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Virginia Residential Energy Code Field Study: Baseline Report

October 2019

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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 Commonwealth of Virginia 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 August 2017 and continued through May 2018. During this period, research teams visited 138 homes during various stages of construction, resulting in a substantial 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 indicates over $2.9 million in potential annual savings to Virginia homeowners that could result from increased code compliance.

Methodology

The project team was led by the Southeast Energy Efficiency Alliance (SEEA). 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 in turn drive the analysis and savings estimates. The project team implemented a customized sampling plan representative of new construction within the state, which was originally developed by Pacific Northwest National Laboratory (PNNL), and then vetted through public meetings with key stakeholders in the state.

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 what was observed in the field for each key item. The second 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.

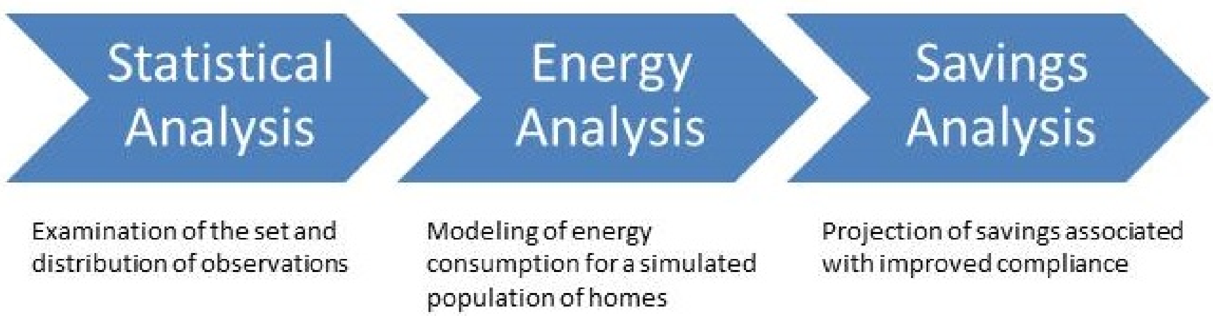

Figure ES.1. Stages of Analysis Applied in the Study

Results

The key items with the greatest potential for savings in Virginia 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 should be considered a focal point for compliance-improvement programs within the state, including energy code educational, training and outreach initiatives.

Table ES.1. Estimated Annual Statewide Savings Potential

Measure	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Total State Emissions Reduction (MT CO2e)
Duct Leakage	6,4168	1,244,243	31,520
Envelope Air Leakage	30,343	474,867	7,117
Lighting	8,808	399,441	20,017
Exterior Wall Insulation	20,984	362,571	7,267
Ceiling Insulation	19,163	351,530	8,038
Foundation Insulation	6,035	56,409	-1,195
Window SHGC	130	31,505	2,053
Window U-Factor	1,122	16,276	175
TOTAL	**150,752 MMBtu**	**$2,936,843**	**74,992 MT CO2e**

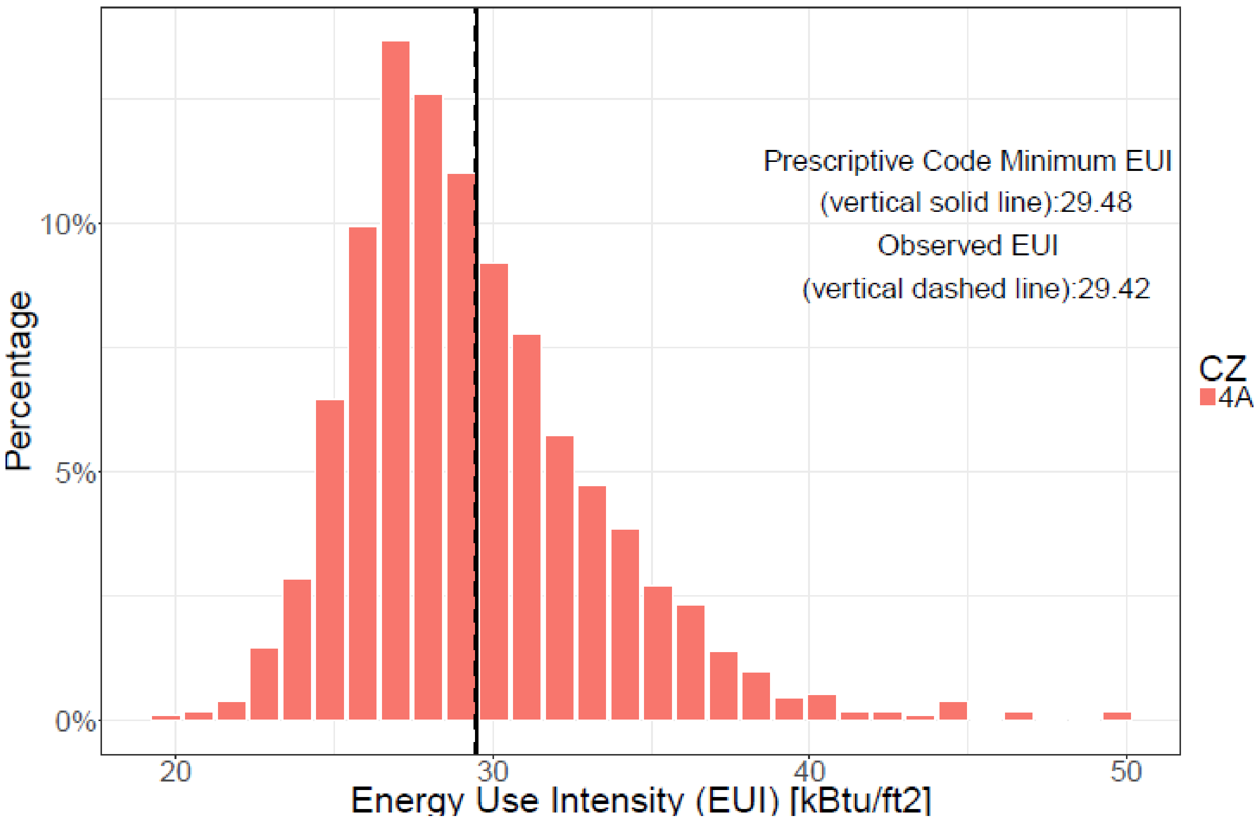

Figure ES.2. Modeled Distribution of Regulated EUI (kBtu/ft^2/year)

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 29.42 kBtu/ft^2-yr statewide compared to 29.48 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 0.2% better than code. Note that it is difficult to see both the vertical solid line and the vertical dashed line in Figures ES.2 as the values are nearly identical.

Acknowledgments

The following members comprised the Virginia project team:

- Lauren Westmoreland, *Southeast Energy Efficiency Alliance (SEEA)*
- Sareena Nagpal, *SEEA*
- KC Bleile, *Viridiant*
- Sean Evensen-Shanley, *Viridiant*
- Nathaniel Bauman, *Viridiant*
- Bill Riggs, *Viridiant*
- Austin Walther, *Viridiant*
- Chris Conway, *Conway Energy*
- Dan Guinn, *GCI Energy Consultants*
- John Semmelhack, *Think Little*
- Jeff Sadler, *Ecovative Energy*
- Leo Watkins, *Wheat Energy*

Southeast Energy Efficiency Alliance (SEEA)

The Southeast Energy Efficiency Alliance (SEEA) is one of six regional energy efficiency organizations in the United States working to transform the energy efficiency marketplace through collaborative public policy, thought leadership, outreach programs, and technical advisory services. SEEA promotes energy efficiency as a catalyst for economic growth, workforce development and energy security across eleven southeastern states. These states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia. For additional information, visit http://www.seealliance.org.

Viridiant

Viridiant, formerly EarthCraft Virginia, is a 501(c)(3) nonprofit, providing education, consultation, and certification to advance economic, environmental, and economic sustainability throughout the construction industry. Founded in 2006, the organization relies on successful partnerships with the Home Builders Association of Virginia, Virginia Housing Development Authority, Virginia Department of Housing and Community Development, Habitat for Humanity of Virginia, and Southface to educate thousands of professionals and homeowners on the EarthCraft family of programs and building science best practices. For additional information, visit http://www.viridiant.org/.

Acronyms and Abbreviations

ACH	air changes per hour
AHU	air handling unit
Btu	British thermal unit
cfm	cubic feet per minute
CFA	conditioned floor area
CZ	climate zone
DHCD	Virginia Department of Housing and Community Development
DMME	Virginia Department of Mines, Minerals, and Energy
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
ERV	Energy Recovery Ventilator
EUI	energy use intensity
FOA	funding opportunity announcement
HBAV	Home Builders Association of Virginia
ICC	International Code Council
IECC	International Energy Conservation Code
kBtu	thousand British thermal units
MMBtu	million British thermal units
NA	not applicable
PNNL	Pacific Northwest National Laboratory
RESNET	Residential Energy Services Network
RFI	request for information
SEEA	Southeast Energy Efficiency Alliance
SHGC	solar heat gain coefficient
VA	Virginia
VAEEC	Virginia Energy Efficiency Council

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1.0 Introduction

A research project in the Commonwealth of Virginia investigated the energy code-related aspects of unoccupied, newly constructed, single family homes across the state. The study followed a DOE-prescribed methodology, which allowed the project team to build an empirical data set 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. Study findings can help to justify additional support for energy code education, training & outreach activities, as well as catalyze future investments in compliance improvement programs.

The Virginia field study was initiated in August 2017 and continued through May 2018. During this period, research teams visited 138 homes across the state during various stages of construction. At the time of the study, the state had the 2012 Virginia Energy Conservation Code[1], an amended version of the 2012 International Energy Conservation Code (IECC). 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's (DOE) field study, "Strategies to Increase Residential Energy Code Compliance Rates and Measure Results".[2] 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. [3,4] 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.[5]

1.2 Project Team

The Virginia project was led by the Southeast Energy Efficiency Alliance (SEEA), with field data collected by Viridiant. The Pacific Northwest National Laboratory (PNNL) defined the methodology, conducted data analysis, and provided technical assistance to the project team. Funding and overall program direction was provided by the DOE Building Energy Codes Program as part of a broader initiative being conducted across several U.S. states. More information on the organizations comprising the project team is included in the Acknowledgements section of this report.

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[1] Available for free viewing at http://codes.iccsafe.org/content/VECC2012. Although the 2012 code was in place at the time data was collected, the team chose to use the upcoming 2015 code as the baseline for comparison.
2 Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study.
[3] *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.
[4] Available at http://www.energycodes.gov/adoption/states.
[5] 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. 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
- Subcontractors
- Material supply distributors
- Government agencies
- Energy efficiency advocates
- Utilities
- Other important entities identified by the project team

A description of the stakeholders who participated in the project to date is included in Appendix A.

Members of these and other groups are critical to the success of the project, as they 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 were also identified as a crucial stakeholder, 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 Virginia 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 help to 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 (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 Virginia study, including sampling, data collection, and resulting data analysis. More information on the DOE data

[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 are combined into a single category of foundation insulation.

collection and analysis methodologies 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 Virginia 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, known as a proportional random sample, was 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 state).

An initial sample plan was first developed by PNNL, and then vetted by stakeholders within the state. Special considerations were discussed with stakeholders, such as state-specific construction practices or systematic differences across county boundaries. These considerations were taken into account and incorporated into the final statewide sample plan shown in Appendix B.

2.2.2 Data Collection

Following confirmation of the statewide 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 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 2015 Virginia Energy Conservation Code. The final Virginia data collection form is available in spreadsheet format on the DOE Building Energy Codes Program website.[5] The form included all energy code requirements (i.e., not just the 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[6] protocols.

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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://www.energycodes.gov/compliance/residential-energy-code-field-study and based on the forms typically used by the RES*check* compliance software.
[6] See http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf.

