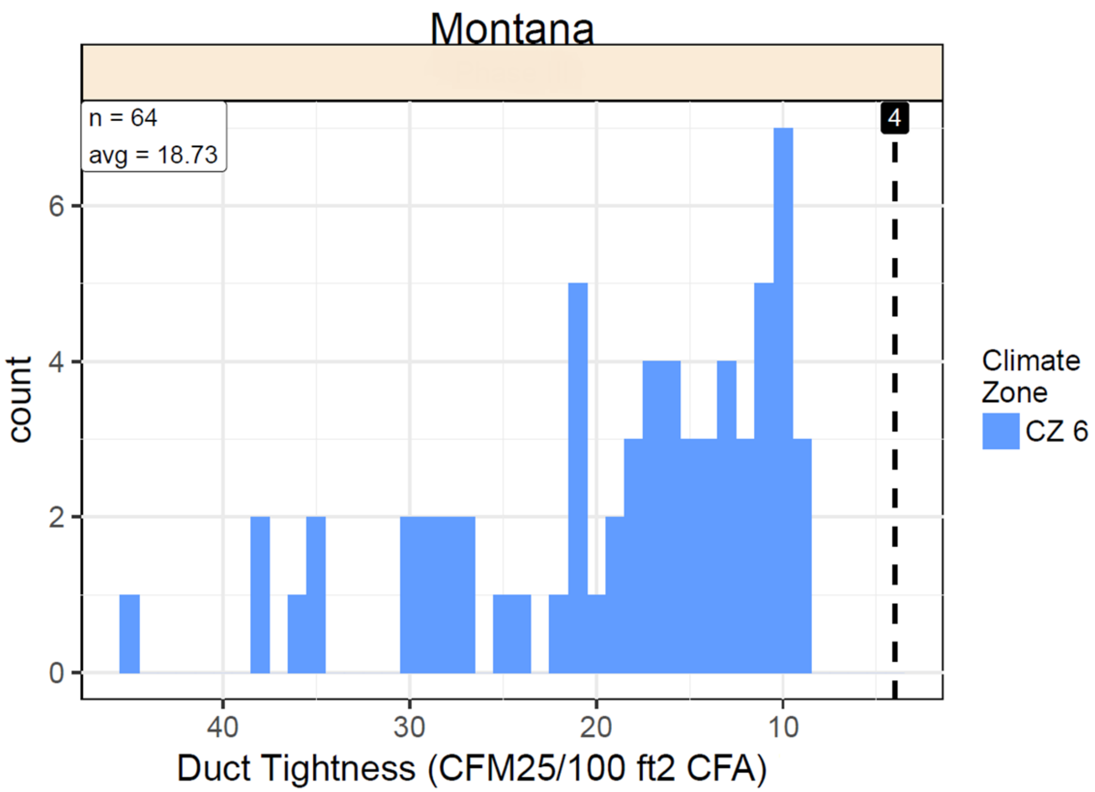

Figure 3.12. Raw Duct Tightness (CFM25/100ft2 CFA)

Table 3.12. Raw Duct Tightness (CFM25/100ft2 CFA)

Climate Zone	CZ6	Statewide
Number	64	64
Range	8.89 to 45.0	8.8 to 45.0
Average	18.7	18.7
Requirement	4	4
Compliance Rate	0 of 64 (0%)	0 of 64 (0%)

