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Idaho Residential Energy Code Field Study

February 2019

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Executive Summary

A research project in the state of Idaho identified opportunities to reduce homeowner energy costs in residential single-family new construction by increasing compliance with the current state energy code. The study was initiated in January 2018; data collection began in March 2018 and continued through June 2018. During this period, research teams visited 127 homes during various stages of construction, resulting in a collection of data 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 indicates nearly $500,000 in potential annual savings to Idaho homeowners that could result from increased compliance with the Idaho Energy Conservation Code.

Methodology

The project team was led by David Freelove, Idaho Energy Code Circuit Rider, with support from Cadmus, the Idaho Association of Building Officials, and the Northwest Energy Efficiency Alliance. The team applied a methodology that was previously developed and tested by the U.S. Department of Energy (DOE). The methodology identified the energy code-required building components that have the largest direct impact on energy consumption. These key items are a focal point of the study, and provide the data used in the analysis and savings estimates. The project team implemented an Idaho-specific sampling plan representative of new construction within the state. This sampling plan was developed by Pacific Northwest National Laboratory (PNNL).

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 field observations 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 and consumer cost savings 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.
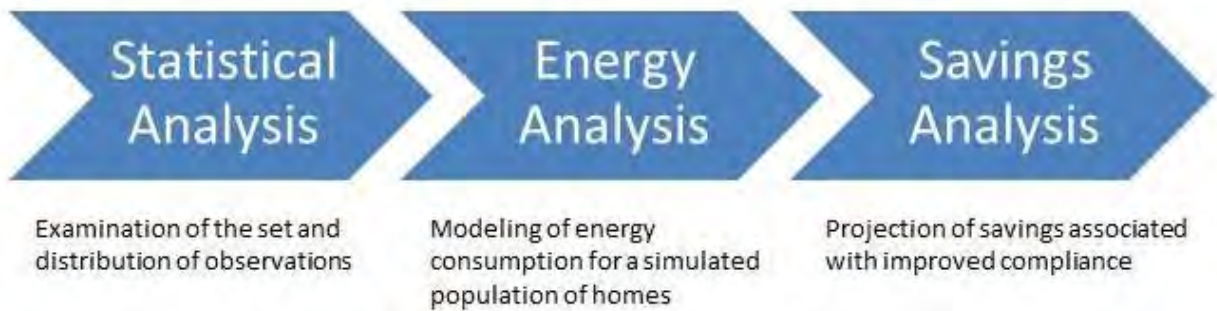
Figure ES.1. Stages of Analysis Applied in the Study

Results

The key items with the greatest potential for savings in Idaho are presented in Table ES.1. The estimates presented in the table represent the savings associated with each measure and are extrapolated based on projected new construction. These items may be considered during consideration of compliance-improvement programs within the state, including energy code education, training and outreach initiatives.

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

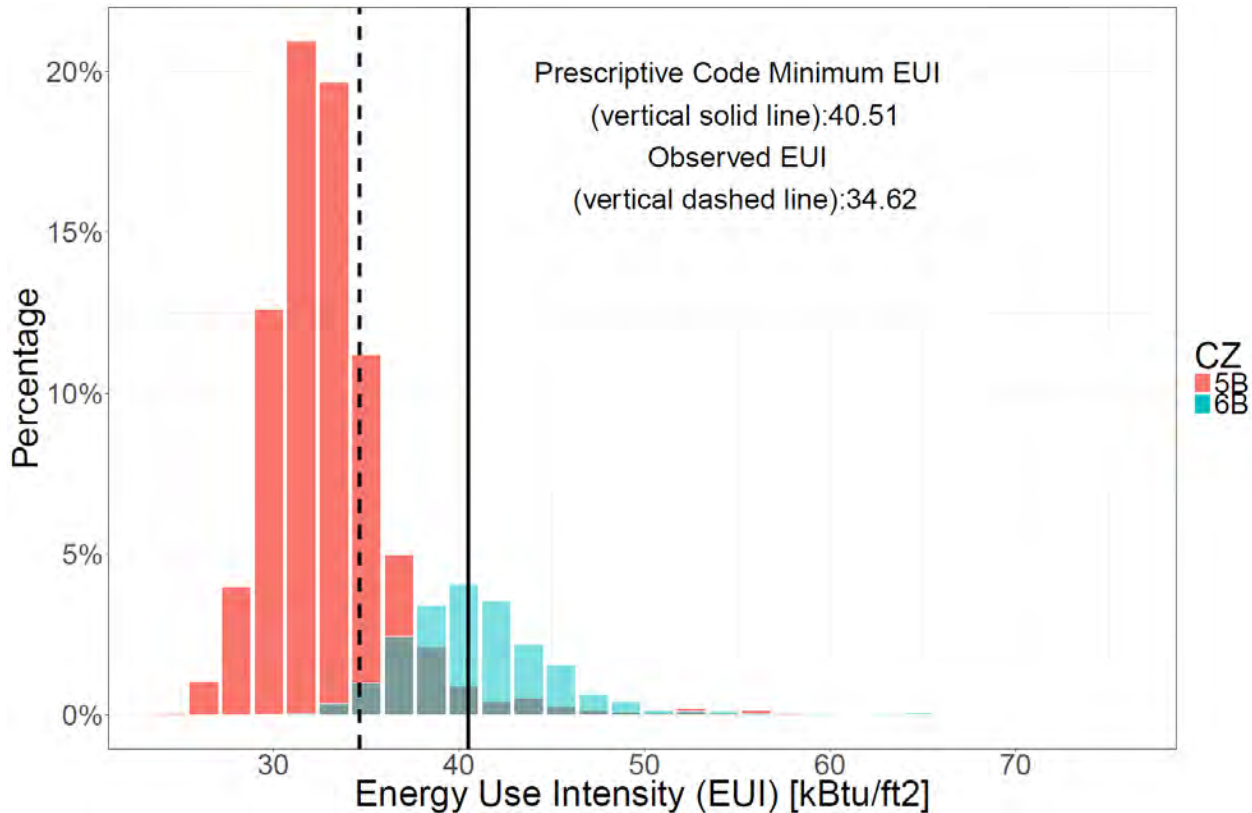| Measure	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)
Duct Leakage	27,966	307,201
Exterior Wall Insulation	17,088	167,182
Foundation Insulation	1,383	5,436
TOTAL	**46,436 MMBtu**	**$479,819**

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

In terms of overall energy consumption, the analysis shows that homes within the state use *less* 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 34.62 kBtu/ft^2-yr statewide compared to 40.51 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 15% better 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 still a significant energy savings opportunity (estimated at $500,000 annually) from energy code compliance enhancement activities in Idaho.

Acknowledgments

The following members comprised the Idaho project team:

- David Freelove, *Idaho Energy Code Circuit Rider*
- Jerica Stacey and Jolyn Green, *Cadmus*

The Idaho project team wishes to acknowledge the Northwest Energy Efficiency Alliance (NEEA) for generously providing the funding for this project, as well as the Idaho Association of Building Officials for its support.

The authors would also like to thank the following reviewers who provided insightful reviews of the report:

- Bing Liu, Steve Phoutrides, Dulane Moran and Christina Steinhoff, NEEA

- Sharon Grant and Ken Baker, Idaho Energy Code Collaborative group

- John Chatburn and Katie Pegan, Idaho Office of Energy and Mineral Resources

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.

Idaho Association of Building Officials

The Idaho Association of Building Officials (IDABO) was first recognized as a State organization in 1958. IDABO's mission is to promote public health and welfare by facilitating safe and accessible buildings and by educating citizens and elected officials on Idaho codes and standards. See more information on IDABO at http://www.idabo.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
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
ID	Idaho
IDABO	Idaho Association of Building Officials
IECC	International Energy Conservation Code
kBtu	thousand British thermal units
MMBtu	million British thermal units
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 Idaho investigated the energy code-related aspects of unoccupied, newly constructed, single family homes across the state. The study followed a DOE-developed and tested methodology, which allowed the project team to build an empirical collection of data based on observations made directly in the field. The data was then analyzed to identify compliance trends, their impact on statewide energy consumption, and calculate savings that could be achieved through increased code compliance.

The Idaho field study was initiated in January 2018; data collection began in March 2018 and continued through June 2018. During this period, research teams visited 127 homes across the state during various stages of construction. At the time of the study, the state had the Idaho Energy Conservation Code effective from January 1, 2015. The study methodology, data analysis and resulting findings are presented throughout this report.

1.1   Background

This project was built upon the U.S. Department of Energy (DOE)'s field study, "Strategies to Increase Residential Energy Code Compliance Rates and Measure Results".[1] The purpose of this study is to gather field data on energy code measures, as installed and observed in actual homes and through the subsequent analysis to identify trends and issues, which eventually can inform energy code training and other compliance- improvement programs.

Energy codes for residential buildings have advanced significantly in recent years, with today's model codes approximately 30% more efficient than codes adopted by the majority of U.S. states. [2,3] Hence, the importance of ensuring code-intended energy savings, so that consumers reap the benefits of improved codes—something which will happen only through high levels of compliance. More information on overall DOE interest in compliance is available on the DOE Building Energy Codes Program website.[4]

1.2   Project Team

David Freelove, the Idaho Energy Code Circuit Rider, led the Idaho project team and collected the field data; Cadmus and the Idaho Association of Building Officials (IDABO) provided support to Mr. Freelove throughout the project. The Pacific Northwest National Laboratory (PNNL) defined the methodology, conducted data analysis, and provided technical assistance to the project team. Funding for the project was provided by the Northwest Energy Efficiency Alliance (NEEA), with technical analysis provided by PNNL funded by DOE. More information on the organizations comprising the project team is included in the Acknowledgements section of this report.

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[1] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study
[2] *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
[3] Available at http://www.energycodes.gov/adoption/states
[4] Available at https://www.energycodes.gov/compliance

1.3   Stakeholder Interests

The project started with the formation of a stakeholder group comprised of interested and affected parties within the state. Following an initial kickoff meeting, the project team maintained active communication with the stakeholders throughout the course of the project. Stakeholders were sought from the following groups:

- Building officials

- Homebuilders

- Energy efficiency advocates

- Utilities

- Other important entities identified by the project team

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, and are targets for training. The Idaho team most frequently communicated with building officials and homebuilders, including the members of local IDABO chapters; local building associations; and state and local building officials. Utilities were also identified as a crucial stakeholder and were updated regularly on the progress of the study.

2.0 Methodology

2.1 Overview

The Idaho 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 installed and observed in actual homes. In the subsequent analysis, trends and issues are identified, which can inform energy code training and other compliance- improvement 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 experiment—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 Idaho study, including sampling, data collection, and resulting data analysis. More information on the full DOE

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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.

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

2.2 State Study

The prescribed methodology was customized for Idaho 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).

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 team's field personnel 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 teams 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 Idaho Energy Conservation Code.[5] The final data collection form is available in spreadsheet format on the DOE Building Energy Codes Program 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 on every home where such tests could be conducted, using RESNET[7] protocols.

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] Available at https://dbs.idaho.gov/rules/2018/2018_Building_Statutes_Rules_pkt.pdf.

[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 Building Energy Codes Program website[8].