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 and was therefore used to modify that key item during the energy modeling and savings calculation. 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.[7]

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 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-

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

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

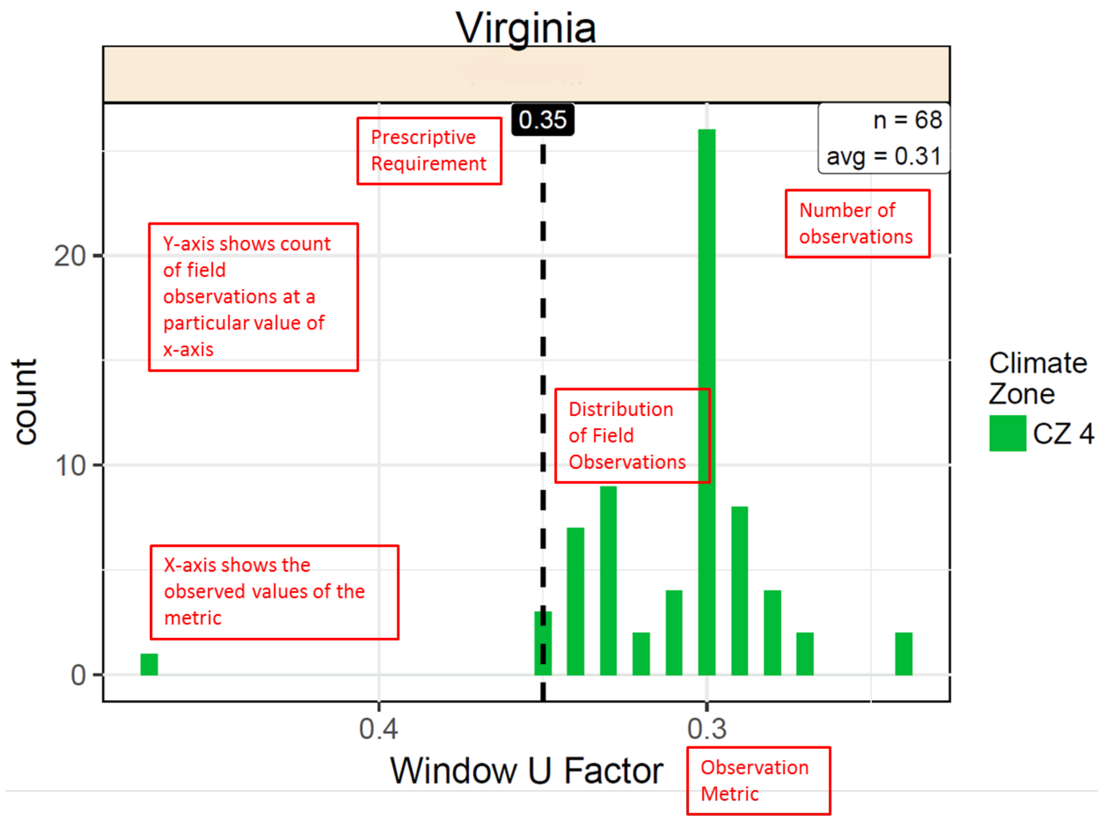

Figure 2.1. Sample Graph

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—values to the right-hand side of this line are *better than code*. Values to the left-hand side represent areas for improvement.

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.

Energy simulation was then conducted using the EnergyPlus™ software.[8] 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 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 a supplemental methodology report (DOE 2018).[9]

2.3.3 Savings Analysis

To begin the third phase, each of the key items was examined individually to determine which had any positive 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). 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 are used to calculate the maximum 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.

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

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

[10] Virginia was the first state evaluated where any observation that did not meet the associated code requirement was used to trigger calculation of measure level savings. In previous studies for other states, the number of observations that did not meet the associated code requirement had to be at least 15% to trigger the calculation of measure level savings.

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 were identified as of interest, such as analysis based on climate zone level, or reporting of non-key items. 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 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™ 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. Virginia is comprised of a single climate zone; zone 4 (CZ4). A discussion of other findings is also covered in the section, including of how certain observations, such as insulation installation quality, are used to modify key item results. (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. Duct tightness (expressed in cfm per 100 ft^2 of conditioned floor area at 25 Pascals)

Nearly 50 percent of the predominant foundation observations were heated basements. There were also 30 floor (over vented crawlspace or unheated basement), 12 unvented crawl space, and 28 slab observations.

3.1.1.1 Envelope Tightness

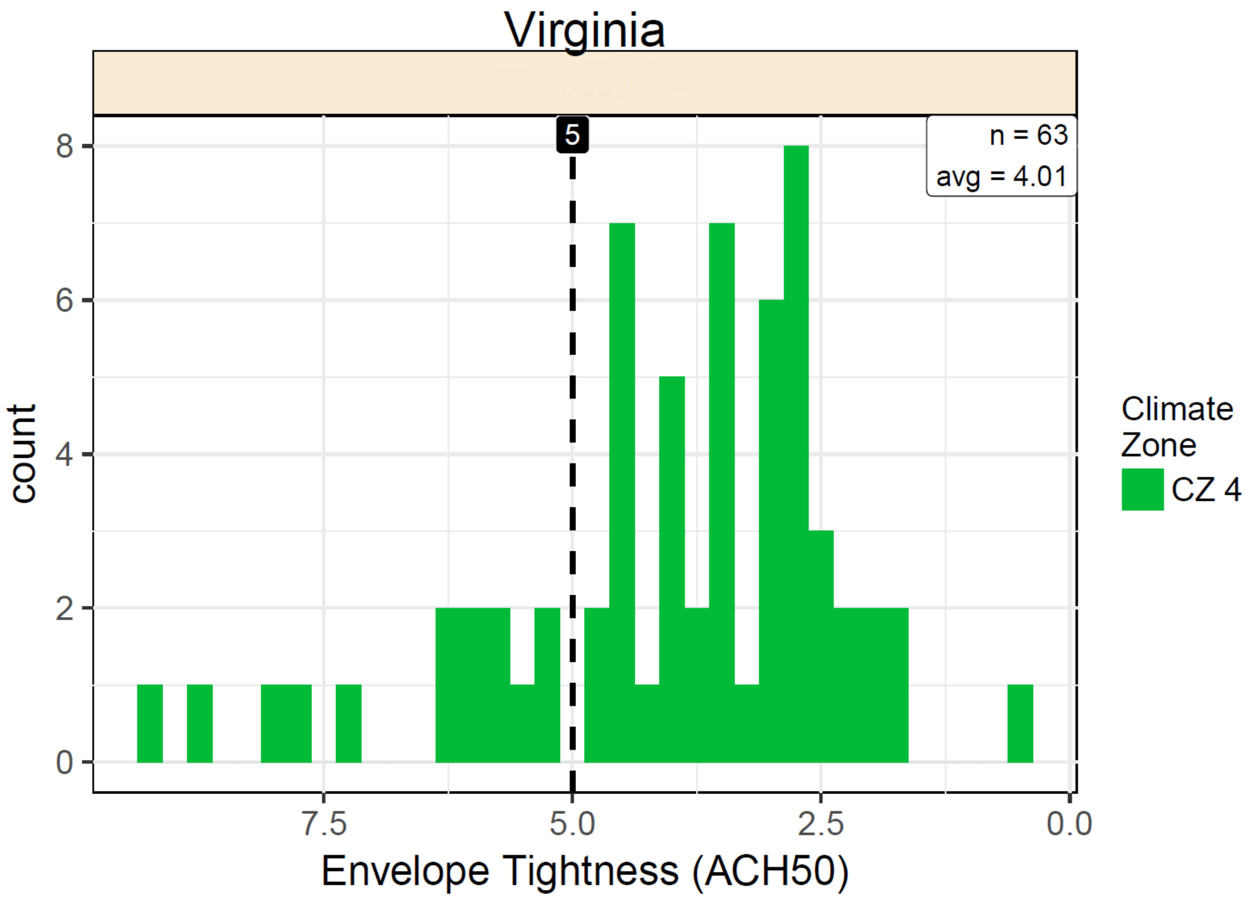

Figure 3.1. Envelope Tightness (ACH50)

Table 3.1. Envelope Tightness (ACH50)

Climate Zone	**CZ4**
Number	63
Range	0.45 to 9.3
Average	4.0
Requirement	5
Compliance Rate	49 of 63 (78%)

- **Interpretations:**

The majority of observations met the requirement. One home was extremely tight at 0.45 ACH50.

Reductions in envelope air leakage represent an opportunity for improvement in the state through future education, training and other compliance-support programs.

3.1.1.2 Window SHGC

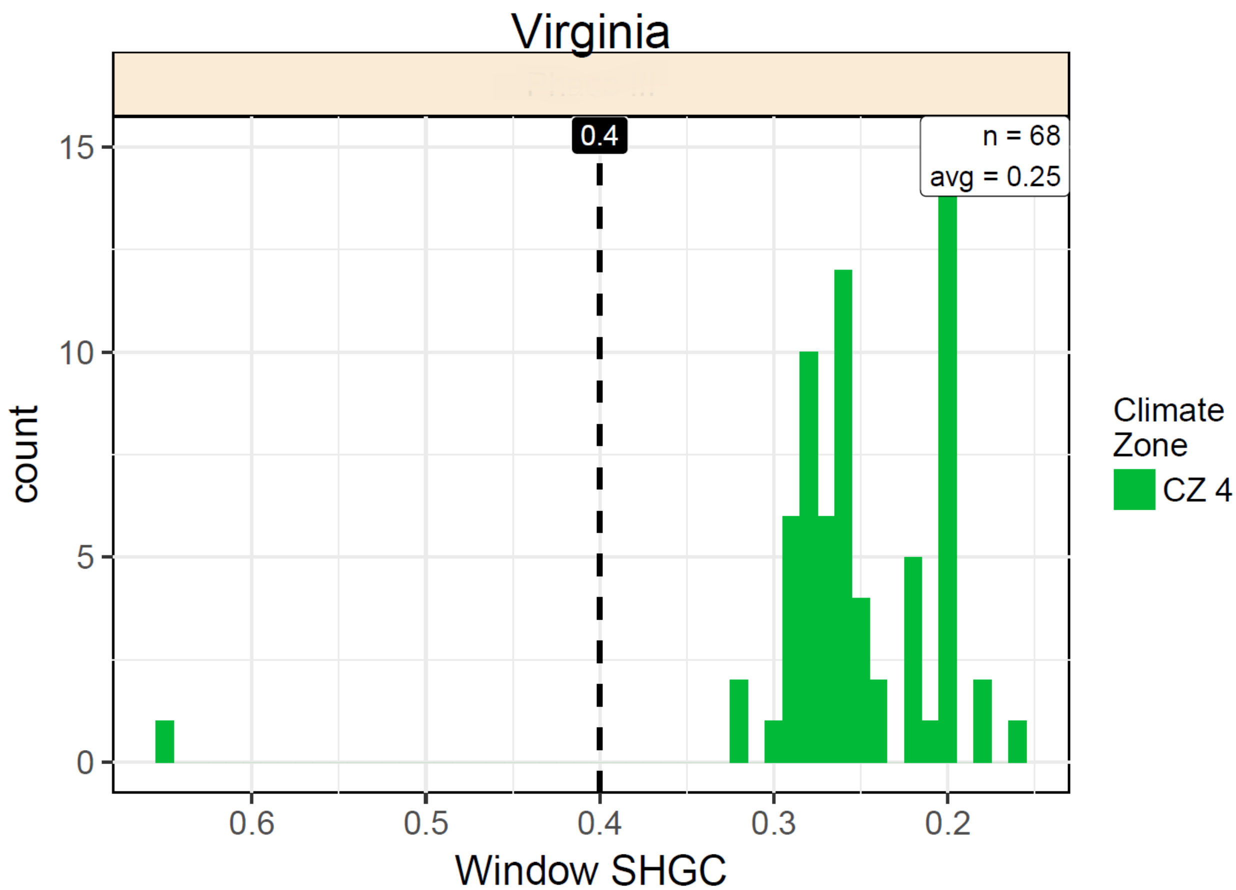

Figure 3.2. Window SHGC

Table 3.2. Window SHGC

Climate Zone	CZ4
Number	68
Range	0.65 to 0.16
Average	0.25
Requirement	0.40
Compliance Rate	67 of 68 (99%)

- **Interpretations:**

All but one observation significantly exceed the prescriptive requirement.