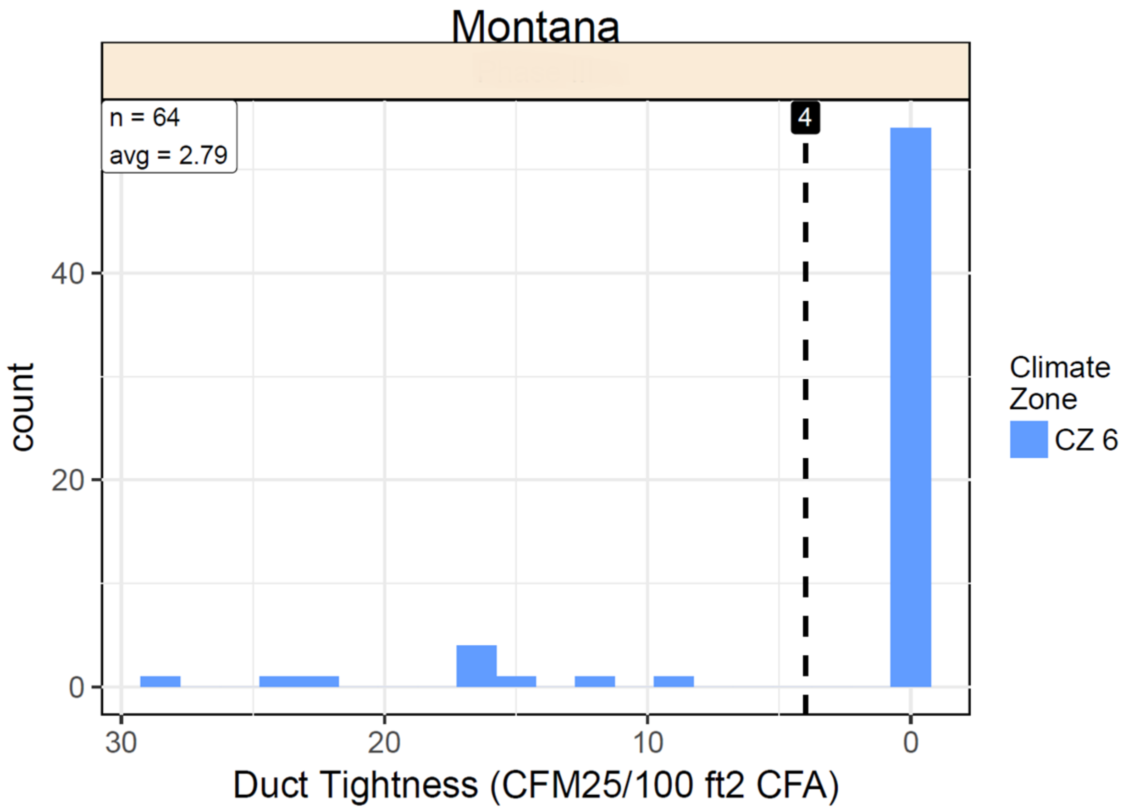

Figure 3.13. Adjusted Duct Tightness (CFM25/100ft2 CFA)

Table 3.13. Adjusted Duct Tightness (CFM25/100ft2 CFA)

Climate Zone	CZ6	Statewide
Number	64	64
Range	0.0 to 29.2	0.0 to 29.2
Average	2.79	2.79
Requirement	4	4
Compliance Rate	54 of 64 (84%)	54 of 64 (84%)

- **Interpretations:**
  - The average total duct leakage is 17.8 CFM 25/100 ft^2 for the 10 systems with ducts in unconditioned space, and 18.6 CFM 25/100 ft^2 for the 53 systems located entirely in conditioned space.

– Most of the raw observations do not meet the requirement for duct leakage.

– Most of the adjusted observations meet the requirement for duct leakage, indicating that many homes had ducts installed entirely in conditioned space.

– Reductions in duct leakage represent a significant area for improvement and should be given increased attention in future training and enforcement.

3.1.1.8 Impact of Insulation Installation Quality

While insulation installation quality is not an explicit energy code requirement, at the start of DOE's FOA projects, it was noted as a particular concern among the project team and stakeholders, as it plays an important role in the energy performance of envelope assemblies. Insulation installation quality was collected by the project team whenever possible and applied as a *modifier* to the cavity insulation R-value observations in the calculation of U-factors[3] during the analyses for applicable key items (i.e., ceiling insulation, wall insulation, and foundation insulation). The team followed the RESNET[4] assessment protocol which has three grades, Grade I being the best quality installation and Grade III being the worst.

Table 3.14 shows the insulation installation quality levels for framed envelope assemblies, as observed in the state. A slight majority of the observations (150 of 219) were classified as Grade II, with the remainder Grade I, indicating that there is improvement needed in insulation installation quality. Roof insulation installation quality was almost all Grade I, but other assemblies show the majority of observations to be Grade II. No assemblies were found to have Grade III quality insulation.

Table 3.14. Insulation Installation Quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Roof Cavity	63	2	0	**65**
Floor	0	0	0	**0**
Above Grade Wall	2	61	0	**63**
Basement Wall	2	30	0	**32**
Crawlspace Wall	0	0	0	**0**
Knee Wall	2	57	0	**59**

3.1.2 Additional Data Items

The project team collected data on all code requirements within the state as well as other areas to inform the energy simulation and analysis for the project (e.g., home size, installed equipment systems, etc.). While these items were not the focal point of the study, and many are not considered statistically representative, they do provide some insight surrounding the energy code and residential construction within the state.