2.3 Data Analysis

All data analysis in the study was performed by PNNL, and was applied 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 and consumer cost savings 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

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[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.
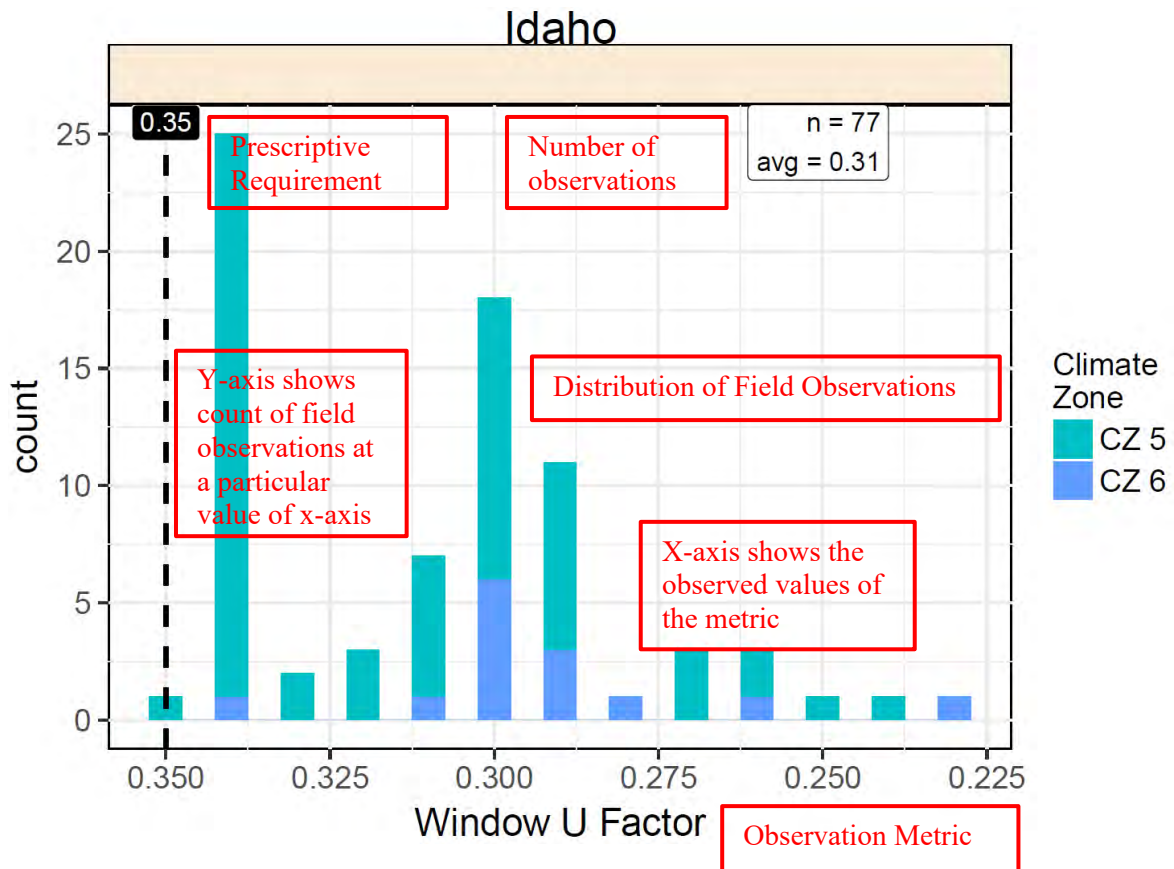
Figure 2.1. Sample Graph

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/ft2-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 4 is 0.35)—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, comprised 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 each climate zone within the state. 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 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 energy savings potential for the state in terms of *energy* (MMBtu) and *energy cost* ($).

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

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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.

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 (key item distributions, EUI, and measure-level savings) can be considered statistically significant only at the state level. Other results, such as analysis based on climate zone level, or reporting of non-key items (such as gas furnace efficiency), are included but should not be considered statistically representative.

2.4.2   Determination of Compliance

The field study protocol is based upon 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^{TM} 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

Field teams were 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 key items form the basis of the study and are therefore the focus of this section. Idaho is comprised of multiple climate zones; zone 5 (CZ 5) and zone 6 (CZ 6). Both climate zones are represented in the sampling, data collection, and resulting analysis and statewide savings calculations. A discussion of other findings is also covered in this section, 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.)

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 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 and floors (assembly U-factor)

8. Duct tightness (expressed in cfm per 100 ft^2 of conditioned floor area at 25 Pascals)

The three main foundation types observed in Idaho were floors over vented crawlspaces (82 observations), heated basements (22 observations), and unvented crawlspaces. In addition there were four slab observations, but due to that small number, a graphic is not provided for slabs. Note that these counts are for the number of homes observed to have these foundation types. The graphs below report the observed foundation insulation values and the number of observations will be less than or equal to the number of homes that have a particular foundation type.

3.1.1.1 Envelope Tightness
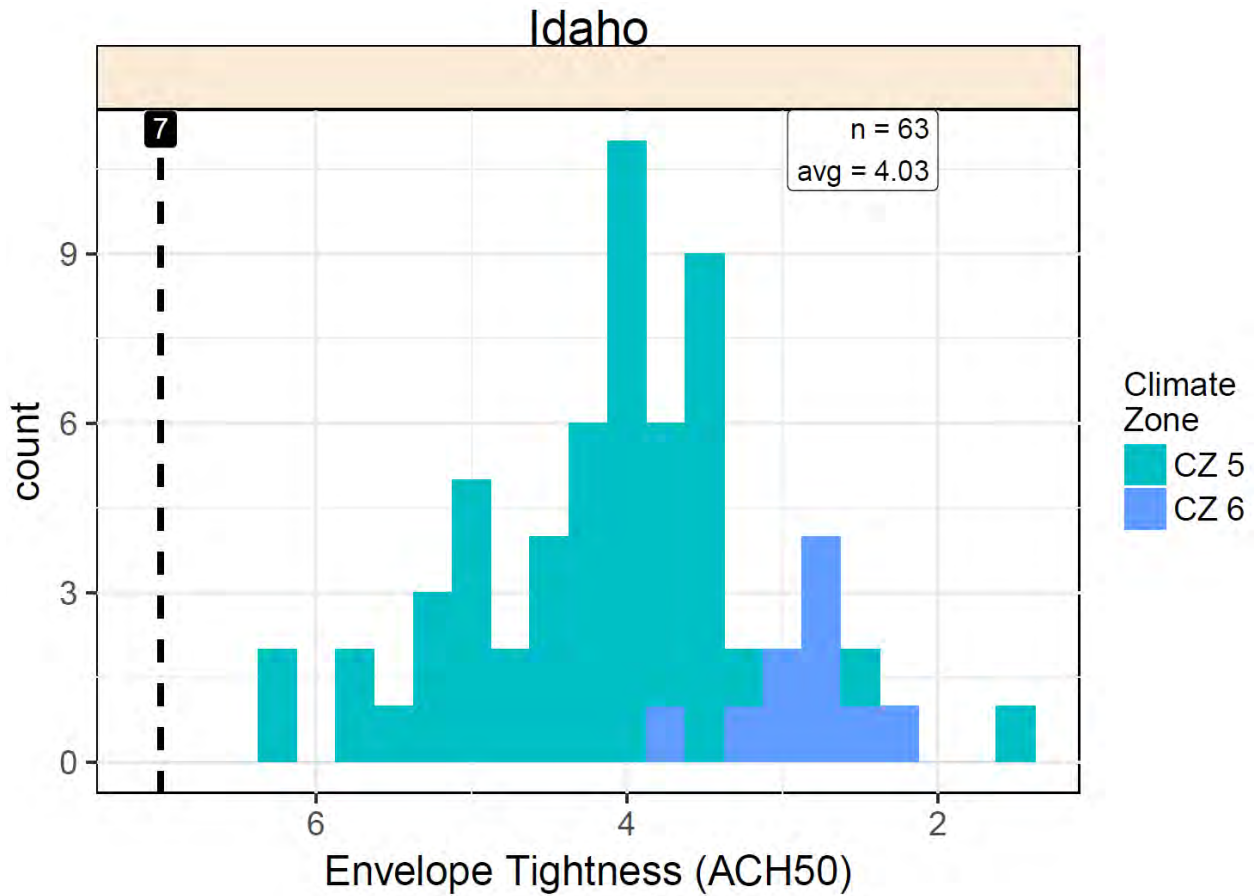
Figure 3.1. Envelope Tightness (ACH50)

Table 3.1. Envelope Tightness (ACH50)

Climate Zone	CZ5	CZ6	Statewide
Number	53	10	63
Range	1.4 to 6.4	2.3 to 3.8	1.4 to 6.4
Average	4.2	2.9	4.0
Requirement	7	7	7
Compliance Rate	53 of 53 (100%)	10 of 10 (100%)	63 of 63 (100%)

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

3.1.1.2   Window SHGC
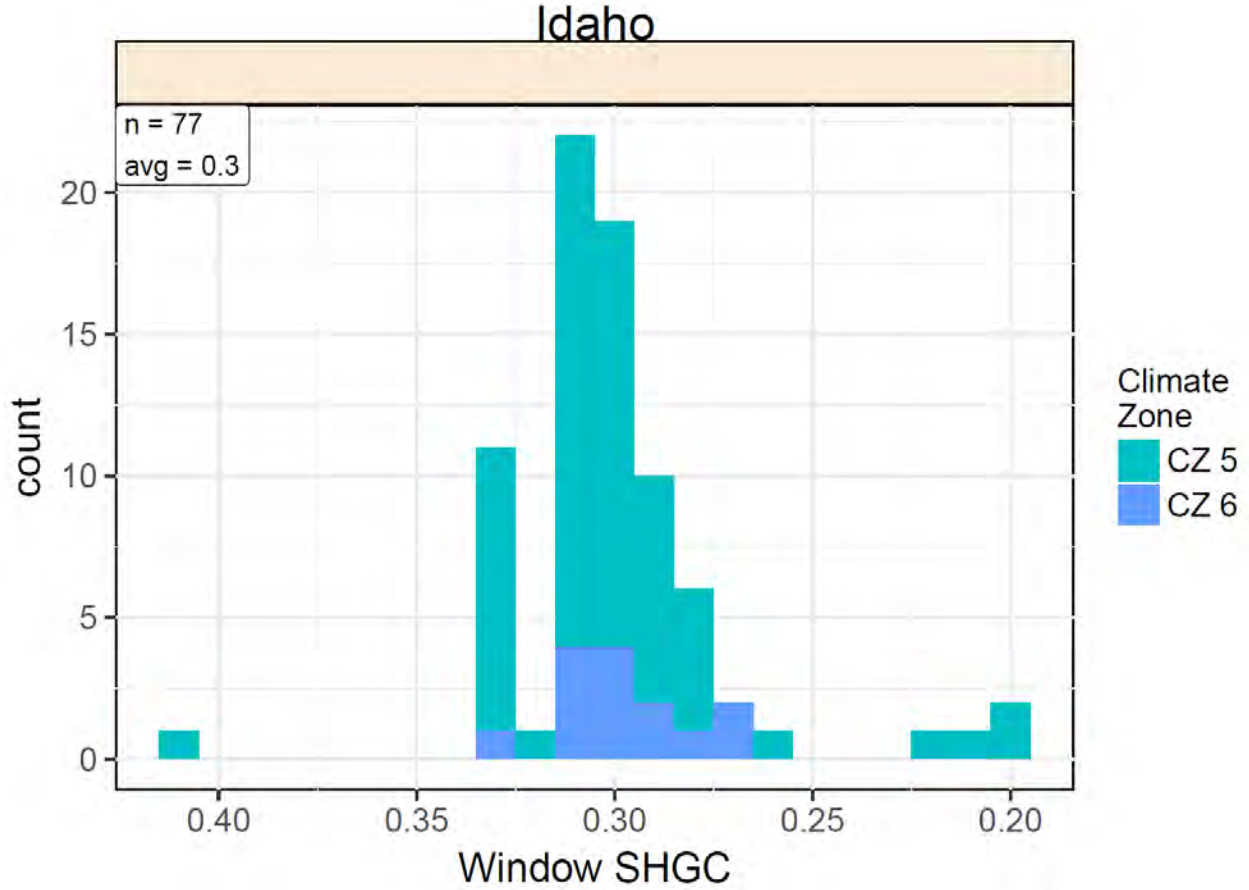
Figure 3.2. Window SHGC

Table 3.2. Window SHGC

Climate Zone	CZ5	CZ6	Statewide
Number	63	14	77
Range	0.20 to 0.41	0.27 to 0.33	0.20 to 0.41
Average	0.30	0.30	0.306
Requirement	NA	NA	NA
Compliance Rate	NA	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 Zones 5 and 6.