3.1.1.3 Window U-Factor

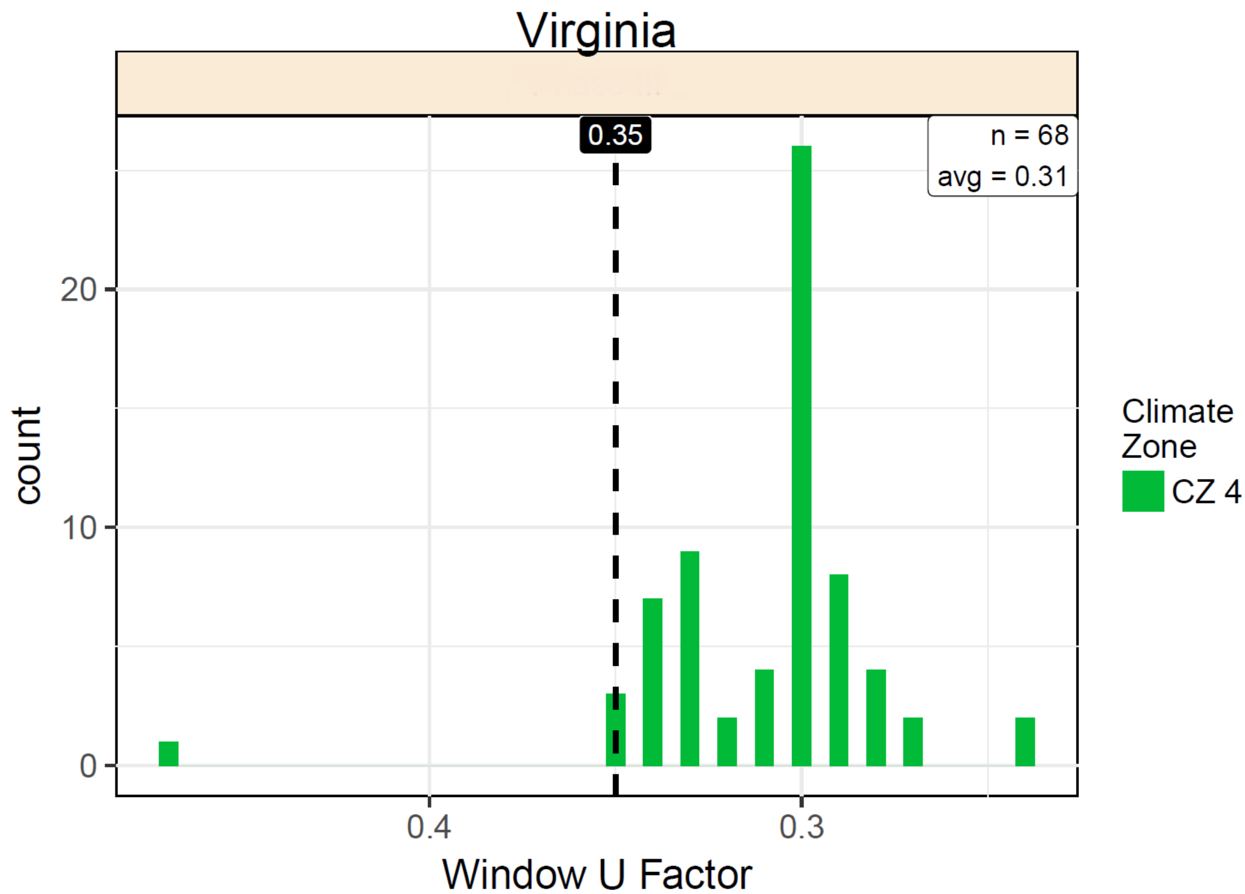

Figure 3.3. Window U-Factor

Table 3.3. Window U-Factor

Climate Zone	CZ4	Statewide
Number	68	68
Range	0.47 to 0.24	0.47 to 0.24
Average	0.31	0.31
Requirement	0.35	0.35
Compliance Rate	67 of 68 (99%)	67 of 68 (99%)

- **Interpretations:**

Window U-factor requirements appear to have been implemented with a high rate of success across the state, with only a single observation not meeting the prescriptive requirement.

3.1.1.4 Wall Insulation

Wall insulation data is presented in terms of both frame cavity insulation and overall assembly performance in order to capture the conditions seen in the field. The cavity insulation data is based on the observed value (R-value), as printed on the manufacturer label and installed in the home. While cavity insulation is important, it is not fully representative of wall assembly performance, since this data point alone does not account for other factors that can have a significant effect on the wall system (e.g., combinations of cavity and continuous insulation). Therefore, wall insulation is also presented from a second perspective—overall assembly performance (U-factor).

Figure 3.4 represents the distribution of observed values for wall cavity insulation.

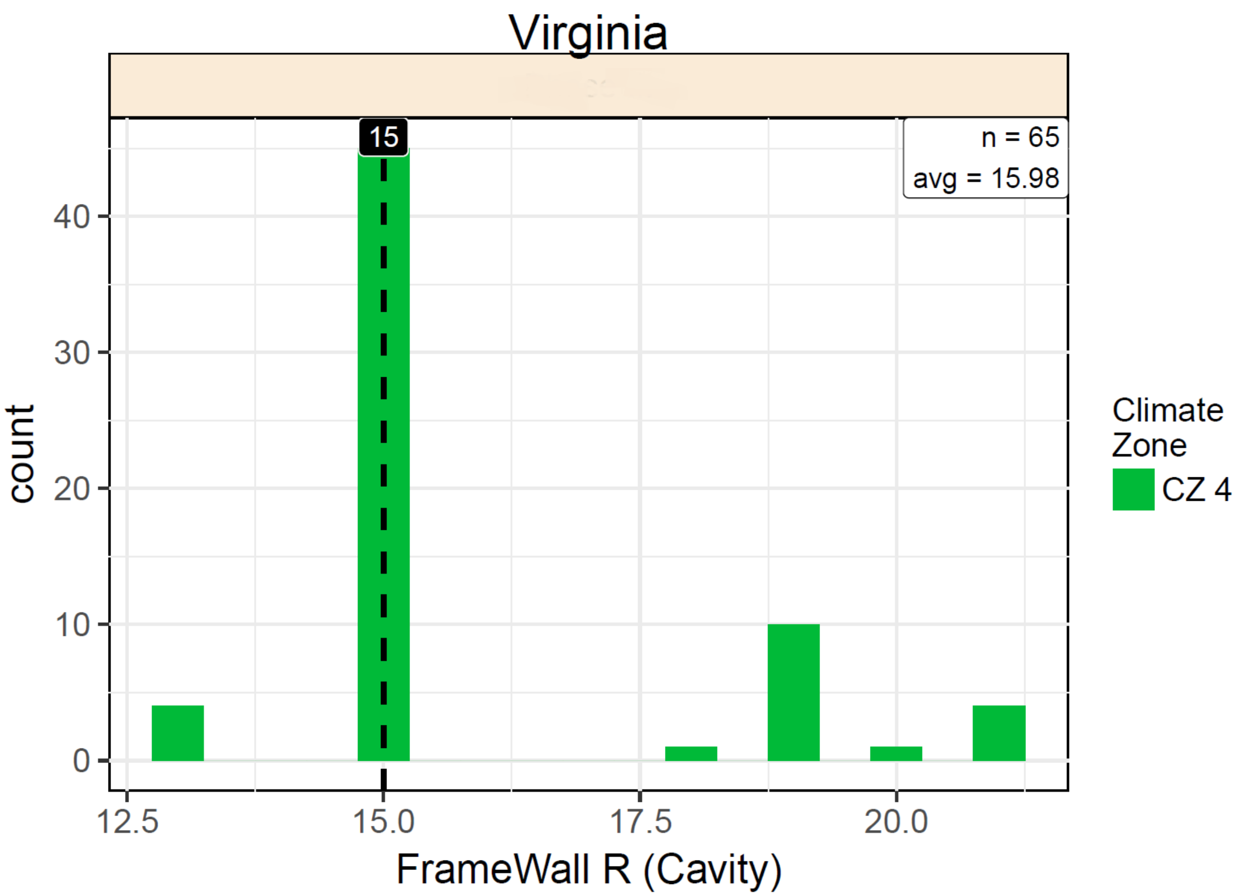

Figure 3.4. Frame Wall R-Value (Cavity)

Figure 3.5 represents overall wall assembly performance (U-factor). The U-factor perspective takes into account combined insulation values (any cavity and/or continuous insulation that was installed in the home), as well as framing, and insulation installation quality, as observed in the field. This approach illustrates the additional savings possible through proper installation. In the graph, observations are binned for clearer presentation based on the most commonly observed combinations.

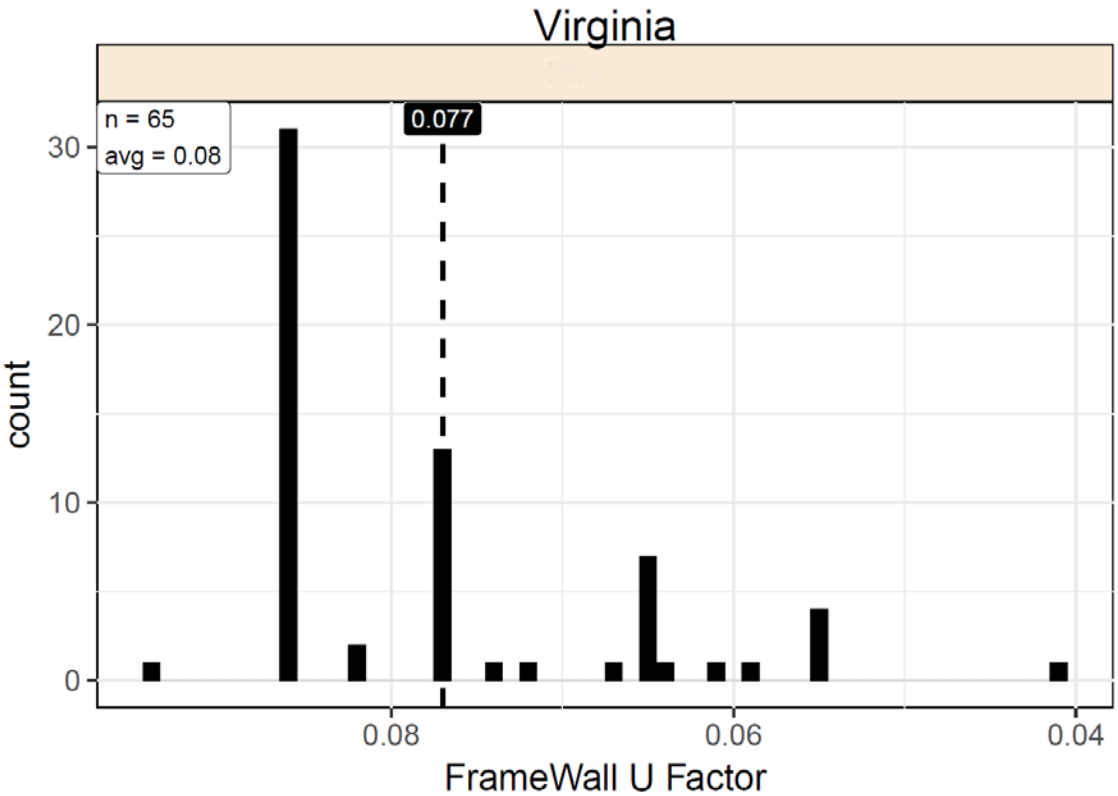

Figure 3.5. Wall Assembly Performance, including Wall Insulation Installation Quality

Figure 3.5 combines all cavity R-value and wall insulation installation quality data observed in each climate zone to generate "effective U-factor" charts. The overall U-factor, as shown, is negatively affected due to the observed insulation installation quality. A more detailed discussion of insulation installation quality is included at the end of the section (3.1.1.9).