The following sections summarize this data and outline some of the more significant findings, in many cases including the observation or compliance rate associated with the specified item. A larger selection of the additional data items collected as part of the state field study is contained in Appendix C.

[3] See DOE/PNNL 2018 for more details on the use of insulation installation quality.

[4] See http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf

3.1.2.1 Average Home

- Size: 2,652 ft^2 and 1.33 stories

3.1.2.2 Compliance

- All homes (100%) were permitted under the 2012 IECC with Montana amendments.
- No homes were noted as participating in an above-code program.

3.1.2.3 Envelope

- **Profile:**
  - Foundations: Mix of unvented crawlspaces (55%), heated basements (32%), and slab on grade (13%)
- **Successes (percentage of observations that complied):**
  - Insulation labeled (100%)
  - IC-rated light fixtures sealed (98%)
  - Rim joists sealed (97%)
- **Areas for Improvement:**
  - Attic access openings complied (10%)
  - Knee walls sealed (3%)
  - Envelope areas behind bathroom tubs & showers sealed (7%)
  - Dropped ceilings sealed (4%)

3.1.2.4 Duct & Piping Systems

- **Profile:**
  - Ducts were generally located within conditioned space (percentage of duct system):
    - Supply: 88%
    - Return: 88%
  - 80% of duct systems located *supply* ducts entirely within conditioned space (129 homes with 103 duct systems entirely within conditioned space)
  - 82% of duct systems located *return* ducts entirely within conditioned space (129 homes with 106 duct systems entirely within conditioned space)
  - 81% of duct systems had the *entire* system within conditioned space.
  - Pipe Insulation (R-value): 2.5
- **Successes:**
  - Air handlers sealed (76%)
- **Areas for Improvement:**
  - Air ducts sealed (22%)

3.1.2.5 HVAC Equipment

- **Profile:**
  - Heating: Mostly gas furnaces with an average efficiency of 92 AFUE
  - Cooling: Mostly central AC with an average efficiency of 13 SEER
  - Water Heating: Mix of gas (64%) and electric (36%) storage (95%) with an average capacity of 51 gallons and average efficiency rating of EF 0.73
- **Successes:**
  - User manuals for mechanical systems provided (100%)

3.2 Energy Intensity

The statewide energy analysis results are shown in the figure below, which compares the weighted average energy consumption of the observed data set to the weighted average consumption based on the state energy code. The observed data set (as gathered in the field) was compared against the same set of homes meeting prescriptive code requirements. In terms of overall energy consumption, the average home in Montana appears to use *more* energy than would be expected relative to a home built to the current minimum state code requirements.

Analysis of the collected field data indicates an average regulated EUI (dashed line in Figure 3.14) of approximately 39.66 kBtu/ft^2-yr compared to 39.01 kBtu/ft^2-yr for homes exactly meeting minimum *prescriptive* energy code requirements (black line in Figure 3.14). This suggests the EUI for a “typical” home in the state is about 2% worse than code.