  – The vast majority of the observations were in the 0.26 to 0.34 SHGC range.

3.1.1.3 Window U-Factor
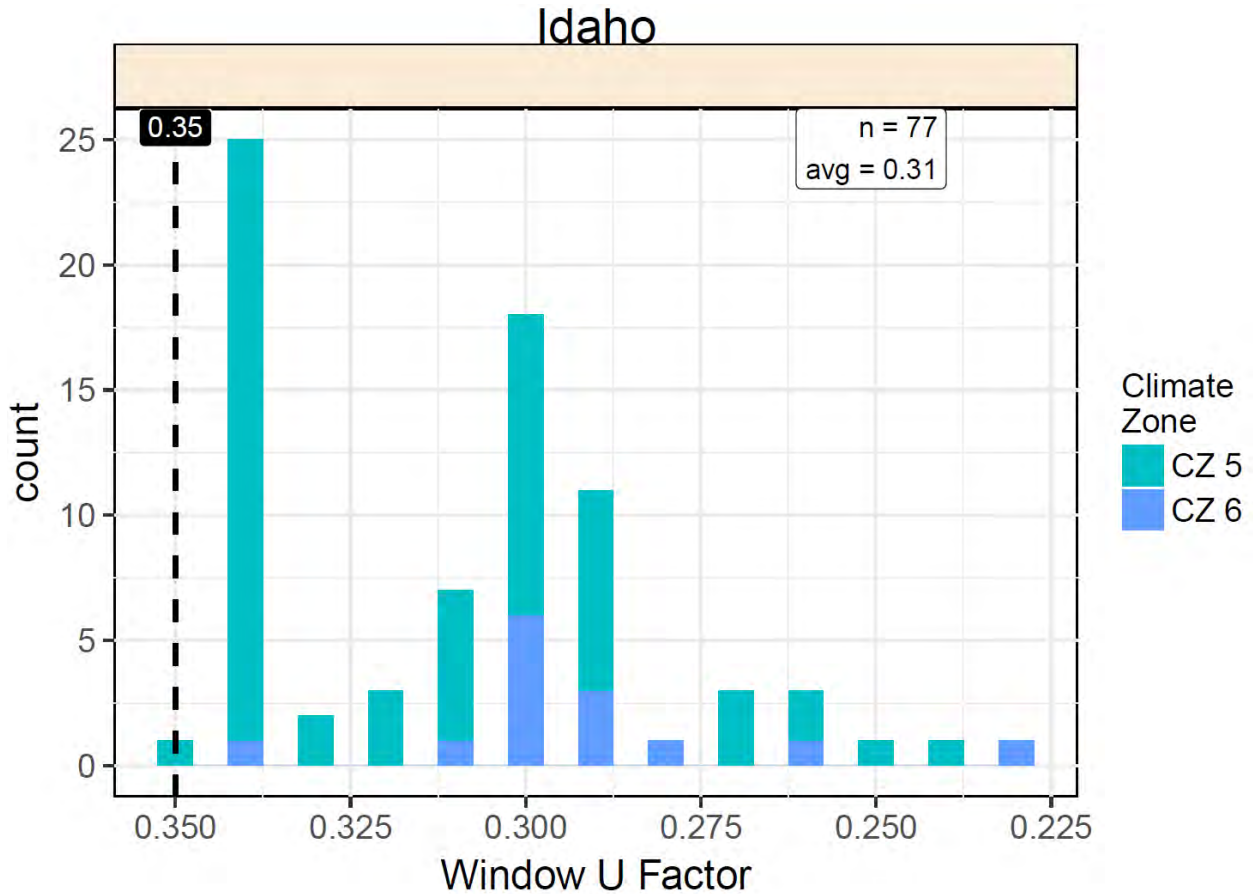
Figure 3.3. Window U-Factor

Table 3.3. Window U-Factor

Climate Zone	CZ5	CZ6	Statewide
Number	63	14	77
Range	0.24 to 0.35	0.23 to 0.34	0.23 to 0.35
Average	0.31	0.29	0.31
Requirement	0.35	0.35	0.35
Compliance Rate	63 of 63 (100%)	14 of 14 (100%)	77 of 77 (100%)

- **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 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.

3.4

3.1.1.4 Wall Insulation

Two graphs are shown for each climate zone 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 both cavity and continuous insulation layers, 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.
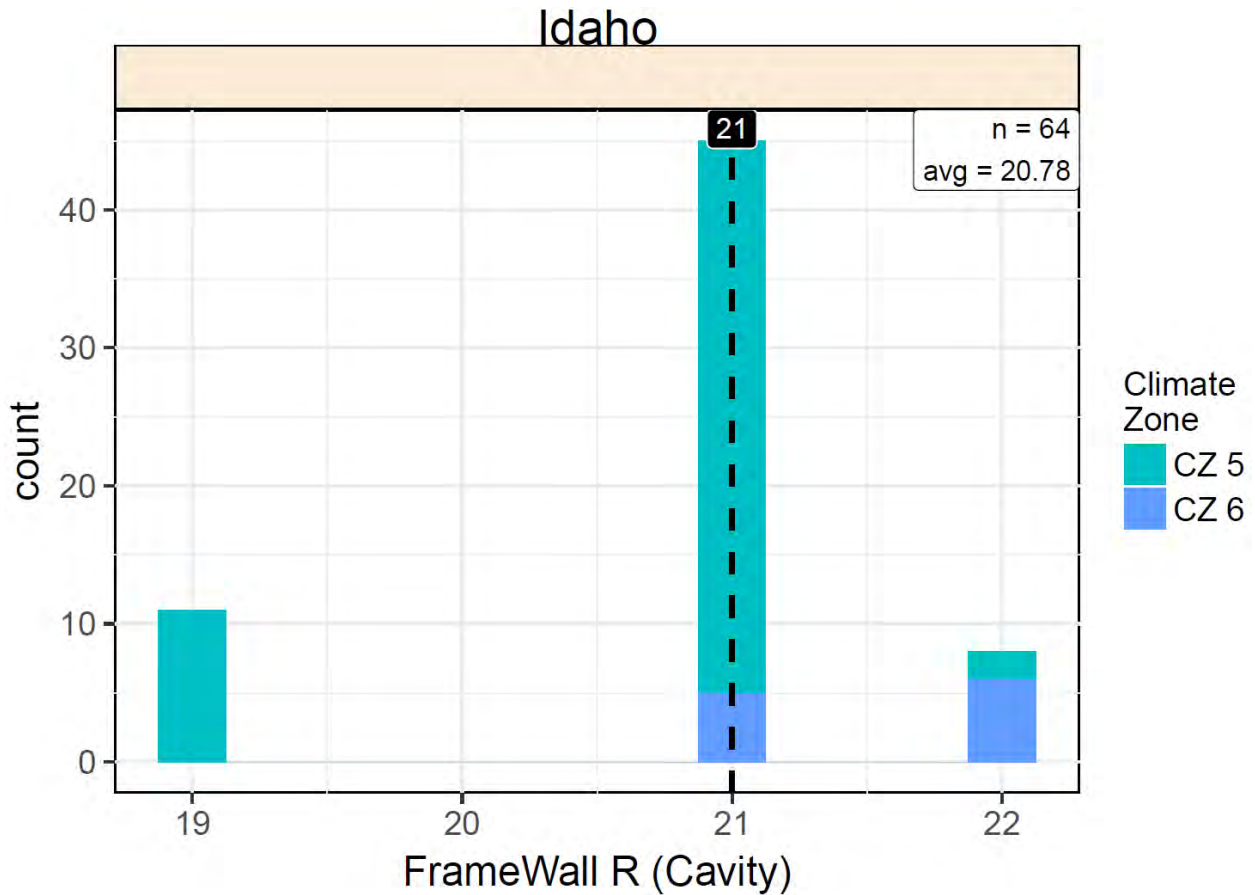
Figure 3.4. Wall R-Values

Table 3.4. Wall R-Value

Climate Zone	CZ5	CZ6	Statewide
Number	53	11	64
Range	R-19 to R-22	R-21 to R-22	R-19 to R-22
Average	R-20.6	R-21.6	R-20.8
Requirement	R-21	R-21	R-21
Compliance Rate	42 of 53 (21%)	11 of 11 (100%)	53 of 64 (83%)
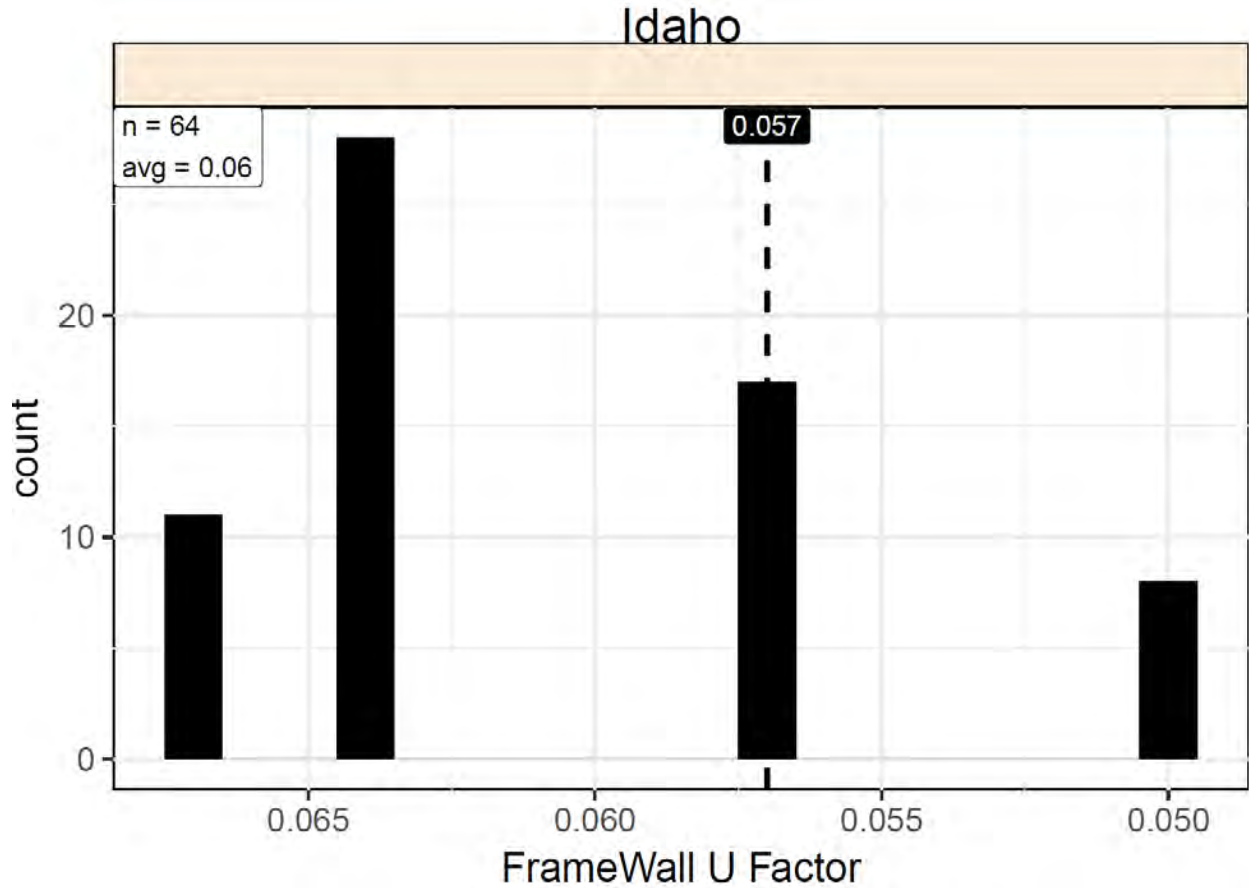
Figure 3.5. Wall Assembly Performance, including Wall Insulation Installation Quality

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

Climate Zone	CZ5	CZ6	Statewide
Number	53	11	64
Range	0.067 to 0.050	0.064 to 0.050	0.067 to 0.050
Average	0.062	0.054	0.061
Assembly U-Factor (expected)	0.057	0.057	0.057
Rate	16 of 53 (30%)	9 of 11 (82%)	25 of 64 (39%)

- **Interpretations:**

  – Looking at the R-values, most of the observations in CZ5 met or exceeded the prescriptive code requirement, and all in CZ6 did, indicating that the only issue with the amount of insulation are the homes with R-19 insulation in CZ5.