Table 3.4. Frame Wall Assembly

Climate Zone	CZ4
Number	65
Range	0.094 to 0.041
Average	0.078
Assembly U-Factor (expected)	0.077
Rate	15 of 65 (23%)

- **Interpretations:**

Cavity insulation is achieved at a high rate—nearly all observed instances meet or exceed the prescriptive requirement for wall cavity insulation (based on labeled R-value).

From an assembly perspective, about one-third of observations had Grade I insulation installation quality—with the rest rated as Grades II or III (Table 3.14).

While cavity insulation appears to be achieved successfully (R-value), the overall assembly performance (U-factor) represents an opportunity for improvement in the state through future education, training and other compliance-support programs.

3.1.1.5 Ceiling R-Value

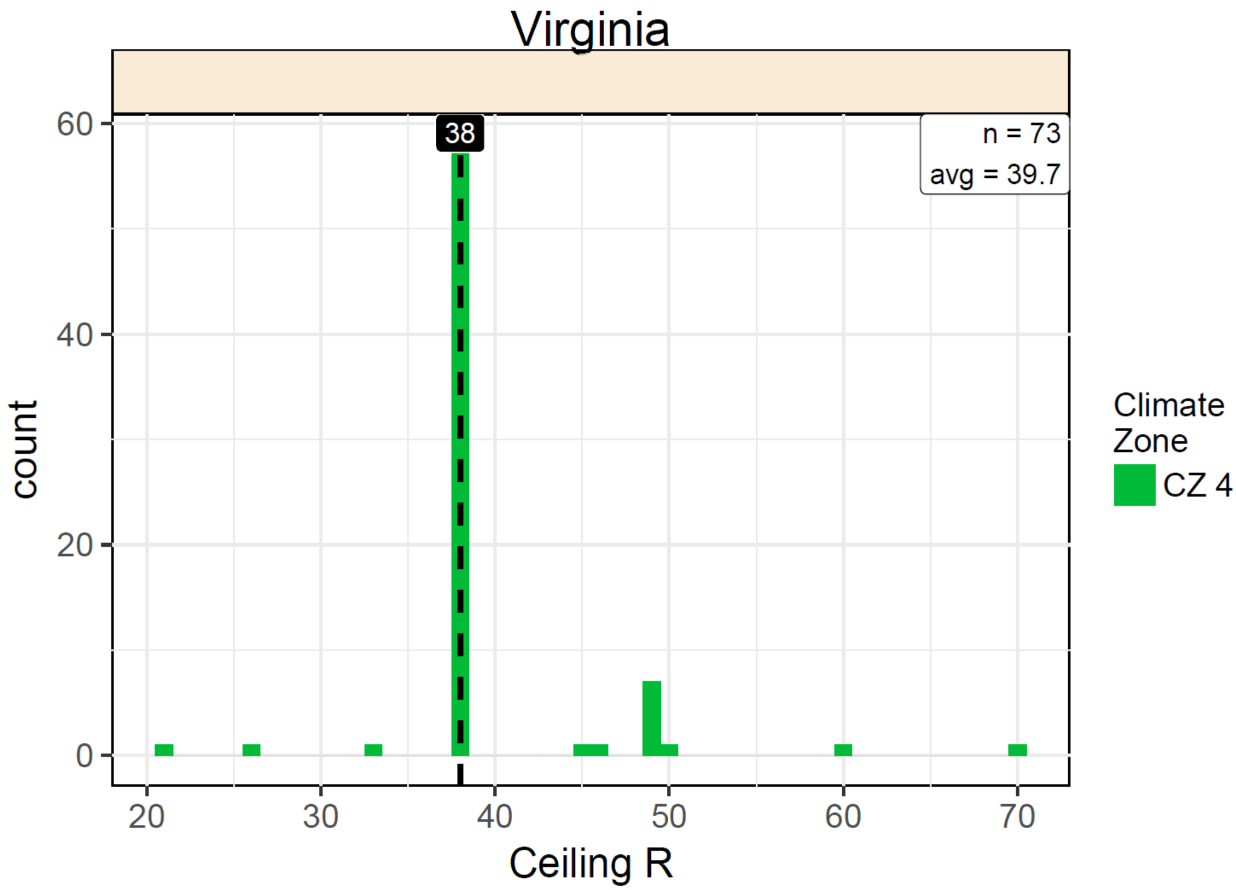

Figure 3.6. Ceiling R-Value

Table 3.5. Ceiling R-Value

Climate Zone	CZ4
Number	73
Range	21 to 70.3
Average	39.7
Requirement	38
Compliance Rate	70 of 73 (96%)

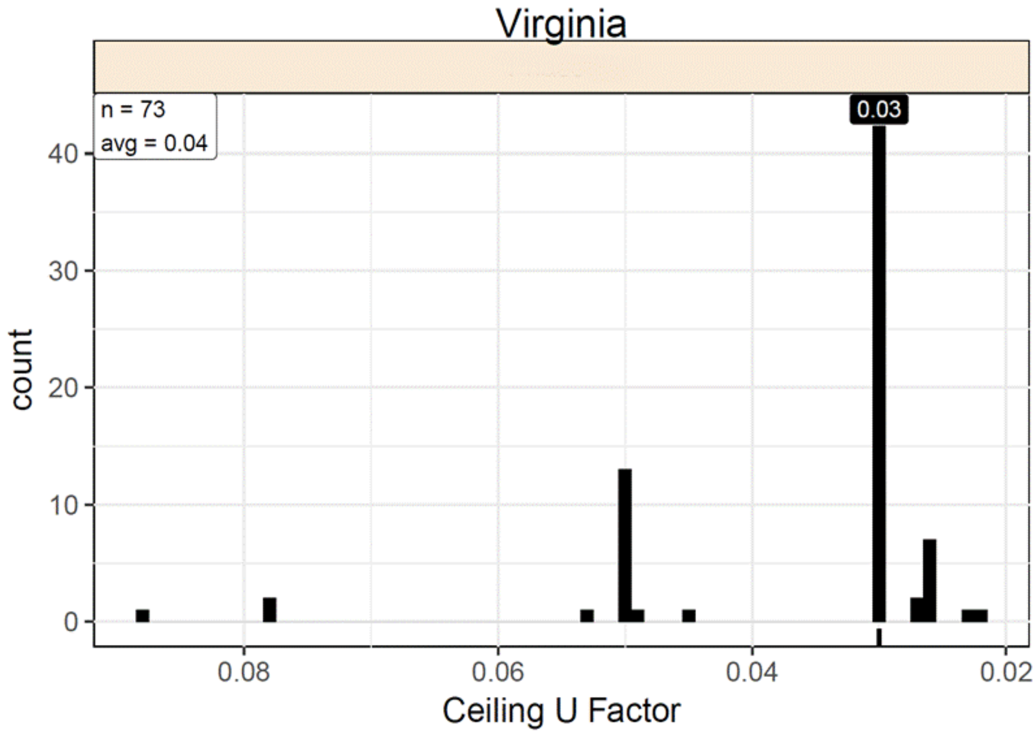

Figure 3.7. Ceiling U-Factor

Table 3.6. Ceiling U-Factor

Climate Zone	**CZ4**
Number	73
Range	0.088 to 0.022
Average	0.036
Requirement	0.030
Compliance Rate	54 of 73 (74%)

- **Interpretations:**

All but three observations meet or exceed the R-value requirement.

Nearly three quarters of the U-factor observations meet or exceed the prescriptive requirement.

In terms of insulation installation quality, 55 of 73 (75%) observations were rated Grade I.

While cavity insulation appears to be achieved successfully (R-value), the overall assembly performance (U-factor) represents an opportunity for improvement in the state through future education, training and other compliance-support programs.

3.1.1.6 Lighting

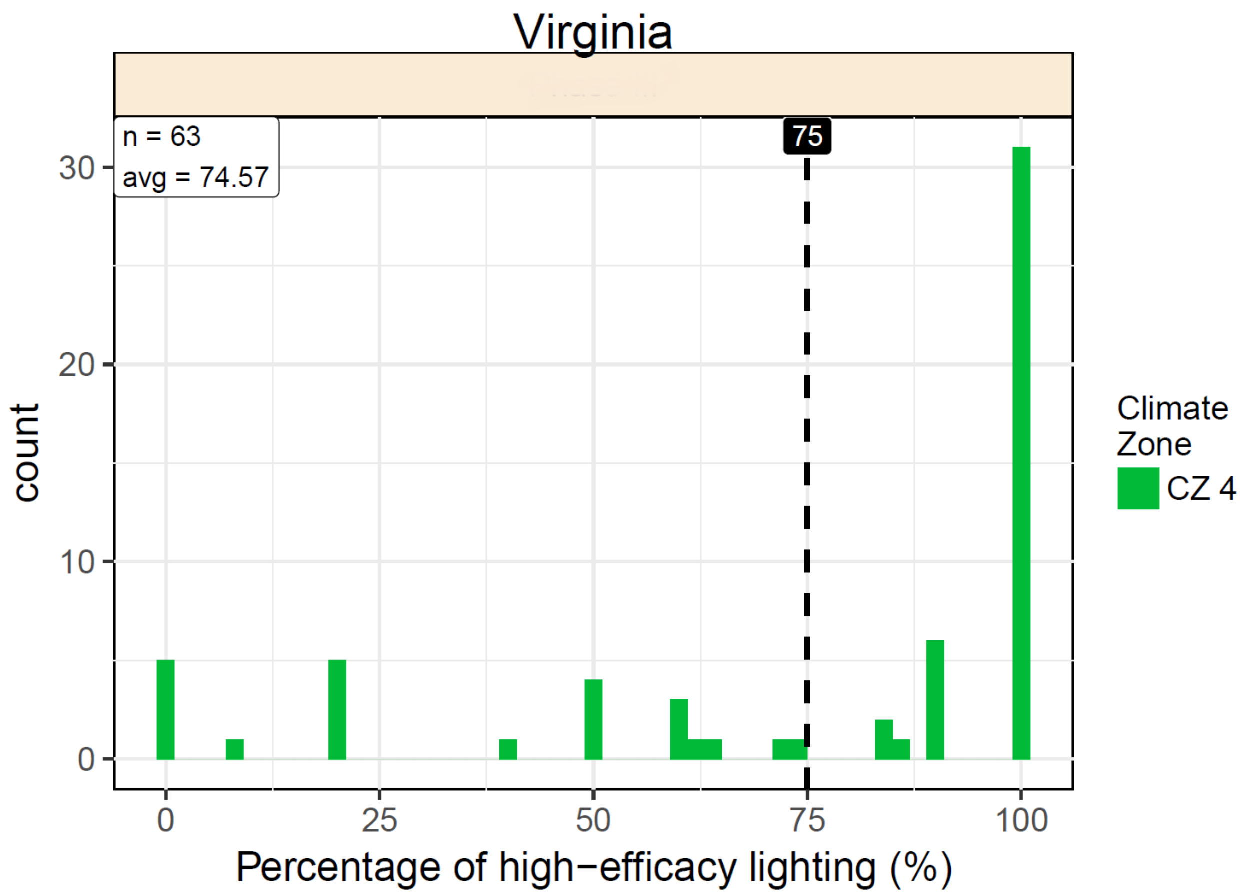

Figure 3.8. High-Efficacy Lighting Percentage

Table 3.7. High-Efficacy Lighting Percentage

Climate Zone	CZ4
Number	63
Range	0 to 100
Average	74.6
Requirement	75
Compliance Rate	41 of 63 (65%)

- **Interpretations:**

Nearly two-thirds of the field observations meet the prescriptive requirement. The most common observations are in the 75-100 range, but there are a significant quantity and wide range of non-compliant observations.

High-efficacy lighting represents an opportunity for improvement in the state through future education, training and other compliance-support programs..

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.