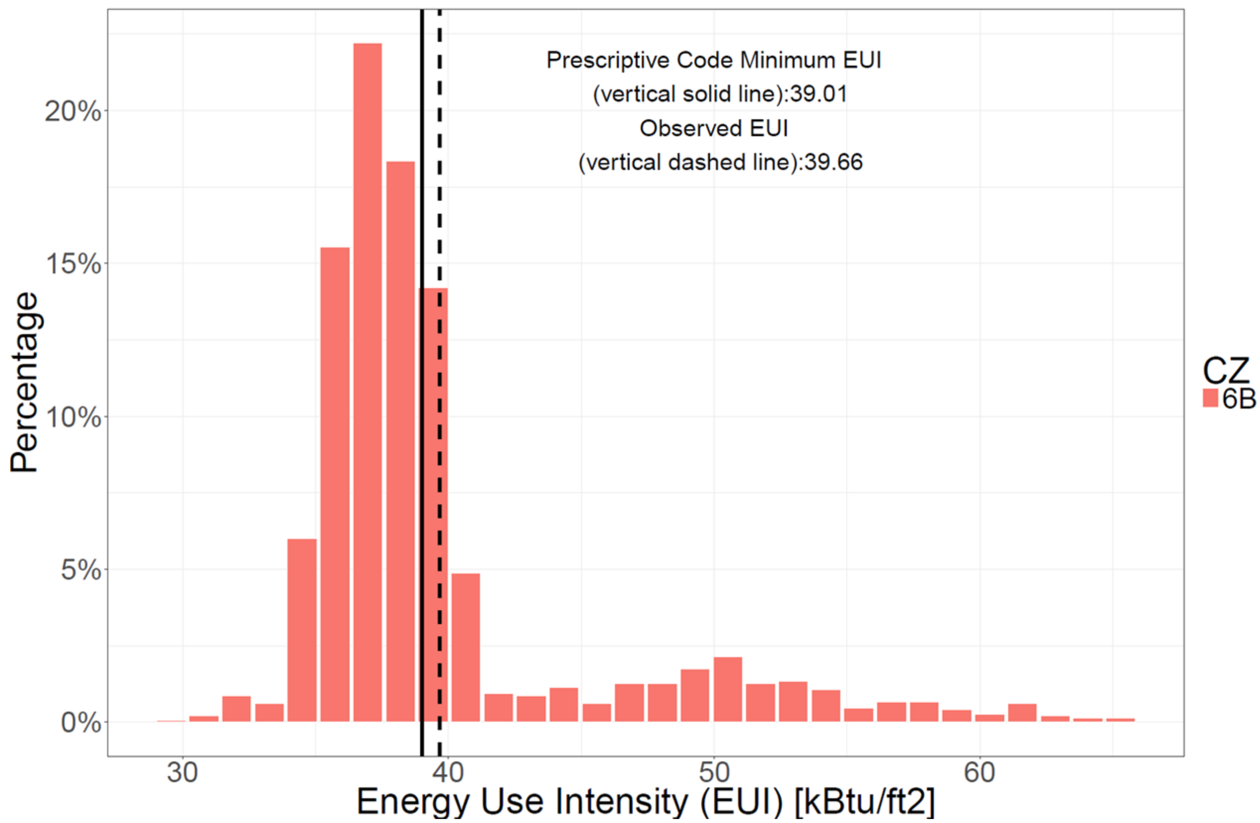

Figure 3.14. Statewide EUI Analysis for Montana

3.3 Savings Potential

The key items with the greatest potential are defined here as those key items with more than 15% of observations (or calculated U-factors which include consideration of insulation installation quality in the case of opaque assemblies) not meeting the prescriptive code requirement. Key items that meet this criteria are shown below, followed by the percent that did not meet code. These key items were then analyzed to calculate the associated savings potential, including energy, cost, and carbon savings.

- Duct Leakage (16% of adjusted observations)
- Exterior Wall Insulation (97%)
- Envelope Air Leakage (27%)
- Foundations
  - Basement Wall Insulation (92%), and
  - Slab Edge Insulation (50%).

For analytical details, refer to Section 2.3.3 (Savings Analysis) or the DOE methodology document (DOE/PNNL 2018).

Estimated savings resulting from the analysis are shown in Table 3.15 in the order of highest to lowest total energy, cost, and carbon savings. There are significant savings opportunities, with the greatest total savings potential associated with duct leakage and exterior wall insulations. In addition, Table 3.17 shows the total savings and emissions reductions that will accumulate over 5, 10, and 30 years of construction.

Table 3.15. Statewide Annual Measure-Level Savings for Montana

Measure	Climate Zone	Electricity Savings (kWh/ home)	Natural Gas Savings (therms/ home)	Total Savings (kBtu/home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Total State Emissions Reduction (MT CO2e)
Duct Leakage	6B	67	30	3,259	3,161	10,302	97,836	1,195
Exterior Wall Insulation	6B	44	24	2,598	3,161	8,212	75,123	787
Envelope Air Leakage	6B	1	5	480	3,161	1,516	11,721	21
Foundation Insulation	6B	-16	20	1,984	1,307	1,141	7,051	-86
TOTAL		**95**	**80**	**8,321**	**3,161**	**21,171**	**191,731**	**1,783**

* Negative values mean that savings or reductions decrease if the measure is brought up to code.
**See Table 3.16 for annual measure-level savings results by foundation type.