  – In more than half of the above-grade wall observations, the insulation installation quality was rated as Grade II, indicating an issue that should be addressed.

3.1.1.5 Ceilings
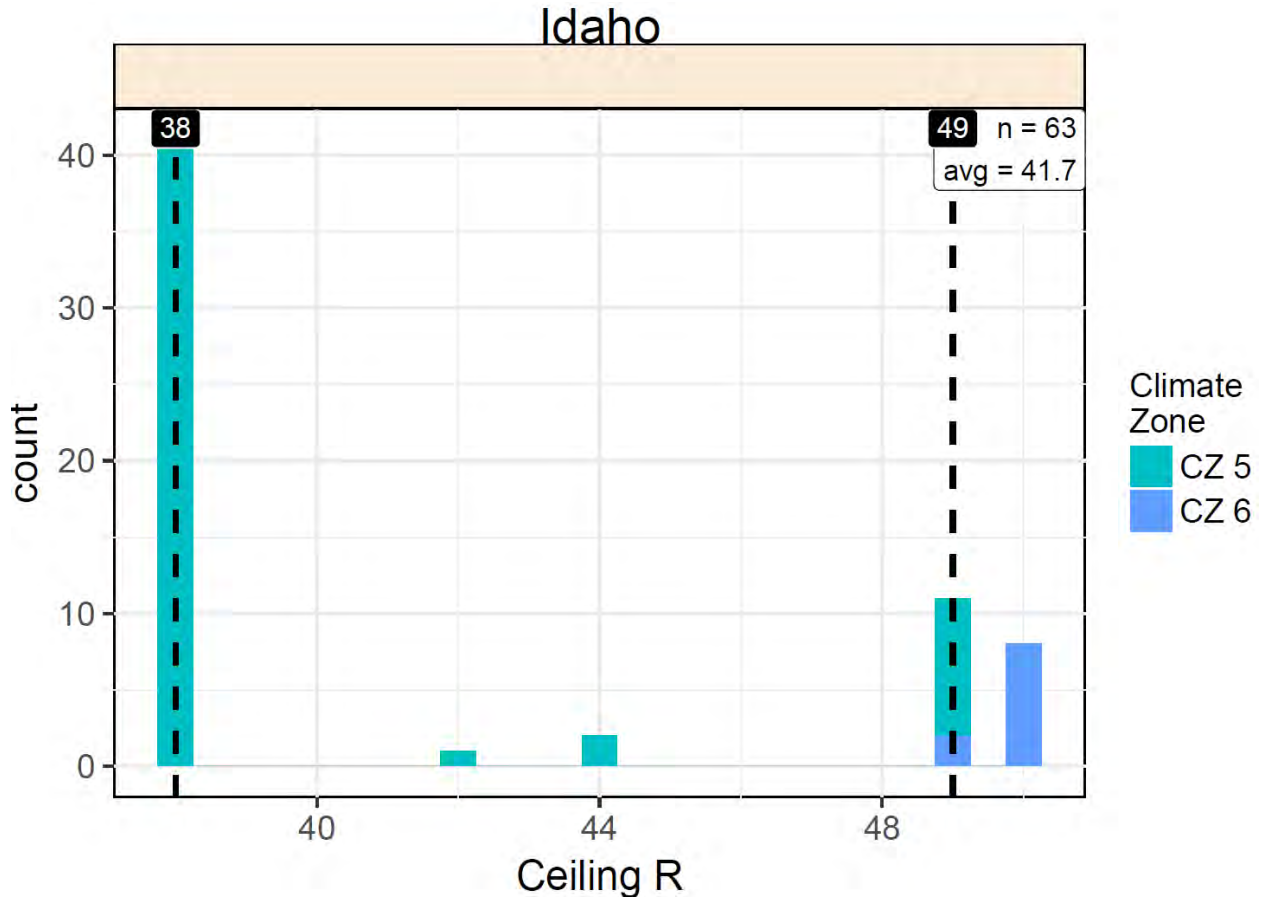
Figure 3.6. Ceiling R-Value

Table 3.6. Ceiling R-Value

Climate Zone	CZ5	CZ6	Statewide
Number	53	10	63
Range	R-38 to R-49	R-49 to R-50	R-38 to R-50
Average	R-40.2	R-49.8	R-41.7
Requirement	R-38	R-49	Varies
Compliance Rate	53 of 53 (100%)	10 of 10 (100%)	63 of 63 (100%)

- **Interpretations:**
  - The vast majority of observations met the code requirement exactly.
  - All of the roof cavity insulation installation quality observations were Grade I, indicating that roofs are well insulated in Idaho.
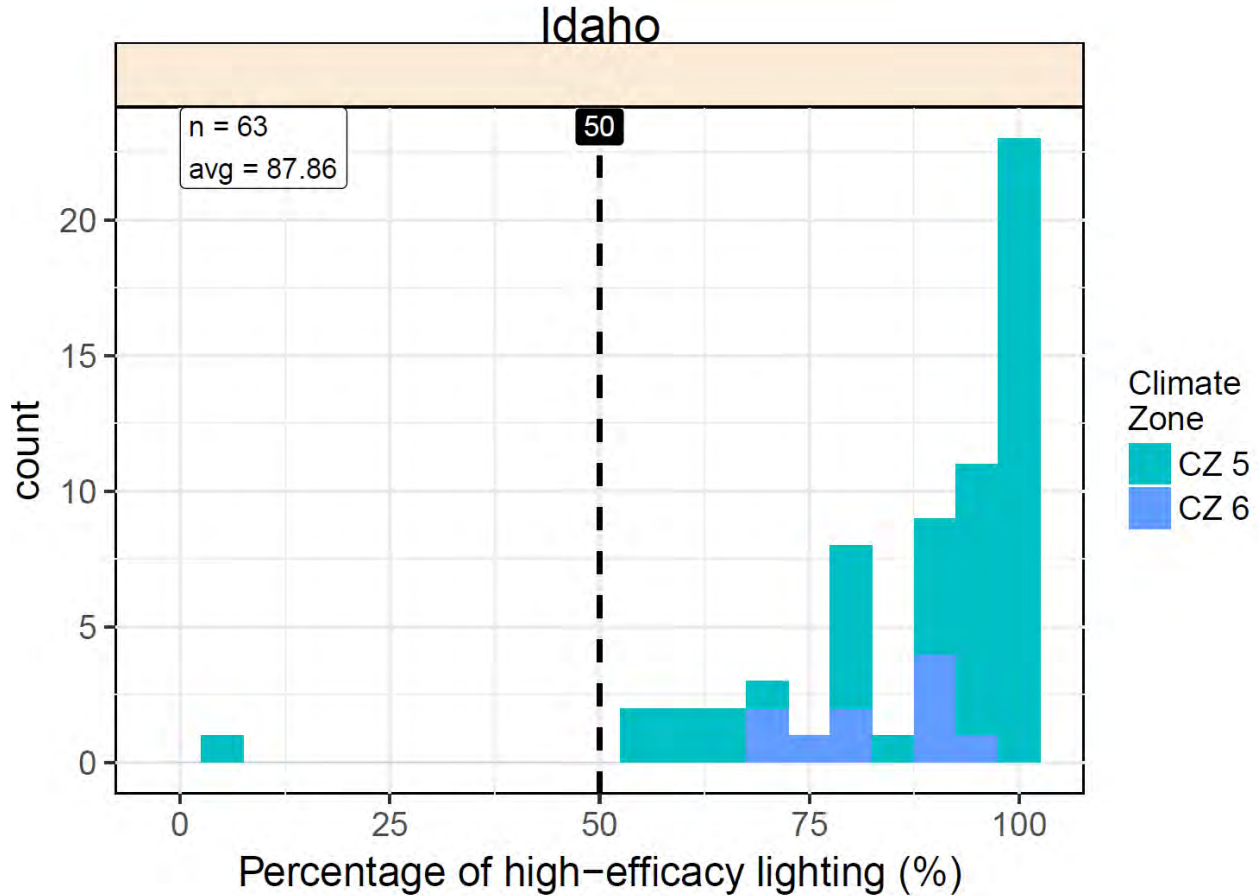
Figure 3.7. High-efficacy Lighting Percentage

Table 3.7. High-efficacy Lighting Percentage

Climate Zone	CZ5	CZ6	Statewide
Number	53	10	63
Range	4 to 100	70 to 96	4 to 100
Average	89	83	88
Requirement	50	50	50
Compliance Rate	52 of 53 (98%)	10 of 10 (100%)	62 of 63 (98%)

- **Interpretations:**
  - Nearly all of the field observations met the requirement.

3.1.1.6   Foundation Assemblies

There were three predominant foundation types observed in Idaho, heated basements, floors over vented crawlspaces and unvented crawlspaces. Two graphs are shown for each climate zone for foundations, insulation (R-value) and binned assembly (U-factor). The R-value graphs show the insulation R-values observed. The binned U-factor graphs indicate the U-factor of the assembly, including both cavity and continuous insulation layers, 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 and climate zone, 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 the cavity insulation observations. There are an additional 5 homes that have only continuous insulation and these homes are not shown on Figure 3.8. These 5 homes are shown in the U-factor plot (Figure 3.9).
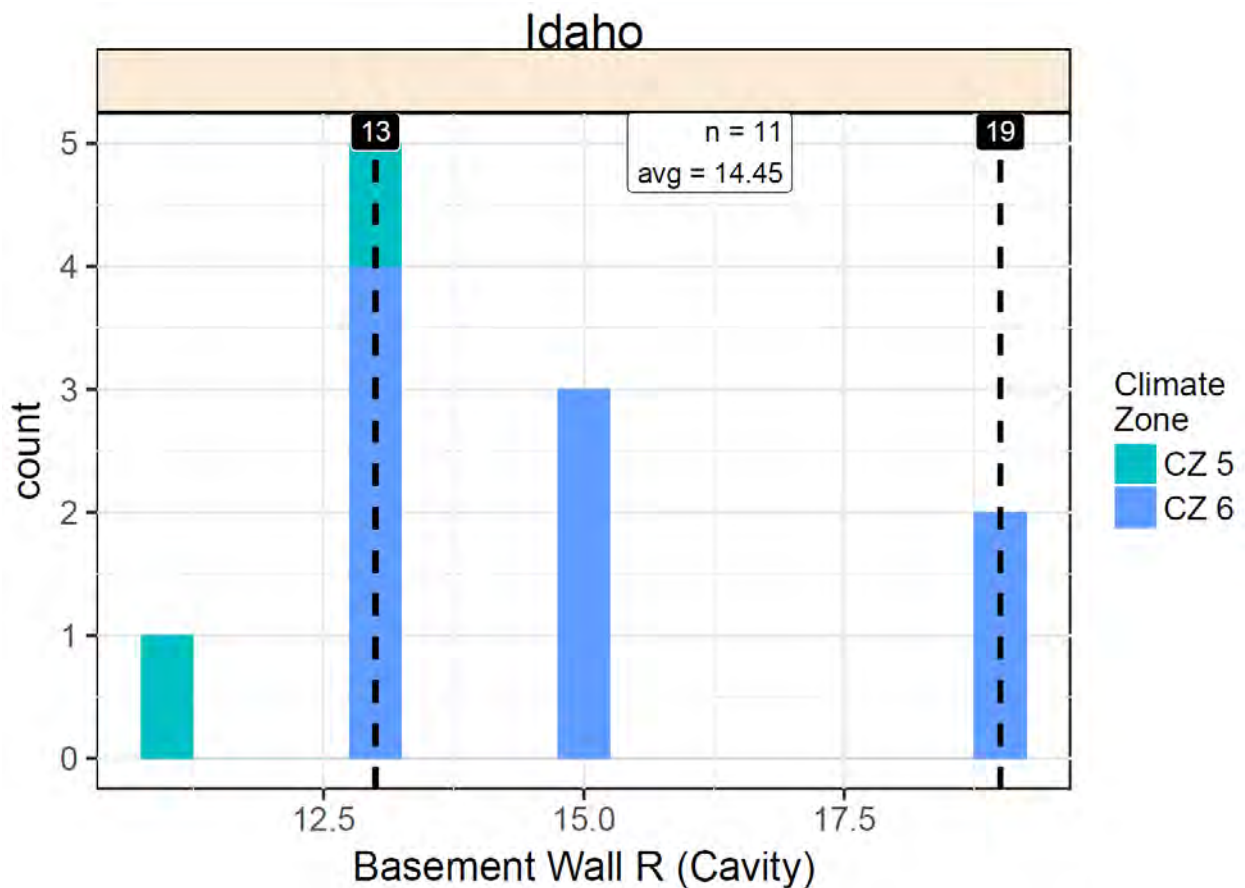
Figure 3.8. Basement Wall Cavity R-Values