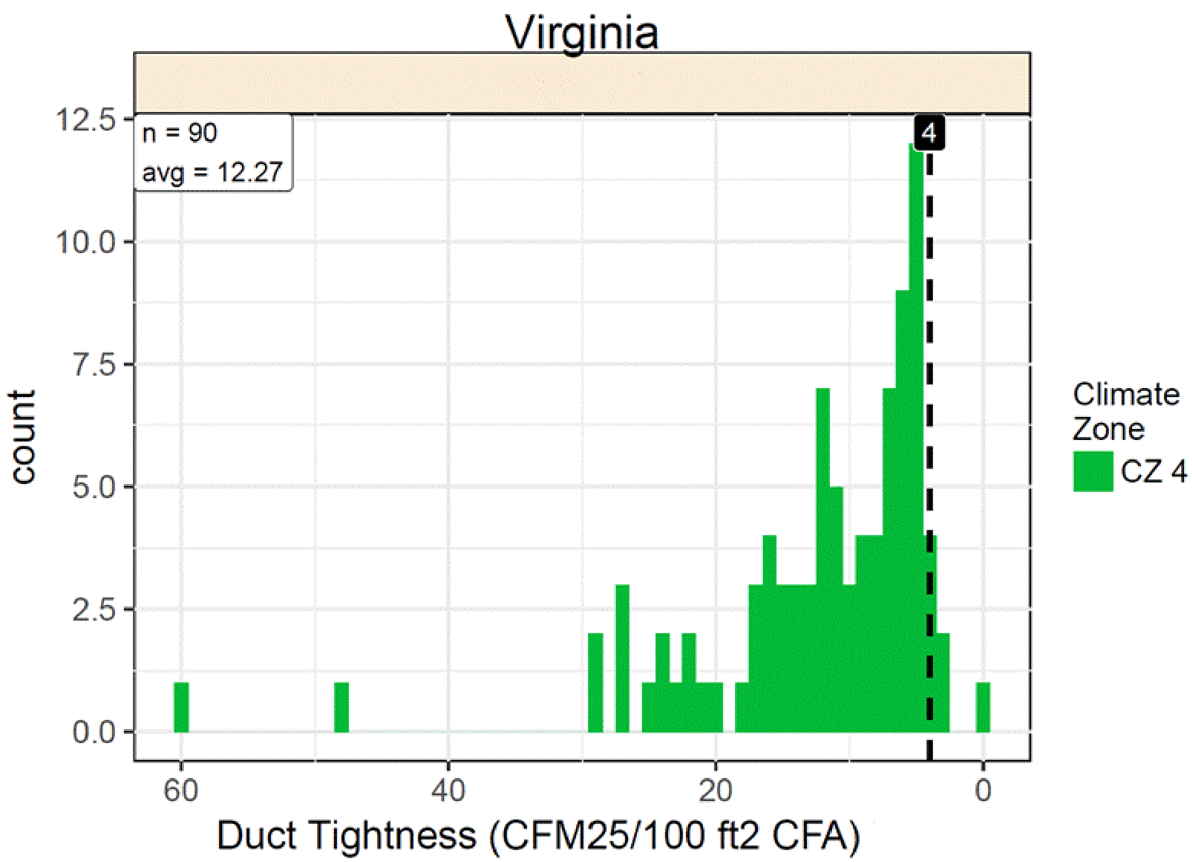

Figure 3.9. Duct Tightness (Raw) (CFM25/100ft2 CFA)

Table 3.8. Duct Tightness (Raw)

Climate Zone	CZ4
Number	90
Range	60.2 to 0.5
Average	12.3
Requirement	4
Compliance Rate	6 of 63 (7%)

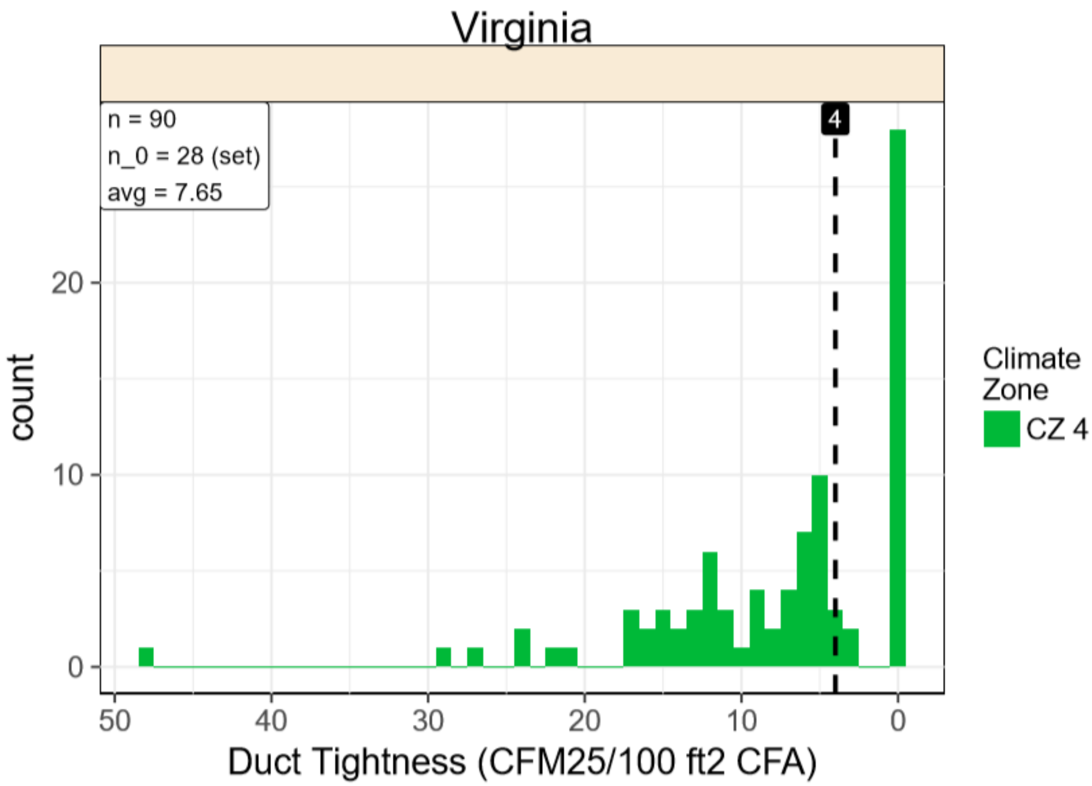

Figure 3.10. Duct Tightness (Adjusted) (CFM25/100ft2 CFA)

Table 3.9. Duct Tightness (Adjusted)

Climate Zone	CZ4
Number	90
Range	48 to 0.0
Average	7.7
Requirement	4
Compliance Rate	33 of 63 (37%)

- **Interpretations:**

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

Based on adjusted duct leakage (accounting for ducts entirely in conditioned space), only one-third met the prescriptive requirement. There were 28 homes with ducts entirely in conditioned space.

Reductions in duct leakage represent an opportunity for improvement in the state through future education, training and other compliance-support programs.

Note: The 28 duct leakage observations were set to 0 in the Duct Tightness (Adjusted) graph because both the supply and return ducts were completely in conditioned space.

3.1.1.8 Foundations

All four foundation types were observed in Virginia, basements, crawlspaces, slabs and floors. However, basements were the predominant foundation type observed. Basement walls include those observations where wall insulation is installed in a conditioned basement. Floors include those observations where floor insulation is installed, such as over vented crawlspaces and unconditioned basements.

Two types of graphs are shown – R-value and U-factor. The R-value graph shows the insulation R-values observed. The U-factor graph indicates the U-factor of the assembly, including cavity insulation, continuous insulation, and framing, with consideration of insulation installation quality, as observed in the field. A summary table is also provided for the U-factor results (or R-value results in the case of slabs-on-grade.)

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 applicable 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.