Table 3.16. Statewide Annual Measure-Level Savings by Foundation Type for Montana

Measure	Climate Zone	Electricity Savings (kWh/ home)	Natural Gas Savings (therms/ home)	Total Savings (kBtu/home)	Number of Homes	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Total State Emissions Reduction (MT CO2e)
Basement Wall Insulation	6B	-16	9	826	1,125	929	5,441	-88
Slab Insulation	6B	0	12	1,158	182	211	1,610	2
Foundation TOTAL	**State Total**	**-16**	**20**	**1,984**	**1,307**	**1,141**	**7,051**	**-86**

*For basement wall insulation and floor over unvented insulation, note that while total energy savings are positive, electricity savings are negative. This is the result of increased insulation leading to lower natural gas usage in the winter, but higher electricity usage in the summer. Note also that floor insulation total energy cost savings and emissions reductions are negative, even though total energy savings are positive. This is again related to lower gas usage in the winter, but higher electricity use 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 3.17. Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings for Montana

	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
Measure	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Duct Leakage	154,532	566,618	4,790,494	1,467,544	5,380,996	45,493,873	17,920	65,706	555,511
Exterior Wall Insulation	123,178	451,653	3,818,517	1,126,850	4,131,783	34,932,347	11,800	43,268	365,808
Envelope Air Leakage	22,744	83,396	705,077	175,814	644,650	5,450,221	313	1,148	9,703
Foundation Insulation	17,108	62,728	530,336	105,763	387,797	3,278,645	-1,296	-4,753	-40,185
TOTAL	**317,562**	**1,164,394**	**9,844,425**	**2,875,971**	**10,545,225**	**89,155,086**	**28,737**	**105,368**	**890,837**

4.0 Conclusions

The Montana field study provides an enhanced understanding of statewide code implementation and suggests that potential savings are available through increased compliance. From a statewide perspective, the average home in Montana uses about 2% more energy than a home exactly meeting the state energy code. Savings potential exists through increased compliance with targeted measures. Potential statewide annual energy savings are 21,171 MMBtu, which equates to $191,731 in cost savings, and emission reductions of 1,783 MT CO2e. Over a 30-year period, these impacts grow to 9.8 million MMBtu, $89 million, and nearly one million metric tons CO2e in avoided emissions.

Several key measures directly contribute to these savings and should be targeted through future education, training and outreach activities. The savings associated with each are shown in Table 4.1.

Table 4.1. Annual Statewide Savings Potential in Montana

	Annual Savings		
Key Measure	**Energy** (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
Duct Leakage	10,302	97,836	1,195
Exterior Wall Insulation	8,212	75,123	787
Envelope Air Leakage	1,516	11,721	21
Foundation Insulation	1,141	7,051	-86
Total	**21,171 MMBtu**	**$191,731**	**1,783 MT CO2e**

5.0 References

Census Bureau. 2017. Censtats Building Permits Database. http://censtats.census.gov/.

DOE. 2012. *National Energy and Cost Savings for New Single- and Multifamily Homes: A Comparison of the 2006, 2009, and 2012 Editions of the IECC.* Available at http://www.energycodes.gov/development.

DOE Building Energy Codes Program's residential field study website is available at https://www.energycodes.gov/compliance/residential-energy-code-field-study (accessed January 25, 2019).

DOE/PNNL 2018. *Residential Building Energy Code Field Study: Data Collection & Analysis Methodology*. Available at https://www.energy.gov/sites/prod/files/2018/06/f52/bto-Res-Field-Study-Methodology-060618-2.pdf.

EnergyPlus. https://energyplus.net/.

Appendix A

Stakeholder Participation

Appendix A

Stakeholder Participation

The Montana project team conducted a kickoff meeting for interested parties to learn more about the field study, ask questions, and raise concerns. The meeting was held in conjunction with a Montana Energy Code Collaborative meeting and was hosted by Dale Horton, Energy Program Manager at the National Center for Appropriate Technology. The organizations represented by stakeholders in attendance are listed in Table A.1.

Table A.1. Stakeholder Participation in Project Kickoff Meeting (June 9, 2018)

Stakeholder	Description
Integrated Design Lab, Montana State University	Affiliated with the MSU's School of Architecture, Integrated Design Lab is one of five labs in the Pacific Northwest funded by the Northwest Energy Efficiency Alliance. The lab conducts daylight and energy modeling and analysis to assist architects and engineers design high-performance buildings that achieve at least 25 percent energy savings over code.
Jurisdictional Representatives	Interested stakeholders from jurisdictions throughout Montana attended the kickoff meeting. These jurisdictions include Bozeman and Missoula.
Montana Department of Environmental Quality	The Department of Environmental Quality's mission is to protect, sustain, and improve a clean and healthful environment to benefit present and future generations.
Montana Department of Labor and Industry	The Montana Department of Labor and Industry promotes the well-being of Montana's workers, employers, and citizens, and upholds their rights and responsibilities. Organized into five divisions, the Department of Labor and Industry provides oversight and regulation of the Montana Workers' Compensation system, enforces state and federal labor standards, enforces state and federal safety and occupational health laws, provides adjudicative services in labor-management disputes, establishes and enforces building industry codes, licenses and regulates professions and occupations, regulates all weighing or measuring devices used in commercial transactions, conducts research, and collects employment statistics that enable strategic planning.
Montana Environmental Information Center	The Montana Environmental Information Center is a non-profit organization dedicated to ensuring clean air and water for Montana's future generations.