Table 3.8. Basement Wall Cavity R-Values

Climate Zone	CZ5	CZ6	Statewide
Number	2	9	11
Range	R-11 to R-13	R-13 to R-19	R-11 to R-19
Average	R-12	R-15	R-14.5
Assembly U-Factor (expected)	R-13	R-19	R-13 in CZ5 and R-19 in CZ6
Rate	1 of 2 (50%)	2 of 9 (22%)	3 of 11 (27%)
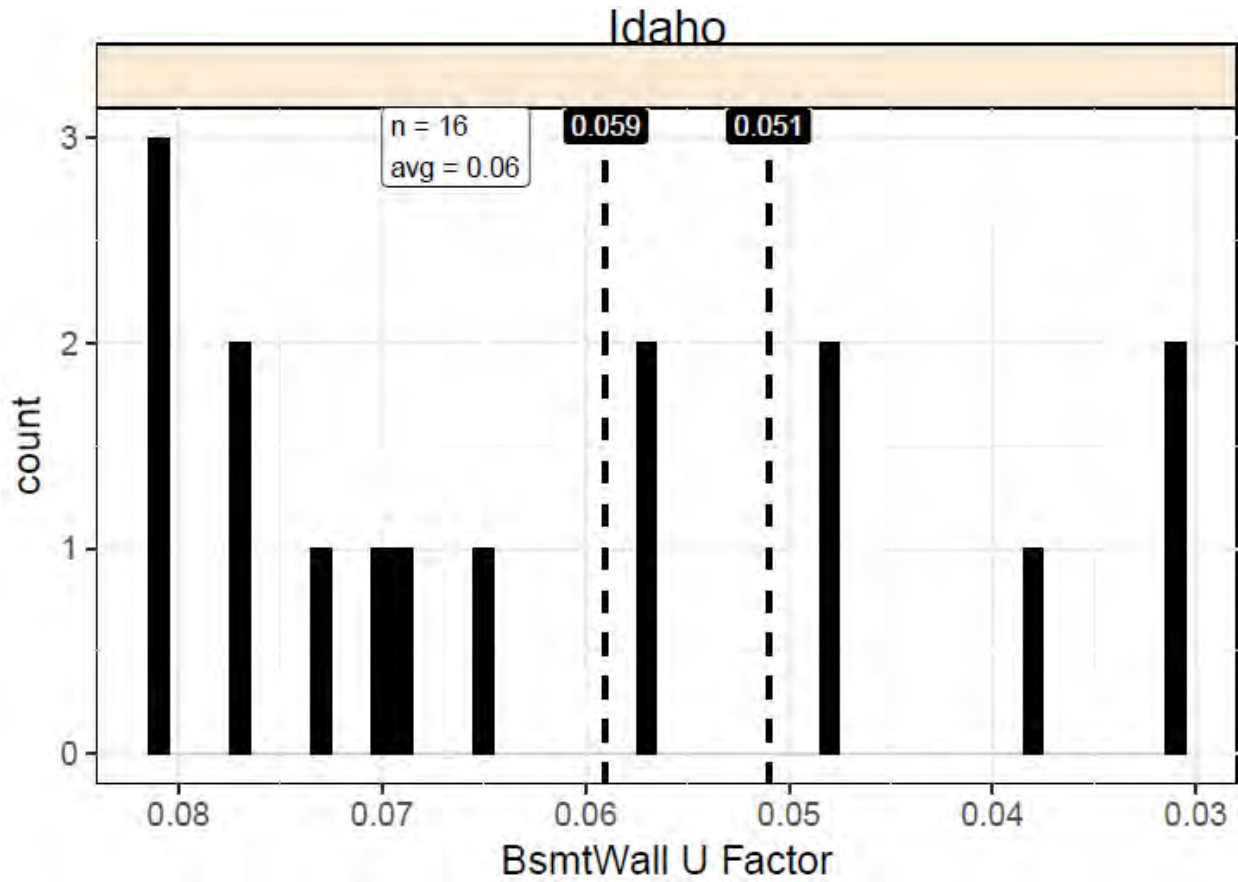
Figure 3.9. Basement Wall Assembly Performance, including Wall Insulation Installation Quality

Table 3.9. Basement Walls U-Factor

Climate Zone	CZ5	CZ6	Statewide
Number	4	12	16
Range	0.069 to 0.031	0.081 to 0.038	0.081 to 0.031
Average	0.049	0.065	0.061
Assembly U-Factor (expected)	0.059	0.051	0.059 in CZ5 and 0.051 in CZ6
Rate	2 of 4 (50%)	3 of 12 (25%)	5 of 16 (31%)

- **Interpretations:**

  – Comparison of the U-factor and R-value graphs for CZ5 indicates that insulation installation quality may be an issue for basement walls with cavity insulation in CZ5. However, the two homes with basement walls with continuous insulation did meet code. The sample size for CZ5 is very small.

  – Comparison of the U-factor and R-value charts for CZ6 indicates that the main reason for the poor performance on the U-factor chart is the amount of insulation. In CZ6, the presence of three homes with continuous basement insulation again provided all of the homes that meet the code requirement. This implies that for the two homes that meet the cavity insulation R-value, the insulation installation quality for those homes raised their U-factor.

Insulation in Floors over Unconditioned Spaces
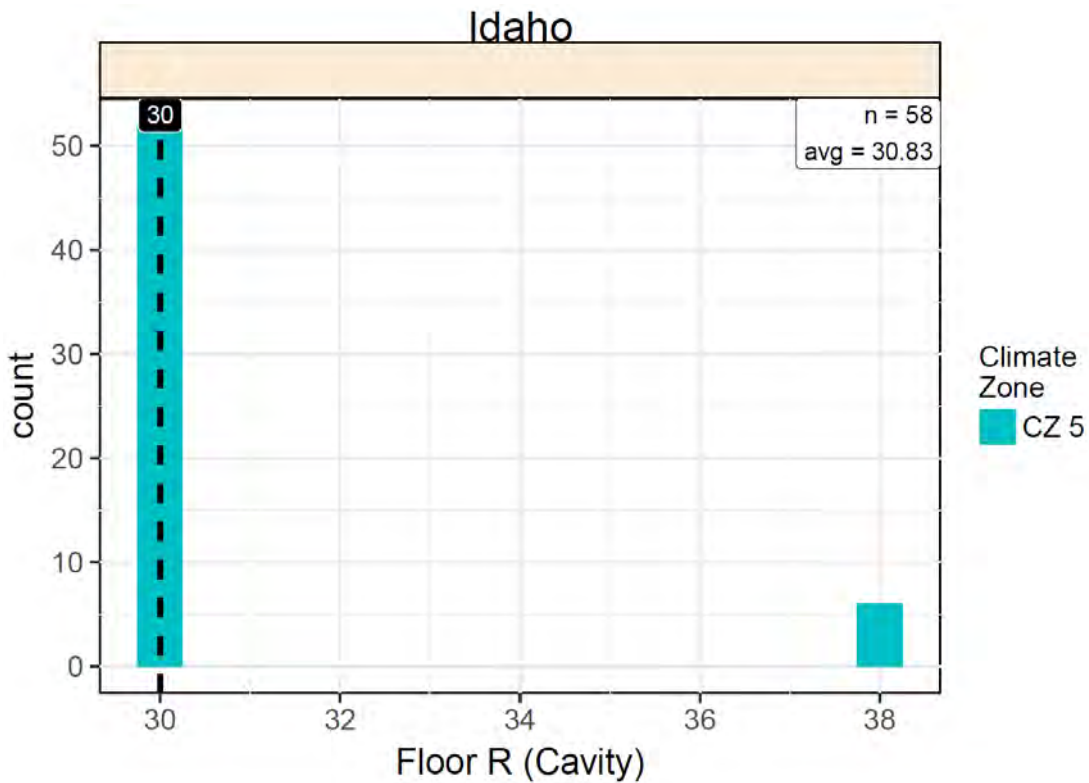
Figure 3.10. Floor R-Values

Table 3.10. Floor R-Value

Climate Zone	CZ5	CZ6	Statewide
Number	58	0	58
Range	30 to 38	NA	30 to 38
Average	30.8	NA	30.8
Assembly U-Factor (expected)	30	30	30
Rate	58 of 58 (100%)	NA	58 of 58 (100%)
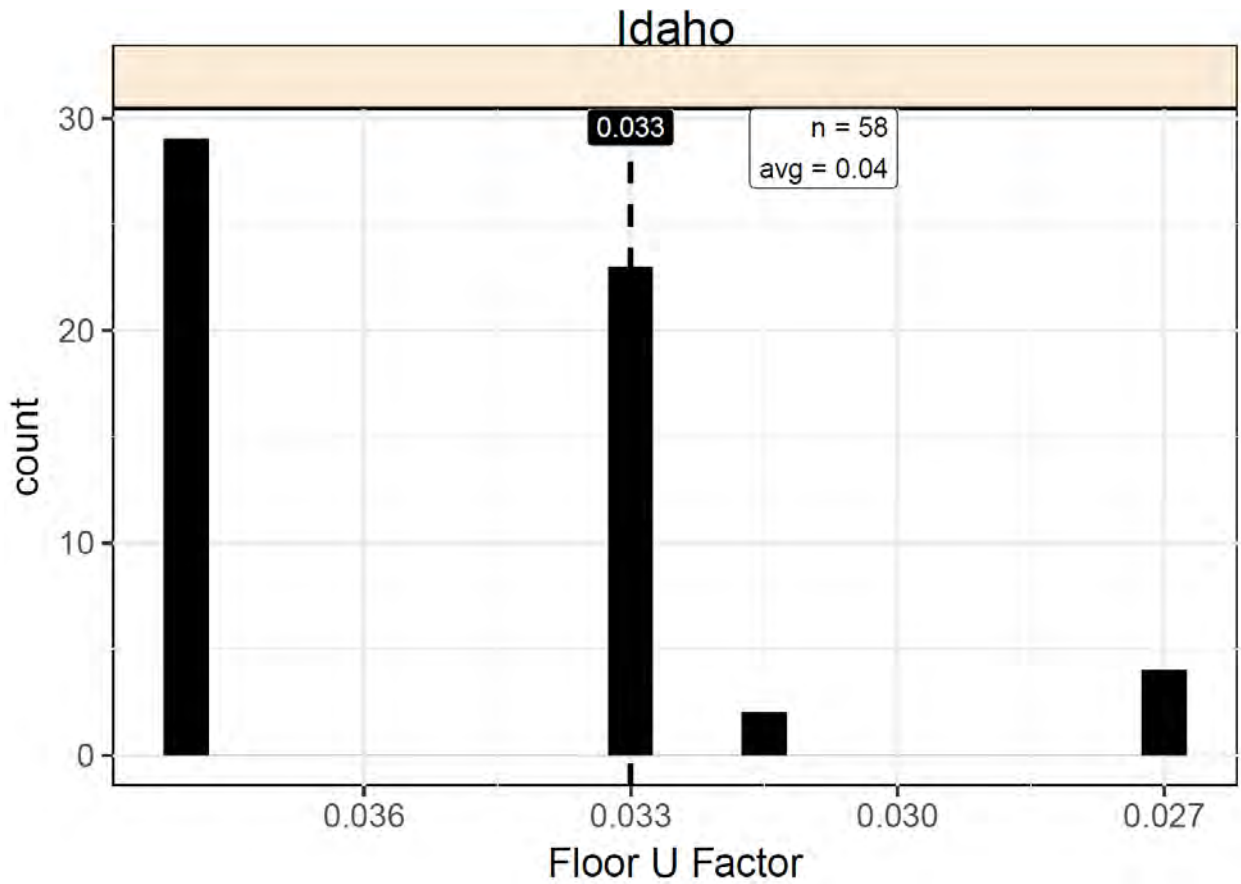
Figure 3.11. Floor Assembly Performance, including Insulation Installation Quality