Basements

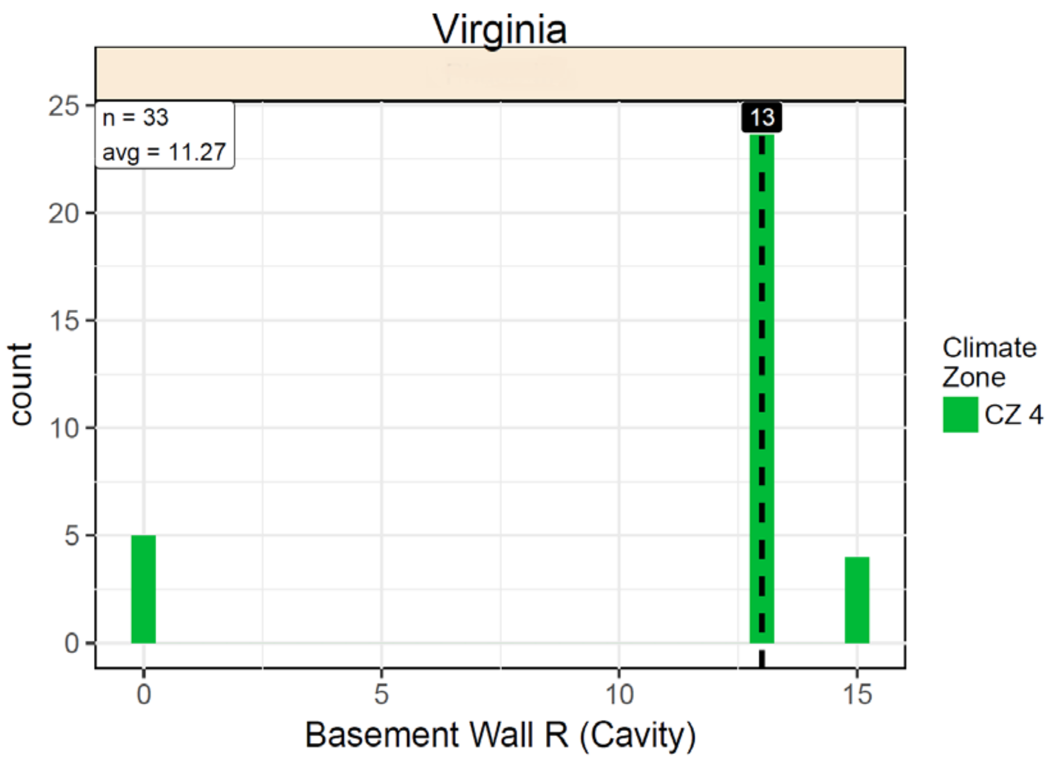

Figure 3.11. Basement Wall Cavity R-Values

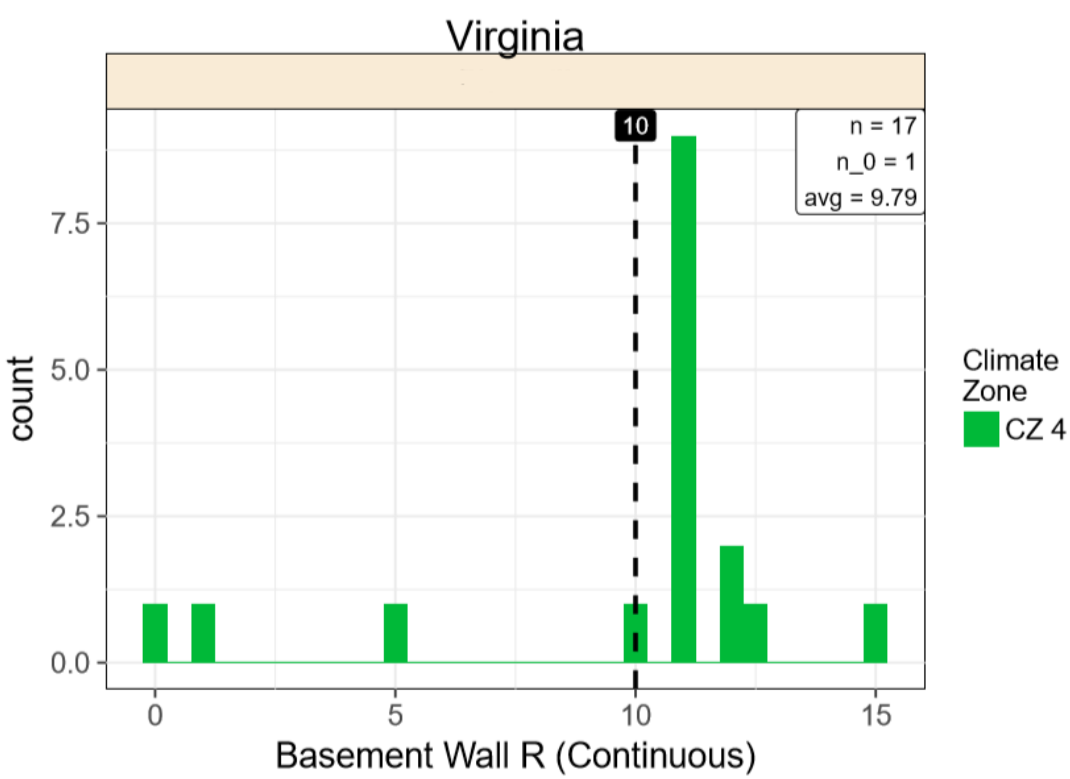

Figure 3.12. Basement Wall Continuous R-Values

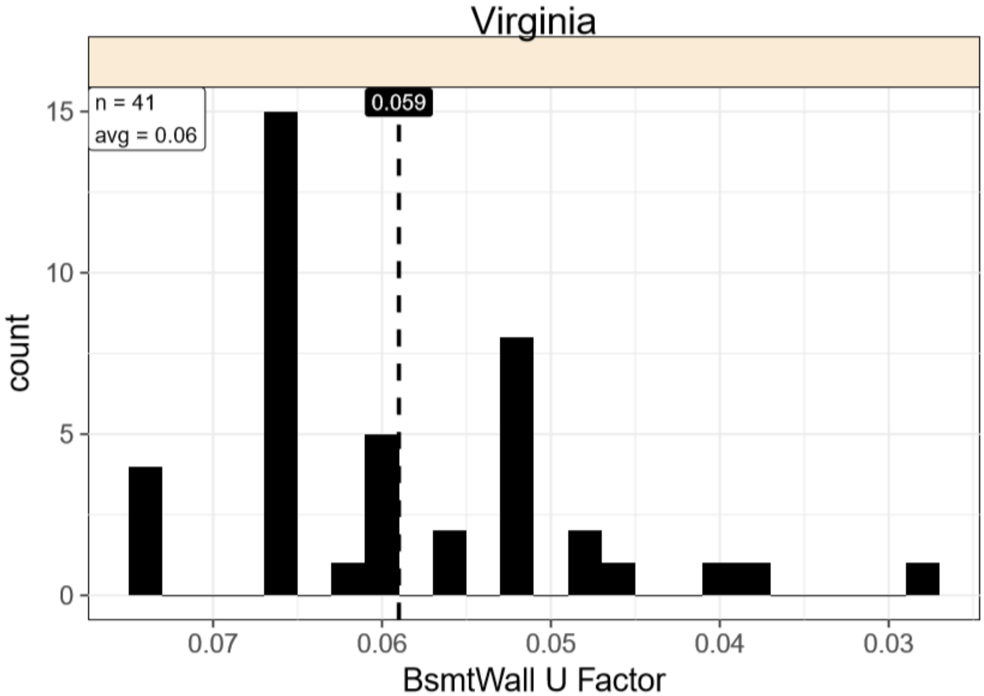

Figure 3.13. Basement Wall U-Factors

Table 3.10. Basement Wall U-Factor

Climate Zone	CZ4
Number	42
Range	0.317 to 0.029
Average	0.065
Requirement	0.059
Compliance Rate	21 of 42 (50%)

- **Interpretations:**

Most basement wall insulation R-value observations meet or exceed the prescriptive requirements. However, the compliance rate for basement wall insulation U-factor is 50%. Examination of the IIQ results indicates that only one-third of the basement wall insulation cavity insulation R-values are Grade I, indicating that IIQ is the issue that is likely driving many of the U-factor observations not meeting the prescriptive requirement.

Basement wall insulation and its insulation installation quality represent opportunities for improvement through future education, training and other compliance-support programs.

Notes: 1) raw data observations for both cavity and continuous insulation R-values contain R-0 values indicating no insulation as shown in the graphics and 2) there were 42 basement wall observations, but one observation of R-0 cavity / R-0 continuous was removed from the graphic so the scale of the x-axis was legible.

Slabs

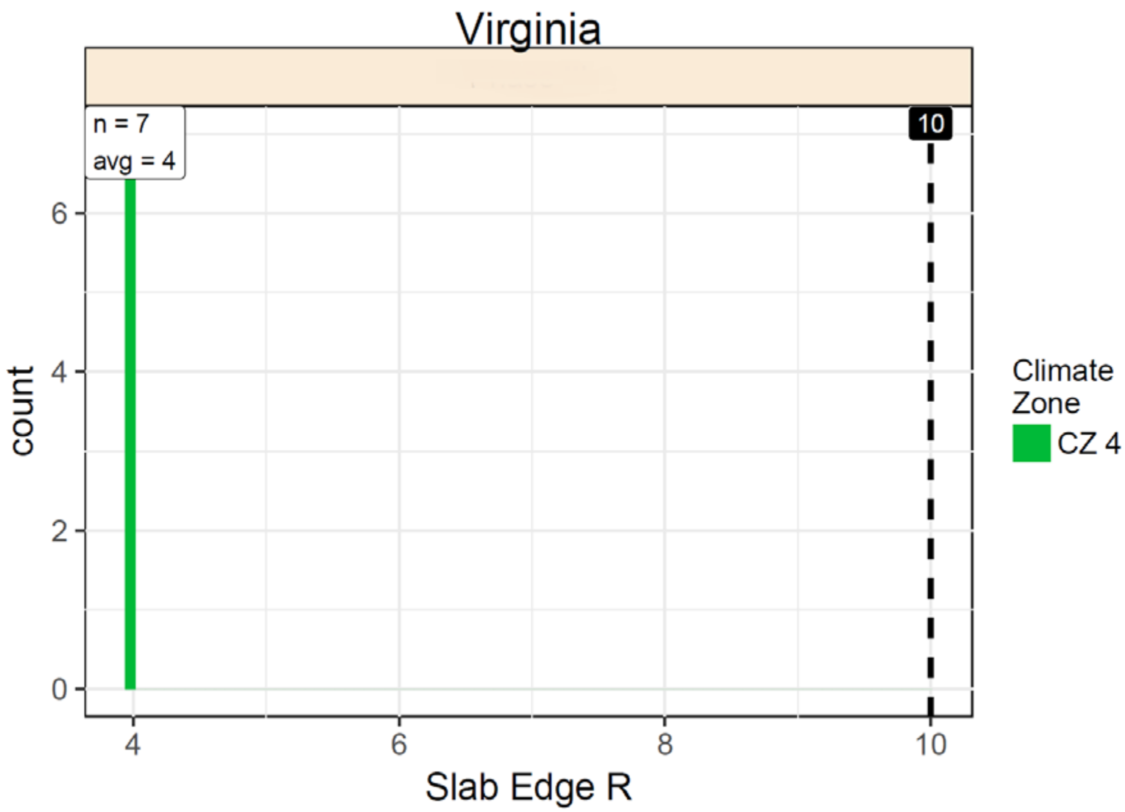

Figure 3.14. Slabs

Table 3.11. Slabs

Climate Zone	**CZ4**
Number	7
Range	R-4 to R-4
Average	R-4
Requirement	R-10
Compliance Rate	0 of 10 (0%)

- **Interpretations:**

All observations of slab edge insulation are R-4, which is significantly below the R-10 requirement.

Although the number of observations is low, slab edge insulation does represent an area for improvement and should be given increased attention in future training and enforcement.

Floors

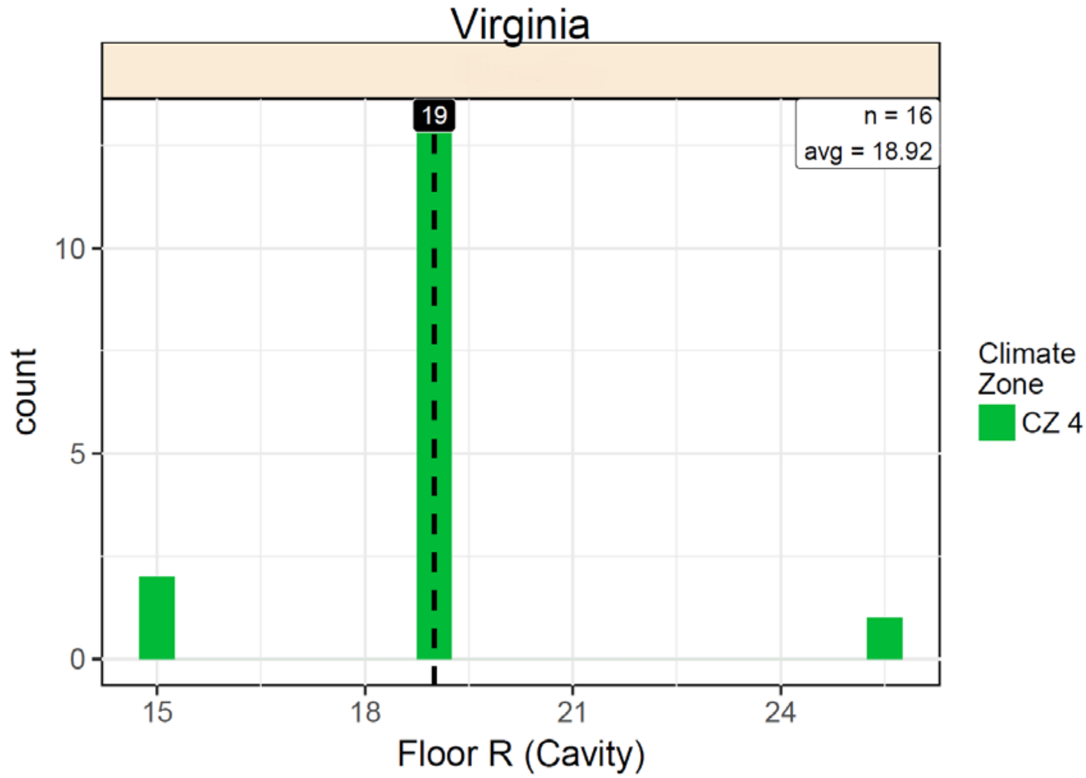

Figure 3.15. Floor Cavity R-Values

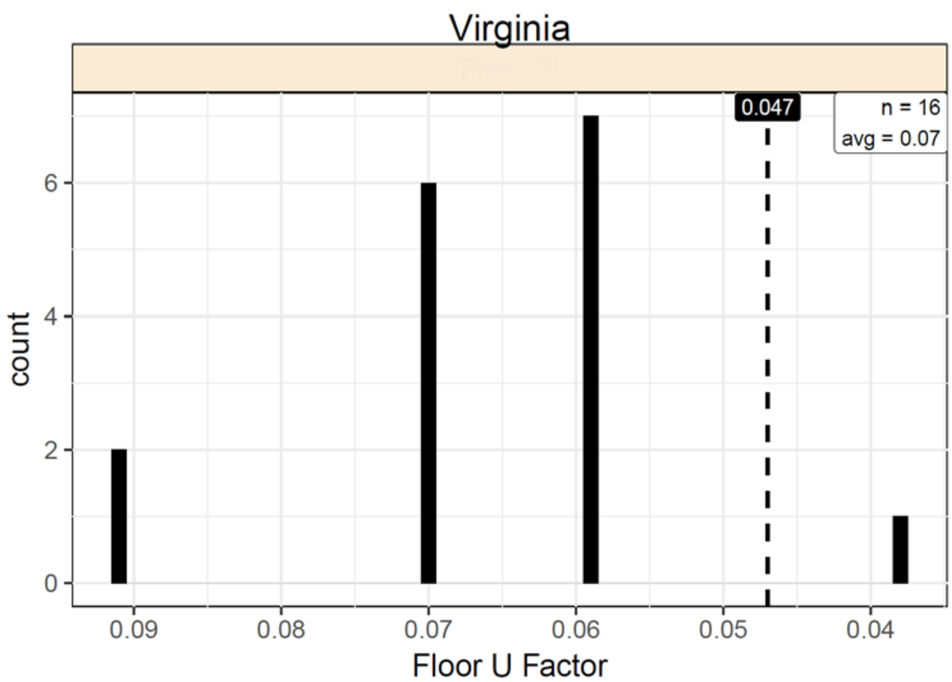

Figure 3.16. Floor U-Factors

Table 3.12. Floor U-Factors

Climate Zone	CZ4
Number	16
Range	0.091 to 0.038
Average	0.066
Requirement	0.047
Compliance Rate	1 of 16 (6%)

- **Interpretations:**

When considering floor R-values, most observations meet the prescriptive requirement, however, when considering floor U-factors, compliance is 6%. The implication is that IIQ for floors is a problem, and this is confirmed by Table 3.14, where only 6% of the observations are Grade I.