Stakeholder	Description
Montana State University, School of Architecture	Students at MSU's School of Architecture learn how to design the spaces and structures where people live, work, and play. Architects strive to play an essential and innovative role in improving the human condition for all communities. The School of Architecture empowers students to critically engage with the complexities of society and the natural environment by instilling the fundamental principles of design and inspiring a spirit of exploration and creative experimentation in shaping the built environment.
National Center for Appropriate Technology	The National Center for Appropriate Technology (NCAT) has been promoting sustainable living for over 40 years. Established in 1976, NCAT is a national nonprofit that helps people by championing small-scale, local, and sustainable solutions to reduce poverty, promote healthy communities, and protect natural resources.
NorthWestern Energy	NorthWestern Energy has provided reliable and affordable energy to customers in Montana, South Dakota, and Nebraska for more than 100 years. The company got its start in small communities, providing essential service that allowed them to grow and prosper. Today, NorthWestern Energy serves more than 718,300 residential and business customers with electricity and natural gas.
NW Energy Coalition	The NW Energy Coalition (NWEC) is an alliance of about 100 environmental, civic, and human service organizations, progressive utilities, and businesses in Oregon, Washington, Idaho, Montana and British Columbia. NWEC promotes development of renewable energy and energy conservation, consumer protection, low-income energy assistance, and fish and wildlife restoration on the Columbia and Snake rivers
Ravalli Electric Co-op	Ravalli Electric Co-op is a not-for-profit cooperative serving over 10,000 members located just north of Corvallis, Montana. It was incorporated in 1936 as part of the Rural Electrification Administration.

Appendix B

State Sampling Plan

Appendix B

State Sampling Plan

Table B.1. State Sampling Plan

Place, County	Sample	Actual
Yellowstone County Unincorporated Area, Yellowstone county	14	14
Billings, Yellowstone County	10	10
Gallatin County Unincorporated Area, Gallatin County	12	12
Bozeman, Gallatin County	8	8
Missoula, Missoula County	5	5
Missoula County Unincorporated Area, Missoula County	1	1
Cascade County Unincorporated Area, Cascade County	1	1
Belgrade, Gallatin County	2	2
Kalispell, Flathead County	3	3
Whitefish, Flathead County	3	3
Helena, Lewis and Clark County	2	2
Great Falls, Cascade County	2	2

B.1 Substitutions

No substitutions to the sample plan were required.

Appendix C

Additional Data

Appendix C

Additional Data Collected by the Field Team

The project team made observations on several energy efficiency measures beyond the key items alone. The majority of these additional items are based on code requirements within the state, while others were collected to inform the energy simulation and analysis for the project (e.g., installed equipment, whether the home participated in an above-code program, etc.). While these items were not the focal point of the study, and many are not considered statistically representative, they do provide some additional insight surrounding the energy code and residential construction within the state.

The following is a sampling of the additional data items collected as part of the Montana field study. Each item is presented, along with a brief description and statistical summary based on the associated field observations. The full data set is available on DOE's website.[1]

C.1 General

The following represents the general characteristics of the homes observed in the study:

C.1.1 Average Home

- Size (n=126): 2652 ft^2
- Number of Stories (n=126): 1.33

Table C.1. Conditioned Floor Area (ft^2)

Conditioned Floor Area (ft^2)	< 1000	1000 to 1999	2000 to 2999	3000 to 3999	4000+
Percentage	2%	33%	36%	21%	8%

Table C.2. Number of Stories

No. of Stories	1	2	3	4+
Percentage	67%	33%	0%	0%

C.1.2 Wall Profile

- Framing Type (n=125):
  - *All* were framed construction (100%)
- Framing Material (n=125):
  - Wood (100%)
  - Steel (0%)

[1] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study

C.1.3 Foundation Profile

- Foundation Type (n=126):
  - Heated Basement (32%)
  - Slab on Grade (13%)
  - Unvented Crawlspace (55%)
  - Vented Crawlspace (0%)

C.2 Compliance

The following summarizes information related to compliance, including the energy code associated with individual homes, whether the home was participating in an above-code program, and which particular programs were reported. The percentages provided in the sections below represent percentages of total observations or the percentage of observations that complied.