3.12

Table 3.11. Floor U-Factor

Climate Zone	CZ5	CZ6	Statewide
Number	58	0	58
Range	0.040 to 0.028	NA	0.040 to 0.028
Average	0.035	NA	0.035
Assembly U-Factor (expected)	0.033	0.033	0.033
Rate	29 of 58 (50%)	NA	29 of 58 (50%)

- **Interpretations:**

  – Comparison of the U-factor and R-value charts for CZ5 indicates that insulation installation quality is an issue for floors in CZ5. The R-values all meet or exceed the code requirement, but only half of the U-factors meet or exceed the code requirement.

Insulation in Walls of Unvented Crawlspaces

For this assembly, the majority of observations involved continuous insulation, so the R-value plot shown is for vented crawlspace wall continuous R-value. There are an additional three observations of crawlspace walls with cavity insulation, all of which meet prescriptive R-value requirements. These observations are included in the vented crawlspace wall U-factor plot below.

3.13
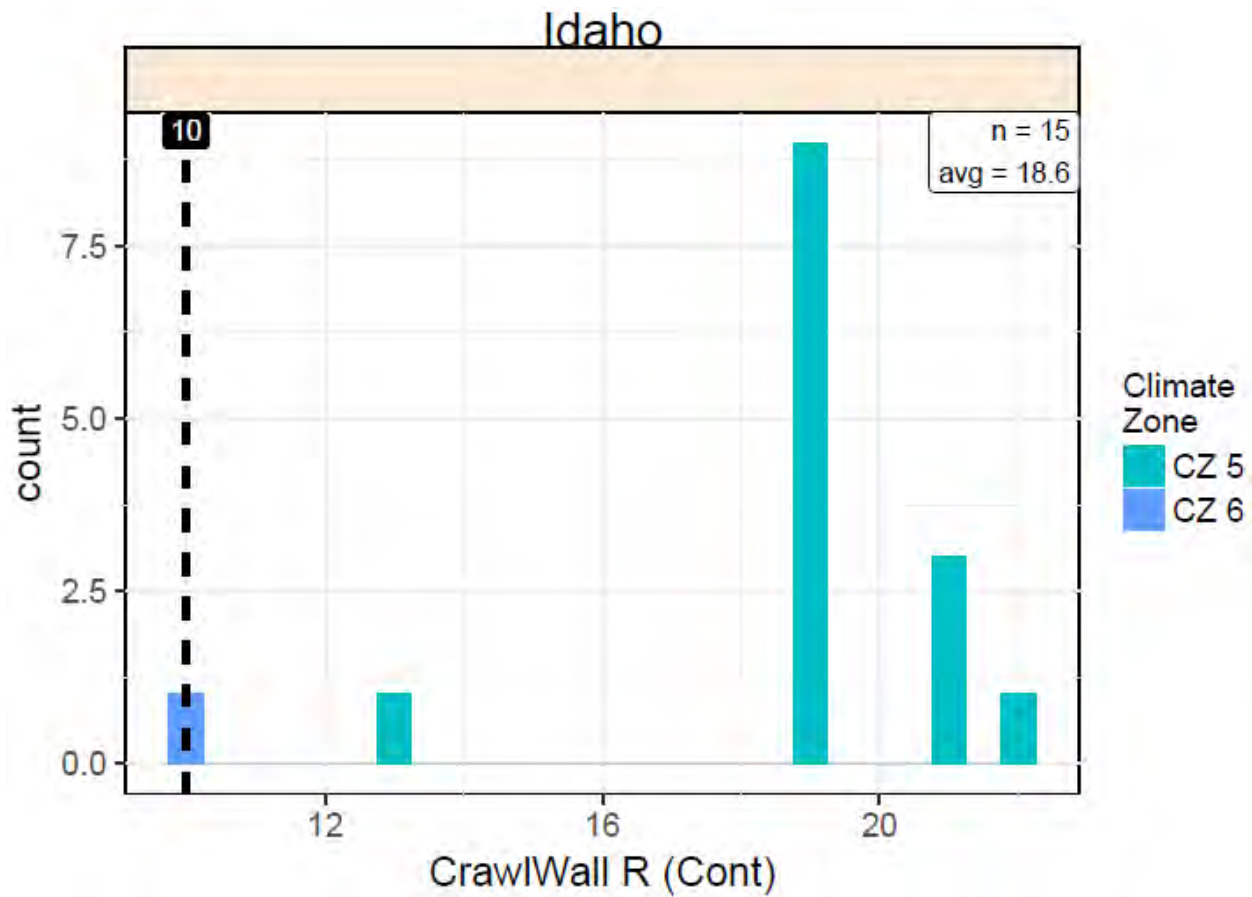
Figure 3.12.Unvented Crawlspace Wall Continuous Insulation R-Value

Table 3.12. Unvented Crawlspace Wall Continuous R-Value

Climate Zone	CZ5	CZ6	Statewide
Number	14	1	15
Range	R-13 to R-22	R-10	R-10 to R-22
Average	R-19.2	R-10	R-18.6
Assembly U-Factor (expected)	R-10	R-10	R-10
Rate	14 of 14 (100%)	1 of 1 (100%)	15 of 15 (100%)
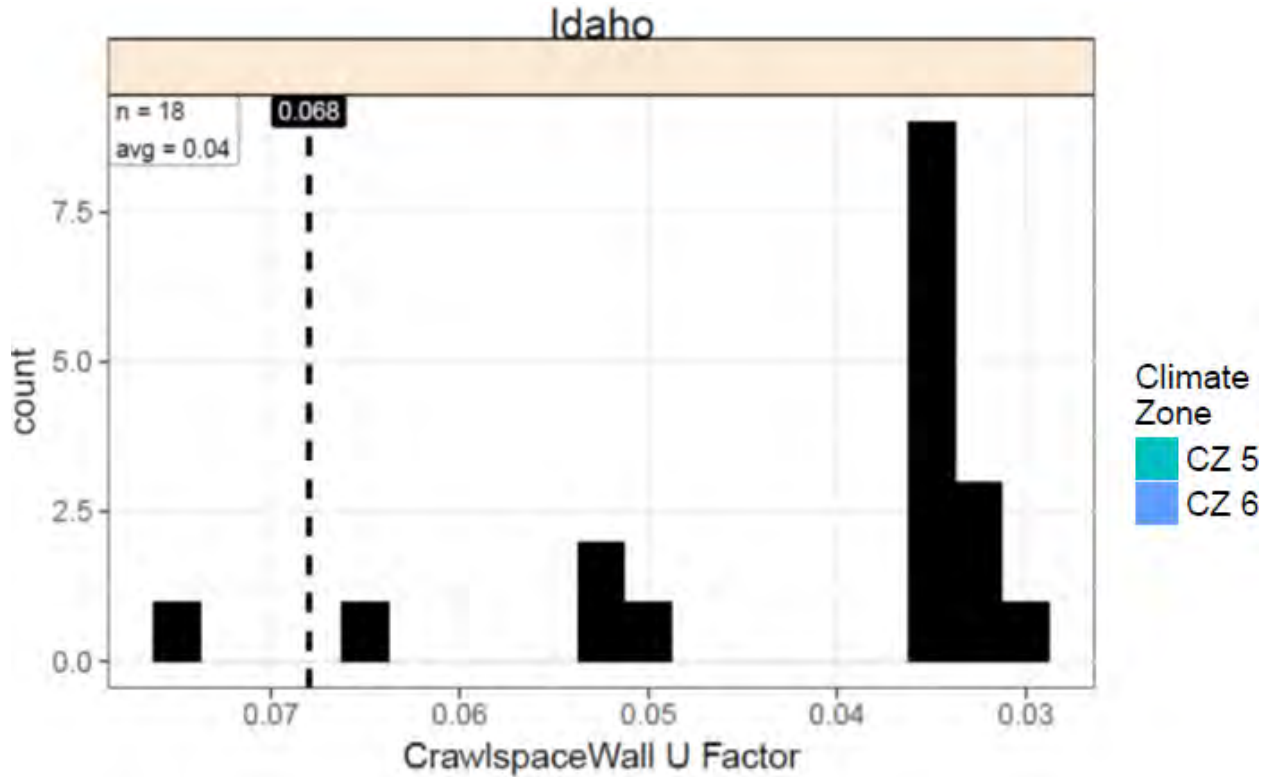
Figure 3.13. Unvented Crawlspace Wall Assembly Performance, including Insulation Installation Quality

Table 3.13. Unvented Crawlspace Wall U-Factor

Climate Zone	CZ5	CZ6	Statewide
Number	17	1	18
Range	0.065 to 0.032	0.065	0.065 to 0.032
Average	0.040	0.065	0..041
Assembly U-Factor (expected)	0.068	0.068	0.068
Rate	16 of 17 (94%)	1 of 1 (100%)	18 of 18 (100%)