Note that fact that the floor cavity R-value graph shows 3 distinct bars, while the floor U-factor graph shows 4 distinct bars. This is because most of the floor IIQ observations are Grade II or Grade III, which divides the R-19 results into two distinct U-factors, both of which fail.

Although the number of observations is low, floor insulation represents an opportunity for improvement in the state through future education, training and other compliance-support programs.

Crawlspaces

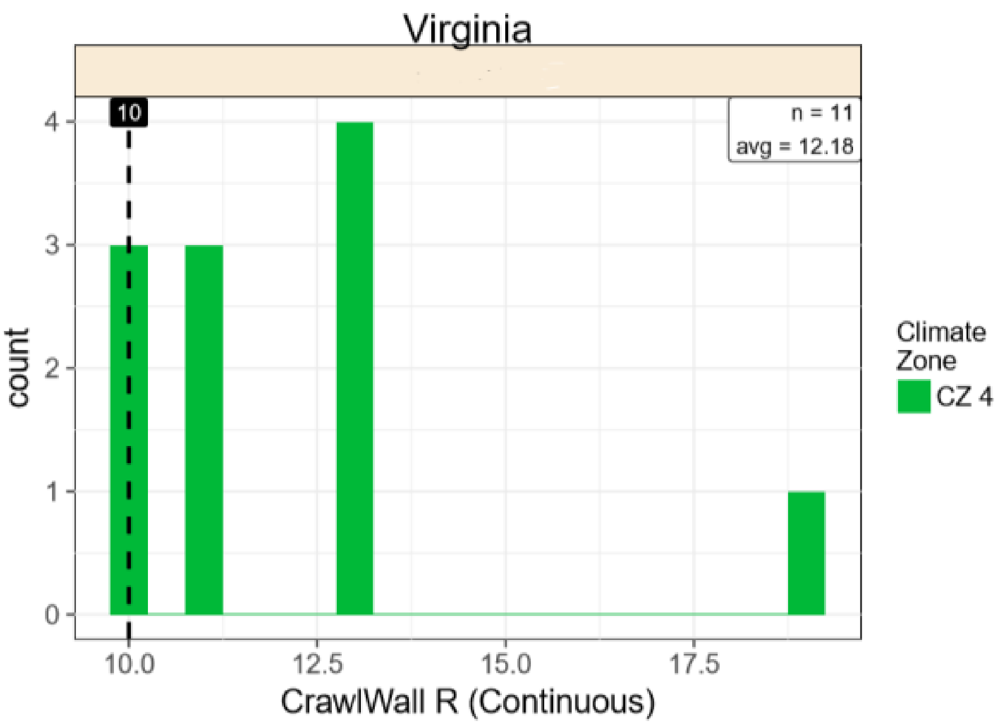

Figure 3.17. Crawl Wall Continuous R-Values

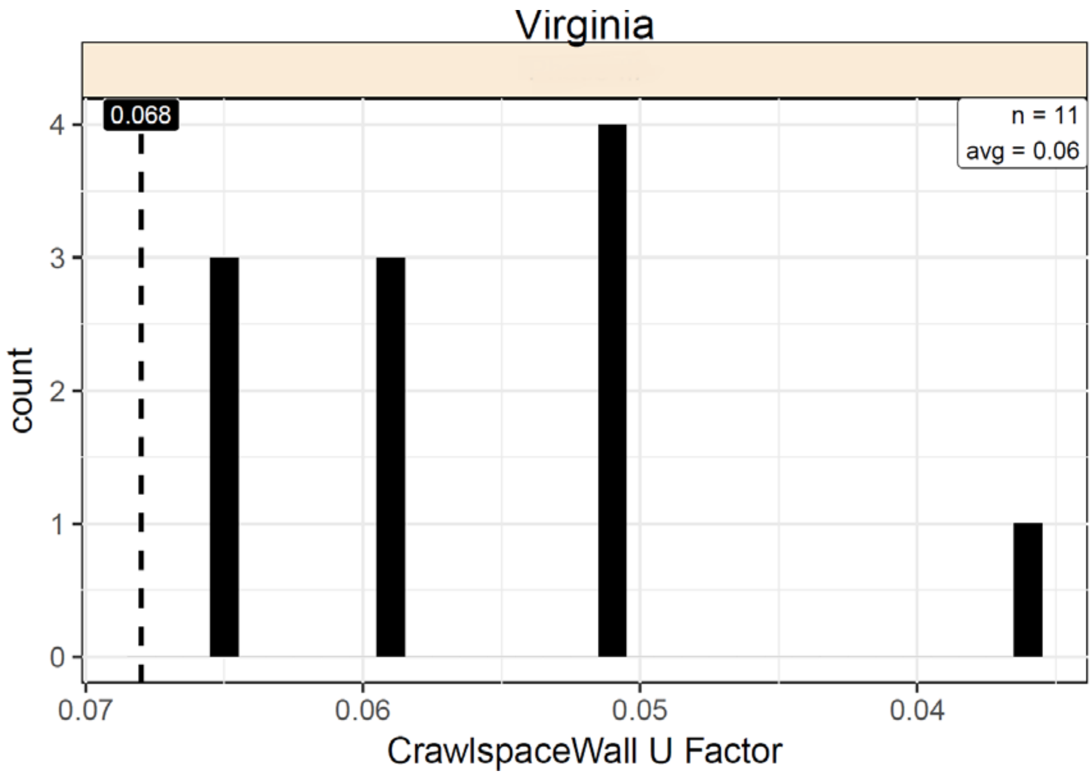

Figure 3.18. Crawl Wall U-Factors

Table 3.13. Crawlspace Wall U-Factors

Climate Zone	CZ4
Number	11
Range	0.065 to 0.036
Average	0.056
Requirement	0.068
Compliance Rate	11 of 11 (100%)

- **Interpretations:**

All crawlspace R-value (and U-factor) observations meet or exceed the prescriptive requirement.

3.1.1.9 Impact of Insulation Installation Quality

At the start of the project, insulation installation quality 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 field teams whenever possible, and applied as a *modifier* in the analyses for applicable key items (i.e., ceiling insulation, wall insulation, and foundation insulation). Teams followed the RESNET[1] assessment protocol which has three grades, Grade I being the best quality installation and Grade III being the worst.

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

Table 3.14 shows the insulation installation quality levels for framed envelope assemblies, as observed in the state. Nearly half of the observations (94 of 211) were classified as Grade I, indicating that insulation installation quality has room for improvement.

Table 3.14. Insulation Installation Quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Roof Cavity	55	15	3	74
Above Grade Wall	23	40	2	65
Knee Wall	4	15	4	23
Floor	1	7	8	16
Basement	11	16	6	33

3.1.2 Additional Data Items

The project team collected data on additional code requirements (beyond the key items) 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. The full data set, including some additional data that did not have enough observations to be deemed meaningful, is also available on the DOE Building Energy Codes Program website.[2]

3.1.2.1 Average Home

- Size: 3478 ft^2 (n=136) and 1.92 stories (n=135)

Table 3.15. Conditioned Floor Area (ft^2)

Conditioned Floor Area (ft^2)	< 1000	1000 to 1999	2000 to 2999	3000 to 3999	4000+
Percentage	0%	13%	32%	21%	35%

Table 3.16. Number of Stories

No. of Stories	1	1.25	2	3	4+
Percentage	16%	1%	76%	8%	0%

3.1.2.2 Envelope

- Foundations (n=137): Mix of basements (50%), slab-on-grade (20%) and crawlspaces (29%)

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

3.1.2.3 Duct & Piping Systems

- Ducts were often not located within conditioned space (percentage of duct system):

Supply (n=95): 53%

Return (n=95): 54%

- Ducts located entirely in conditioned space:

Supply (n=95): 33% of systems

Return (n=95): 32% of systems

3.1.2.4 HVAC Equipment

- Heating (n=97): Split between gas furnace (61%) and electric heat pump (39%)
- Cooling (n=92): Split between central AC (60%) and heat pump (40%)

3.2 Energy Intensity

The statewide energy analysis results are shown in the Figure 3.19, 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, homes in Virginia appear to use less energy than would be expected relative to homes built to the current minimum state code requirements.

Analysis of the collected field data indicates an average regulated EUI (dashed line in Figure 3.19) of approximately 29.42 kBtu/ft^2-yr compared to 29.48 kBtu/ft^2-yr for homes exactly meeting minimum *prescriptive* energy code requirements (black line in Figure 3.19). This suggests the EUI for a “typical” home in the state is about 0.2% better than the 2015 Virginia Energy Conservation Code.

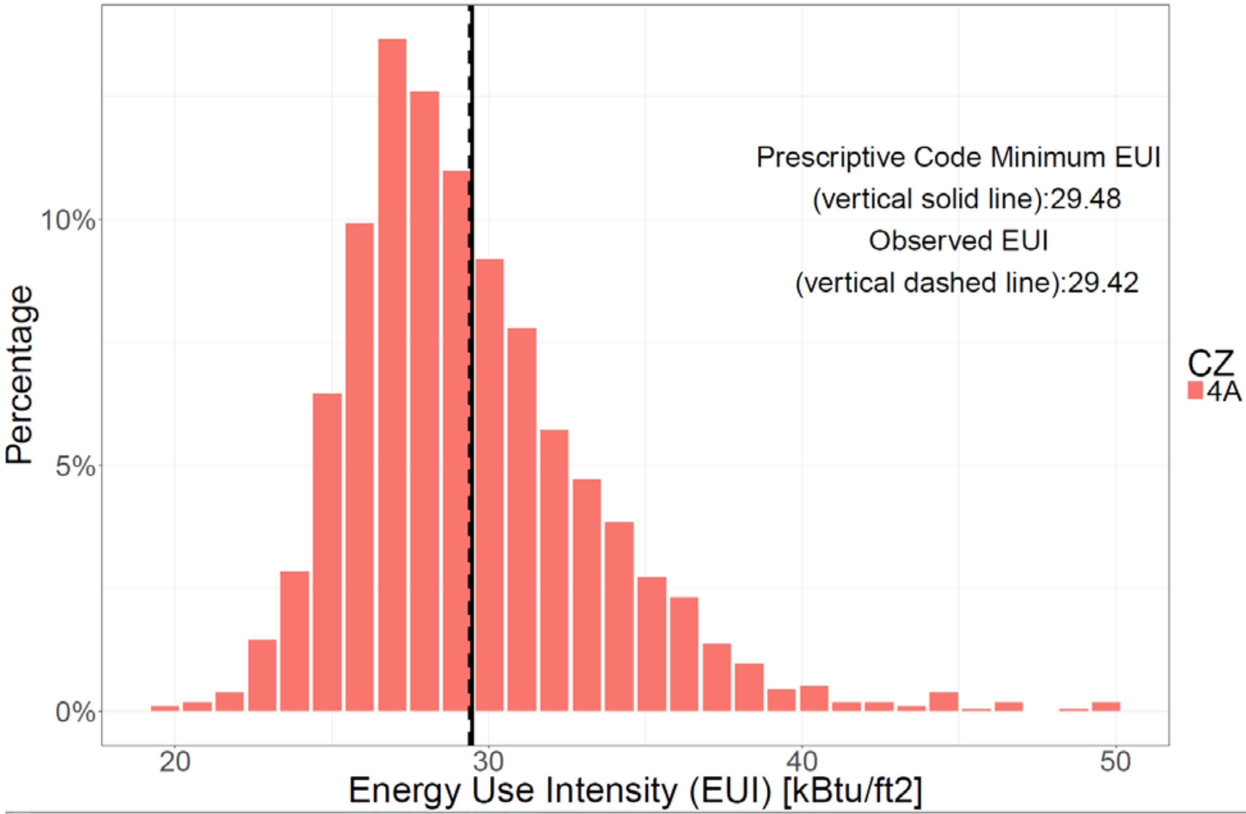

Figure 3.19. Statewide EUI Analysis

When the observed EUI of 29.42 kBtu/ft2-yr is compared to 29.48 kBtu/ft2-yr for homes meeting the Virginia Energy Code (Figure 3.19), the EUI for the typical home in the state is about 0.2% better than code. Note that it is difficult to see both the vertical solid line and the vertical dashed line in Figures ES.2 as the values are nearly identical.