C.2.1 Energy Code Used (n=126):

Table C.3. Energy Code Used

Energy Code	2012 IECC with Montana Amendments
Percentage	100%

- Was the home participating in an above-code program (n=63)?
  - Yes (0%)
  - No (100%)

C.2.2 Envelope

The following list of questions focus on average characteristics of the thermal envelope:

C.2.2.1 Insulation Labels

- Was insulation labeled (n=64)?
  - Yes (100%)
  - No (0%)

C.2.2.2 Ceilings

- Did the attic hatch/door exhibit the correct insulation value (n=21)?
  - Yes (52%)
  - No (48%)

C.2.2.3 Air Sealing[1]

- Thermal envelope sealed (n=63) (75%)
- Openings around windows and doors sealed (n=63) (94%)
- Utility penetrations sealed (n=85) (86%)
- Dropped ceilings sealed (n=25) (4%)
- Knee walls sealed (n=61) (3%)
- Garage walls and ceilings sealed (n=57) (98%)
- Envelope behind tubs and showers sealed (n=60) (7%)
- Common walls sealed (n=0) (0%)
- Attic access openings sealed (n=21) (10%)
- Rim joists sealed (n=71) (97%)
- Other sources of infiltration sealed (n=63) (79%)
- IC-rated light fixtures sealed (n=124) (98%)

C.2.3 Duct & Piping Systems

The following represents an average profile of observed air ducting and water piping systems, followed by a list of additional questions related to such systems:

C.2.3.1 System Profile

- Duct Location in Conditioned Space (percentage):
  - *Supply* (n=126): 81% (102 homes with systems located entirely within conditioned space)
  - *Return* (n=126): 83% (105 homes with systems located entirely within conditioned space)
- Duct Insulation (R-value):
  - *Supply* (n=21): 6.91
  - *Return* (n=19): 6.6
- Air ducts sealed (n=119) (22%)
- Air handlers sealed (n=122) (76%)
- Filter boxes sealed (n=122) (74%)

C.2.4 HVAC Equipment

The following represents an average profile of observed HVAC equipment, followed by:

[1] Note that results in this section are from checklist items that are addressed via visual inspection. When comparing these visual results with the actual tested results, it is clear that there can be significant differences in the two methods.

C.2.4.1 Heating

- Fuel Source (n=126):
  - Gas (98%)
  - Electricity (2%)
- System Type (n=126):
  - Boiler (2%)
  - Furnace (96%)
  - Heat Pump (2%)
- System Capacity (n=125):
  - Furnace: 81,869 Btu
  - Heat Pump: 48,800 Btu
- System Efficiency (n=122):
  - Furnace: 92 AFUE
  - Heat Pump: 8.4 HSPF

C.2.4.2 Cooling

- System Type (n=109):
  - Central AC (97%)
  - Heat Pump (3%)
- System Capacity (n=108):
  - 40,278 (Btu/hr)
- System Efficiency (n=57):
  - 13 SEER (observations ranged from 13 to 14 SEER)

C.2.4.3 Water Heating

- Fuel Source (n=126):
  - Gas (64%)
  - Electric (36%)
- System Type (n=126):
  - Storage (95%)
  - Tankless (5%)
- System Capacity (n=74):
  - 51 gallons (observations ranged from 50 to 100 gallons)

Table C.4. Water Heating System Storage Capacity Distribution

Capacity	< 50 gal	50-59 gal	60-69 gal	70-79 gal	80-89 gal	90+ gal
Percentage	0%	95%	0%	4%	0%	1%

- System Efficiency (n=74):
  - EF 0.73 (range from EF 0.62 to EF 0.92)

C.2.4.4 Ventilation

- System Type (n=126):
  - Exhaust Only (98%)
  - AHU Integrated (2%)
- Exhaust Fan Type (n=123):
  - Dedicated Exhaust (0%)
  - Bathroom Fan (100%)

C.2.4.5 Other

- Mechanical manuals provided (n=32) (100%)

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