- **Interpretations:**

  – All but one unvented crawlspace wall observation 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.
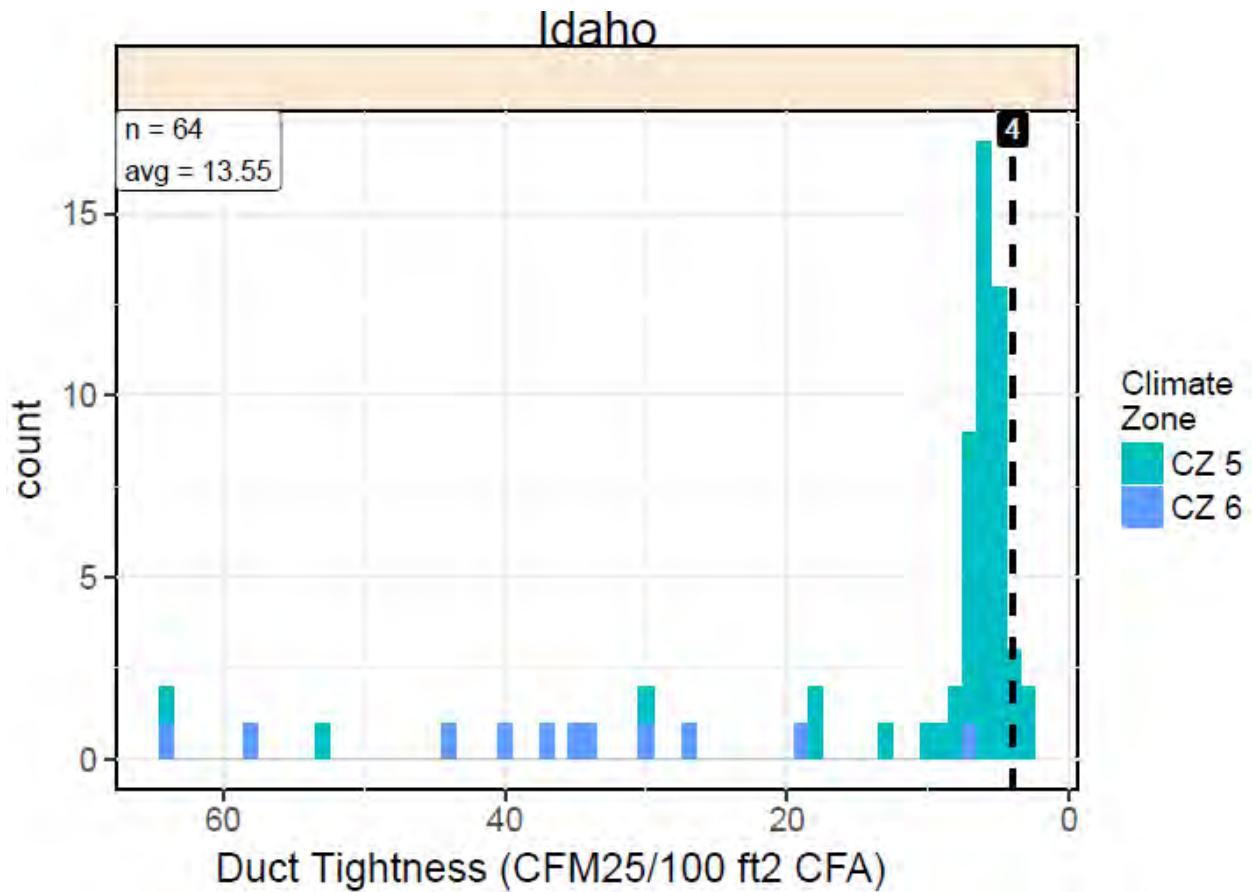
Figure 3.14. Raw Duct Tightness (CFM25/100ft2 CFA)

Table 3.14. Raw Duct Tightness (CFM25/100ft2 CFA)

Climate Zone	CZ5	CZ6	Statewide
Number	53	11	64
Range	3.2 to 64.0	6.9 to 63.6	3.24 to 64.0
Average	8.9	35.9	13.6
Requirement	4	4	4
Compliance Rate	3 of 53 (6%)	0 of 11 (0%)	3 of 64 (5%)

Idaho

n = 64
avg = 6.61
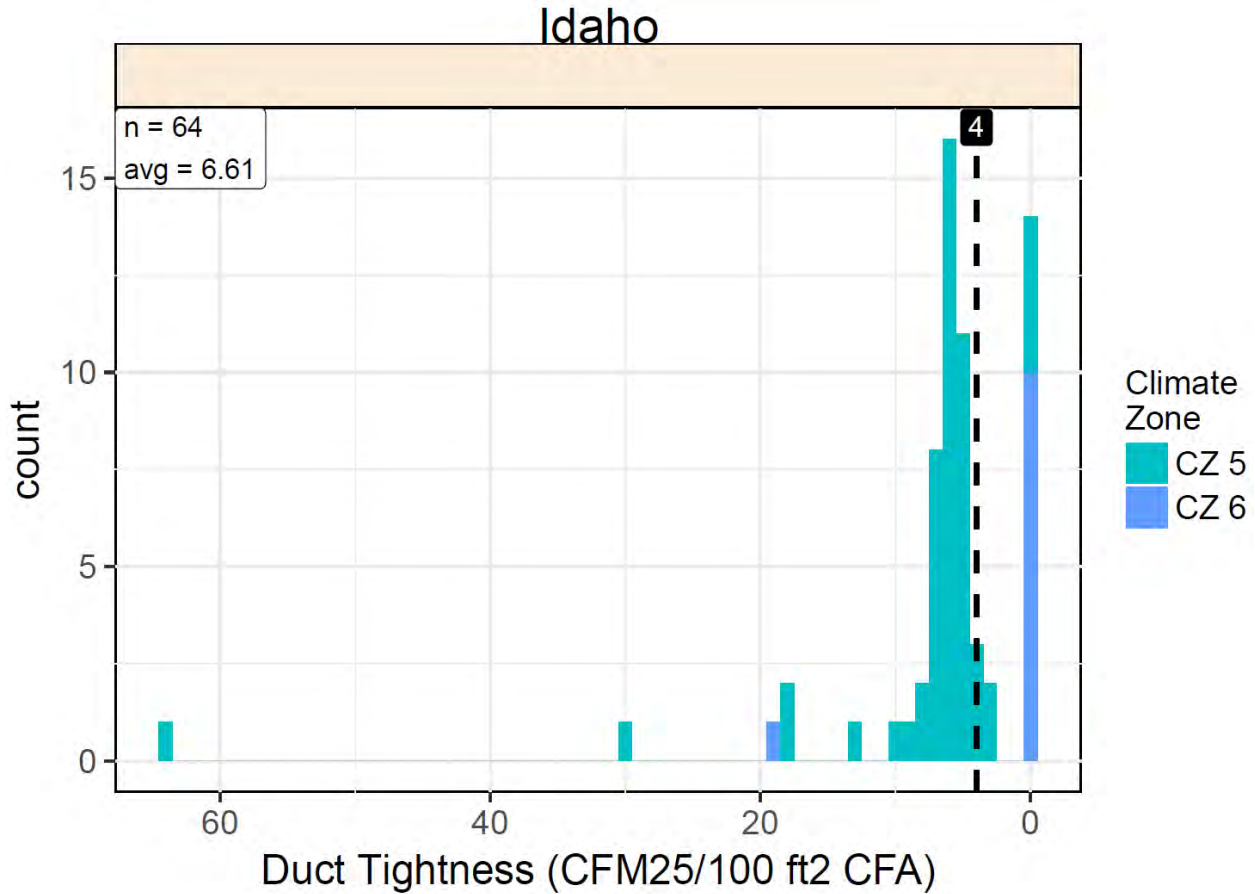
Figure 3.15. Adjusted Duct Tightness (CFM25/100ft2 CFA)

Table 3.15. Adjusted Duct Tightness (CFM25/100ft2 CFA)

Climate Zone	CZ5	CZ6	Statewide
Number	53	11	64
Range	0.0 to 64.0	0.0 to 63.61	3.24 to 64.0
Average	7.6	1.72	6.6
Requirement	4	4	4
Compliance Rate	17 of 53 (32%)	10 of 11 (91%)	26 of 64 (37%)

- **Interpretations:**

  – The average total duct leakage is 8.5 CFM 25/100 ft2 for the 50 systems with ducts in unconditioned space, and 31.8 CFM 25/100 ft2 for the 14 systems located entirely in conditioned space.

  – The majority of raw observations do not meet the Idaho code requirement for duct leakage.

  – The majority of adjusted observations do not meet the Idaho code requirement for duct leakage. However, nearly all adjusted duct leakage values in CZ6 meet the requirement, indicating that many homes in CZ6 are installing ducts 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 project teams and stakeholders, as it plays an important role in the energy performance of envelope assemblies. Insulation installation quality was therefore collected by the project team whenever possible and applied as a *modifier* in the analyses for applicable key items (i.e., ceiling insulation, wall insulation, and foundation insulation). The team followed the RESNET[1] assessment protocol which has three grades, Grade I being the best quality installation and Grade III being the worst.

Table 3.16 shows the insulation installation quality levels for framed envelope assemblies, as observed in the state. A slight majority of the observations (1247 of 243) were classified as Grade I, with remainder Grade II, indicating that there is some improvement needed in insulation installation quality. Roof insulation installation quality was all Grade I, but other assemblies show the majority of observations to be Grade II.

Table 3.16. Insulation Installation Quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Roof Cavity	63	0	0	**63**
Floor	27	31	0	**58**
Above Grade Wall	25	39	0	**64**
Basement Wall	2	9	0	**11**
Crawlspace Wall	0	3	0	**3**
Knee Wall	7	35	2	**44**

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 represents a summary of this data and outlines 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 B.

3.1.2.1 Average Home
- Size: 2,486 ft^2 and 1.35 stories

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

3.1.2.2 Compliance

- Almost all homes (98%) were permitted under the Idaho Energy Conservation Code. Two percent selected the 2015 edition of the International Energy Conservation Code to meet the local jurisdiction requirements. (n=127)

- Nine homes were noted as participating in an above-code program.

3.1.2.3 Envelope

- **Profile:**
  - Walls: All were wood-framed walls with 2x6" studs
  - Foundations: Mix of vented crawlspaces (65%), basements (17%), unvented crawlspaces (15%), and slab on grade (3%).

- **Successes (percentage of observations that complied):**
  - Insulation labeled (100%)
  - IC-rated light fixtures sealed (100%)
  - Utility penetrations sealed (98%)

- **Areas for Improvement:**
  - Attic access openings complied (54%)
  - Knee walls sealed (55%)
  - Envelope areas behind bathroom tubs & showers sealed (39%)
  - Rim joists sealed (27%)
  - Dropped ceilings sealed (49%)

3.1.2.4 Duct & Piping Systems

- **Profile:**
  - Ducts were generally located within conditioned space (percentage of duct system):
    - Supply: 41% (35 homes with 37 duct systems entirely within conditioned space)
    - Return: 31% (25 homes with 27 duct systems entirely within conditioned space)
  - About 28% of duct systems located *supply* ducts entirely within conditioned space
  - About 21% of duct systems located *return* ducts entirely within conditioned space
  - About 19% of duct systems had the *entire* system within conditioned space.
  - Pipe Insulation (R-value): 2.7

- **Successes:**
  - Air handlers sealed (88%)

3.1.2.5 HVAC Equipment

- **Profile:**
  - Heating: Mostly gas furnaces with an average efficiency of 90 AFUE.
  - Cooling: Mostly central AC with an average efficiency of 13.1 SEER
  - Water Heating: Mix of gas (92%) and electric (8%) storage (98%) with an average capacity of 50 gallons and average efficiency rating of EF 0.65.

- **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 Idaho appears to use *less* 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 3.16) of approximately 34.62 kBtu/ft^2-yr compared to 40.51 kBtu/ft^2-yr for homes exactly meeting minimum *prescriptive* energy code requirements (black line in Figure 3.16). This suggests the EUI for a "typical" home in the state is about 15% better than code.
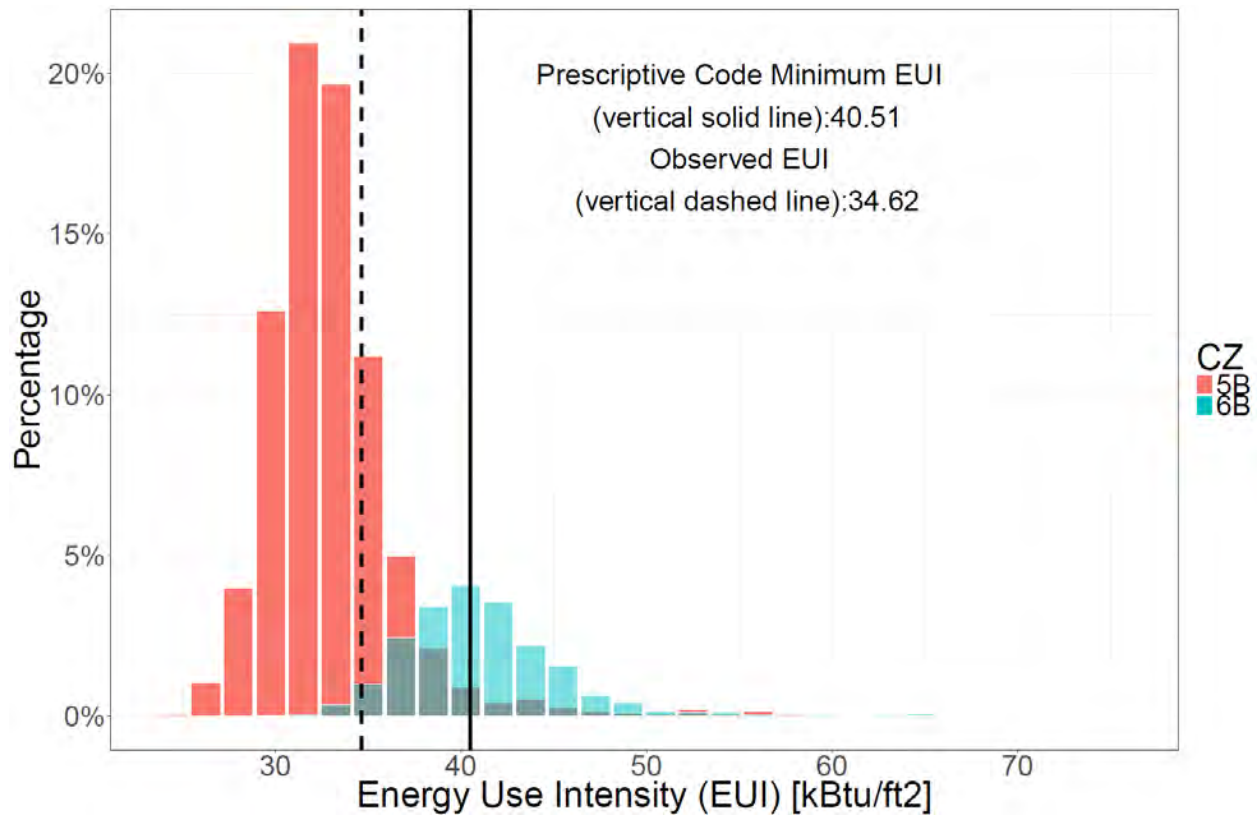
Figure 3.16. Statewide EUI Analysis for Idaho

3.3 Savings Potential

Those key items with the greatest potential,[1] shown below followed by the percent that did not meet code, were analyzed further to calculate the associated savings potential, including energy and cost savings.

- Duct Leakage (63% of adjusted observations),
- Exterior Wall Insulation (61%),
- Foundations
  - Basement Wall Insulation (69%), and
  - Floor Insulation (50%).

For analytical details refer to Section 2.3.3 (Savings Analysis) or the DOE methodology document (2018).
Estimated savings resulting from the analysis are shown below in order of highest to lowest total energy and cost savings (Table 3.17). As can be seen, there are significant savings opportunities, with the greatest total savings potential associated with these measures. In addition,

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[1] Defined here as those with more than 15% of observations not meeting the prescriptive code requirement. For insulated assemblies, the U-factor observations are used.

Table 3.19 shows the total savings reductions that will accumulate over 5, 10, and 30 years of construction.

Table 3.17. Statewide Annual Measure-Level Savings for Idaho

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 ($)
Duct Leakage	5B	107	21	2,430	8,760	21,281	237,040
	6B	107	26	2,959	2,259	6,684	70,161
	State Total	**107**	**22**	**2,538**	**11,019**	**27,966**	**307,201**
Exterior Wall Insulation	5B	42	13	1,477	8,760	12,939	128,174
	6B	41	17	1,837	2,259	4,149	39,008
	State Total	**42**	**14**	**1,551**	**11,019**	**17,088**	**167,182**
Foundation Insulation*	5B	-13	3	240	NA	814	2,474
	6B	-30	12	1,112	NA	570	2,962
	State Total	**-16**	**5**	**418**	**NA**	**1,383**	**5,436**
TOTAL		**133**	**41**	**4,507**	**11,019**	**46,436**	**479,819**

* Negative values mean that savings or reductions decrease if the measure is brought up to code.
**See Table 3.18 for annual measure-level savings results by foundation type.

Table 3.18. Statewide Annual Measure-Level Savings by Foundation Type for Idaho

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 ($)
Heated Basement Wall*	5B	-6	1	119	1,460	173	660
	6B	-23	10	959	377	361	2,043
	State Total	**-9**	**3**	**291**	**1,837**	**534**	**2,703**
Floor*	5B	-7	1	121	5,293	641	1,815
	6B	-6	2	153	1,365	209	918
	State Total	**-7**	**2**	**128**	**6,657**	**849**	**2,733**
TOTAL		**-16**	**5**	**418**	**NA**	**1,383**	**5,436**

*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.
** 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 3.19. Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings for Idaho

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)		
	5yr	10yr	30yr	5yr	10yr	30yr
Duct Leakage	419,483	1,538,104	13,003,973	4,608,019	16,896,069	142,848,583
Exterior Wall Insulation	256,313	939,815	7,945,707	2,507,730	9,195,009	77,739,624
Foundation Insulation	20,748	76,077	643,197	81,541	298,985	2,527,781
TOTAL	**696,544**	**2,553,996**	**21,592,877**	**$7,197,290**	**$26,390,063**	**$223,115,988**

4.0   Conclusions

The Idaho 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 Idaho uses about 15% less energy than a home exactly meeting the state energy code. However, savings potential remains through increased compliance with targeted measures. Potential statewide annual energy savings are 46,436 MMBtu, which equates to $479,819 in cost savings. Over a 30-year period, these impacts grow to 21.6 million MMBtu and $223 million.

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 below.

Table 4.1. Annual Statewide Savings Potential in Idaho

Key Measure	Annual Savings	
	Energy (MMBtu)	**Cost** ($)
Duct Leakage	27,966	307,201
Exterior Wall Insulation	17,088	167,182
Foundation Insulation	1,383	5,436
Total	**46,436 MMBtu**	**$479,819**

5.0 References

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Appendix A

State Sampling Plan

Appendix A

State Sampling Plan

A.1 State Sampling Plan

Table A.1. State Sampling Plan

Location (Place, County)	Sample	Actual
Kootenai County Unincorporated Area, Kootenai	4	4
Coeur d'Alene, Kootenai	3	3
Post Falls, Kootenai	4	4
Hayden, Kootenai	2	2
Rathdrum, Kootenai	1	1
Latah County Unincorporated Area, Latah	1	1
Ada County Unincorporated Area, Ada	5	5
Meridian, Ada	7	7
Eagle, Ada	5	5
Boise, Ada	3	3
Kuna, Ada	2	2
Star, Ada	1	1
Canyon County Unincorporated Area, Canyon	2	2
Nampa, Canyon	4	4
Caldwell, Canyon	2	2
Middleton, Canyon	1	1
Mountain Home, Elmore	1	1
Valley County Unincorporated Area, Valley	1	1
Bonneville County Unincorporated Area, Bonneville	1	1
Idaho Falls, Bonneville	2	2
Ammon, Bonneville	1	1
Jefferson County Unincorporated Area, Jefferson	1	1
Pocatello, Bannock	1	1
Chubbuck, Bannock	2	2
Rexburg, Madison	4	4
Fremont County Unincorporated Area, Fremont	1	1
Twin Falls, Twin Falls	1	1
Total	**63**	**63**

A.2 Substitutions

No substitutions to the state sampling plan were required.

Appendix B

Additional Data

Appendix B

Additional Data

B.1 Additional Data Collected by Field Teams

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 Idaho 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 the DOE Building Energy Codes Program website.[1]

B.1.1 General

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

B.1.1.1 Average Home

- Size (n=127): 2486 ft^2
- Number of Stories (n=127): 1.35

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

Conditioned Floor Area (ft^2)	< 1000	1000 to 1999	2000 to 2999	3000 to 3999	4000+
Percentage	1%	35%	42%	17%	5%

Table B.2. Number of Stories

No. of Stories	1	2	3	4+
Percentage	65%	35%	0%	0%

B.1.1.2 Wall Profile

- Framing Type (n=127):
  - *All* were framed construction (100%)
- Framing Material (n=127):
  - Wood (100%)

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

– Steel (0%)

- Framing Depth (n=127):

  – 6" (100%)

B.1.1.3   Foundation Profile

- Foundation Type (n=127):

  – Heated Basement (17%)

  – Slab on Grade (3%)

  – Unvented Crawlspace (15%)

  – Vented Crawlspace (65%)

B.1.2   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.

B.1.2.1   Energy Code Used (n=127):

Table B.3, Energy Code Used

Energy Code	Idaho Energy Conservation Code	2015 IECC
Percentage	98%	2%

- Was the home participating in an above-code program (n=102)?

  – Yes (9%)

  – No (91%)

B.1.3   Envelope

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

B.1.3.1   Insulation Labels

- Was insulation labeled (n=12)?

  – Yes (100%)

  – No (0%)

B.1.3.2   Ceilings

- Did the attic hatch/door exhibit the correct insulation value (n=8)?

    – Yes (100%)

    – No (0%)

B.1.3.3 Air Sealing[1]

- Thermal envelope sealed (n=64) (97%)

- Openings around windows and doors sealed (n=64) (100%)

- Utility penetrations sealed (n=95) (98%)

- Dropped ceilings sealed (n=39) (49%)

- Knee walls sealed (n=53) (55%)

- Garage walls and ceilings sealed (n=68) (100%)

- Envelope behind tubs and showers sealed (n=64) (39%)

- Common walls sealed (n=0) (0%)

- Attic access openings sealed (n=35) (54%)

- Rim joists sealed (n=30) (27%)

- Other sources of infiltration sealed (n=63) (97%)

- IC-rated light fixtures sealed (n=127) (100%)

B.1.4 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:

B.1.4.1 System Profile

- Duct Location in Conditioned Space (percentage):
  - *Supply* (n=131): 28% (37 homes with systems located entirely within conditioned space)
  - *Return* (n=131): 21% (27 homes with systems located entirely within conditioned space)
- Duct Insulation (R-value):
  - *Supply* (n=61): 7.93
  - *Return* (n=15): 6.8
- Air ducts sealed (n=114) (88%)
- Air handlers sealed (n=123) (98%)
- Filter boxes sealed (n=114) (94%)

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[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.

B.1.5   HVAC Equipment

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

B.1.5.1   Heating
- Fuel Source (n=127):
  - Gas (96%)
  - Electricity (4%)
- System Type (n=122):
  - Furnace (97%)
  - Heat Pump (3%)
- System Capacity (n=124):
  - Furnace: 69,639 Btu
  - Heat Pump: 38,800 Btu
- System Efficiency (n=124):
  - Furnace: 90 AFUE (many furnaces listed as 80 AFUE)
  - Heat Pump: 8.3 HSPF

B.1.5.2   Cooling
- System Type (n=110):
  - Central AC (96%)
  - Heat Pump (4%)
- System Capacity (n=110):
  - 33,350 (Btu/hr)
- System Efficiency (n=64):
  - 13.1 SEER (observations ranged from 13 to 14.5 SEER)

B.1.5.3   Water Heating
- Fuel Source (n=127):
  - Gas (92%)
  - Electric (8%)
- System Type (n=126):
  - Storage (98%)
  - Tankless (2%)
- System Capacity (n=63):
  - 52 gallons (observations ranged from 50 to 100 gallons)

Table B.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%	98%	0%	0%	0%	2%

- System Efficiency (n=63):
    - EF 0.65 (range from EF 0.62 to EF 0.92)

B.1.5.4   Ventilation

- System Type (n=127):
    - Exhaust Only (55%)
    - AHU Integrated (45%)
- Exhaust Fan Type (n=70):
    - Dedicated Exhaust (4%)
    - Bathroom Fan (96%)

B.1.5.5   Other

- Mechanical manuals provided (n=54) (100%)

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