3.3 Savings Potential

All key items exhibit the potential for improvement. In part, this is because Virginia is the first state for which BECP has decided to calculate measure level savings for all key items that had at least one observation that did not meet code, as opposed to previous state analyses where a 15% failure threshold was used. Shown below is a list of key items analyzed, followed by the percent of observations that met or exceeded the associated code requirement. Note that percentages are based on U-factor for any opaque assemblies, except for slab insulation, which is based on R-value. Any key item where the percentage was less than 100 is listed and was analyzed further to calculate the associated savings potential, including energy, cost and carbon savings.

- Exterior Wall Insulation (23%),
- Ceiling Insulation (74%),
- Foundations

Heated Basement Wall Insulation (50%)

Floors over Unconditioned Space (unheated basement or vented crawlspace) (94%)

- Lighting (65%),
- Envelope Air Leakage (78%),
- Window U-factor (99%),
- Window SHGC (99%), and
- Duct Leakage (33%).

For analytical details refer to Section 2.3.3 (Savings Analysis) or the methodology report (DOE 2018).

As can be seen from the list above, some measures have much higher compliance than others. Under the previous BECP 15% threshold, savings would not have been calculated for floors, window U-factor, or window SHGC.

Estimated savings resulting from the analysis are shown below in order of highest to lowest total energy, cost and carbon savings (Table 3.17). As can be seen, there are significant savings opportunities, with the greatest total energy savings potential associated with these measures. In addition, Table 3.19 shows the total savings and emissions reductions that will accumulate over 5, 10, and 30 years of construction.

Table 3.17. Statewide Annual Measure-Level Savings

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	4A	262	20	2,852	22,497	64,168	1,244,243	31,520
Envelope Air Leakage	4A	58	12	1,349	22,497	30,343	474,867	7,117
Lighting	4A	168	-2	392	22,497	8,808	399,441	20,017
Exterior Wall Insulation	4A	60	7	933	22,497	20,984	362,571	7,267
Ceiling Insulation	4A	67	6	852	22,497	19,163	351,530	8,038
Foundation Insulation	4A	-59	13	1,090	Varies	6,035	56,409	-1,195
Window SHGC	4A	17	-1	6	22,497	130	31,505	2,053
Window U-Factor	4A	1	0	50	22,497	1,122	16,276	175
TOTAL		**574**	**56**	**7,523**	**22,497**	**150,752**	**2,936,843**	**74,992**

Table 3.18. Breakdown of Foundation Measure Level Savings

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)
Heated Basement Wall Insulation	4A	-7	3	302	12,433	3,750	39,806	-416
Slab Insulation	4A	13	4	425	2,072	880	12,957	150
Floor over Unconditioned Space	4A	-65	6	364	4,736	1,405	3,646	-929
TOTAL		**-59**	**13**	**1,090**	**Varies**	**6,035**	**56,409**	**-1,195**

Table 3.19. Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
	5yr	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Duct Leakage	962,513	3,529,215	29,837,910	18,663,647	68,433,371	578,573,046	472,807	1,733,627	14,657,031
Envelope Air Leakage	455,139	1,668,843	14,109,312	7,123,008	261,17,697	220,813,254	106,753	391,429	3,309,354
Lighting	132,117	484,429	4,095,625	5,991,610	21,969,237	185,739,915	300,258	1,100,946	9,307,994
Exterior Wall Insulation	314,756	1,154,107	9,757,449	5,438,571	19,941,429	168,595,714	109,001	399,669	3,379,016
Ceiling Insulation	287,440	1,053,947	8,910,646	5,272,950	19,334,152	163,461,464	120,564	442,069	3,737,496
Foundation Insulation	90,528	331,935	2,806,361	846,136	3,102,497	26,230,202	-17,925	-65,725	-555,677
Window SHGC	1,954	7,165	60,579	472,578	1,732,787	14,649,929	30,789	112,893	954,457
Window U-Factor	16,828	61,704	521,677	244,140	895,181	7,568,349	2,628	9,635	81,462
TOTAL	**2,261,276**	**8,291,346**	**70,099,558**	**44,052,641**	**161,526,351**	**1,365,631,874**	**1,124,875**	**4,124,543**	**34,871,135**

4.0 Conclusions

The Virginia field study provides an enhanced understanding of statewide code implementation, and suggests that additional savings are available through increased compliance with the state energy code. From a statewide perspective, the average home in Virginia uses about 0.2% less energy than a home exactly meeting the state energy code. However, significant savings potential remains through increased compliance with targeted measures. Potential statewide annual energy savings are 150,752 MMBtu, which equates to nearly $3 million in cost savings, and emission reductions of nearly 75,000 MT CO2e. Over a 30-year period, these impacts grow to 70 MMBtu, $1.3 billion, and over 34 million 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

	Annual Savings		
Key Measure	**Energy** (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
Duct Leakage	6,4168	1,244,243	31,520
Envelope Air Leakage	30,343	474,867	7,117
Lighting	8,808	399,441	20,017
Exterior Wall Insulation	20,984	362,571	7,267
Ceiling Insulation	19,163	351,530	8,038
Foundation Insulation	6,035	56,409	-1,195
Window SHGC	130	31,505	2,053
Window U-Factor	1,122	16,276	175
TOTAL	**150,752 MMBtu**	**$2,936,843**	**74,992 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 August 9, 2019).

DOE 2018. "Residential Building Energy Code Field Study: Data Collection and Analysis Methodology." Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study

EnergyPlus. https://energyplus.net/.

The Virginia residential field study website is available at https://www.seealliance.org/initiatives/built-environment/building-energy-codes/residential-energy-code-field-study/ (accessed August 16, 2019).

Residential Energy Services Network. 2013. "Mortgage Industry National Home Energy Rating System Standards." Residential Energy Services Network, Oceanside, CA. www.resnet.us.

Appendix A

Stakeholder Participation

Appendix A

Stakeholder Participation

The Virginia Project Team did not hold the traditional full stakeholder kick-off meeting, but did meet specifically with the Virginia Department of Mines, Minerals, and Energy (DMME) as well as the Virginia Department of Housing and Community Development (DHCD) prior to beginning work. The Project Team also met with a range of other stakeholders in Virginia on an individual basis in order to understand the shortcomings in code enforcement, including the Virginia Energy Efficiency Council (VAEEC) and the Home Builders Association of Virginia (HBAV).

Appendix B

State Sampling Plan

Appendix B

State Sampling Plan

B.1 State Sampling Plan

Table B.1. State Sampling Plan

Location	Sample	Actual
Loudoun County, Loudoun County	9	9
Prince William County Unincorporated Area, Prince William County	3	3
Chesterfield County, Chesterfield County	5	5
Stafford County, Stafford County	4	4
Chesapeake, Independent City	7	7
Fairfax County Unincorporated Area, Fairfax County	1	1
Henrico County, Henrico County	2	2
Virginia Beach, Independent City	2	2
Hanover County, Hanover County	2	2
James City County, James City County	2	2
Norfolk, Independent City	1	1
Rockingham County, Rockingham County	2	2
Suffolk, Independent City	1	1
Albemarle County, Albemarle County	2	2
Arlington County, Arlington County	2	2
Fauquier County Unincorporated Area, Fauquier County	1	1
Culpeper County, Culpeper County	3	3
Louisa County, Louisa County	2	2
Augusta County, Augusta County	1	1
Alexandria, Independent City	1	1
Gloucester County, Gloucester County	1	1
Goochland County, Goochland County	1	1
Warren County, Warren County	2	2
Campbell County, Campbell County	1	1
Shenandoah County, Shenandoah County	1	1
Orange County, Orange County	1	1
Mecklenburg County Unincorporated Area, Mecklenburg County	1	Collected in Mecklenburg County and Dinwiddie County
Hopewell, Independent City	1	1
Washington County Unincorporated Area, Washington County	1	Substituted Roanoke County entirely
Total	**63**	**63**

B.2 Substitutions

Only one full jurisdiction needed to be substituted (Washington County), and half of another (Mecklenburg County). In Washington County, 1 sample set was required. Calls to builders and site visits were conducted, but the sample was unable to be completed due to builders being unreachable on-site or by phone, homes not being at the necessary stage for data collection, or builders being unwilling to participate. Roanoke County was selected as a substitute due to it also being located along the I-81 corridor and having a similar median sales price as Washington County.

Mecklenburg County required a partial substitution. Half of the required measures were able to be collected from one house that was at the end of construction. There was minimal permit data available for the county, leading to a small potential pool of participants. In hopes of increasing the pool of willing participants, additional permit data was obtained several months after the original data was gathered, but this did not improve the outcome. No homes were available for the pre-drywall phase data collection, despite calling each builder several times and, in some cases, following up with email. Dinwiddie County was selected as a substitution to collect the remaining sample set data. This was due to it having a similar volume of new single-family construction, similar population density, similar median home prices, and being geographically close to Mecklenburg County.

Appendix C

Additional Data

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Additional Data

C.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 Virginia 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]

C.1.1 General

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

C.1.1.1 Average Home

- Size (n=136): 3478 ft^2
- Number of Stories (n=135): 1.92

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	0%	13%	32%	21%	34%

Table C.2. Number of Stories

No. of Stories	1	1.5	2	3	4+
Percentage	16%	0%	76%	8%	0%

C.1.1.2 Wall Profile

- Framing Type (n=6):

All were framed construction (100%) (There were actually at least 26 framed walls as the other questions in this section suggest, but only 6 walls were specifically listed as framed walls.)

- Framing Material (n=26):

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

Wood (100%)

Steel (0%)

- Framing Depth (n=26):

4” (69%)

6” (31%)

C.1.1.3 Foundation Profile

- Foundation Type (n=137):

Heated Basement (49%)

Unheated Basement (1%)

Slab on Grade (20%)

Vented Crawlspace (20%)

Unvented Crawlspace (9%)

C.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.

C.1.2.1 Energy Code Used (n= 12):

Table C.3. Energy Code Used

Energy Code	2012 IECC
Percentage	100%

C.1.3 Envelope

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

C.1.3.1 Insulation Labels

- Was insulation labeled (n=6)?

Yes (100%)

No (0%)

C.1.3.2 Ceilings

- Did the attic hatch/door exhibit the correct insulation value (n=23)?

Yes (70%)

No (30%)

C.1.3.3 Air Sealing[1]

The following indicate whether sealing was completed in accordance with the checklist and associated code requirements.

- Thermal envelope sealed (n=13) (54%)
- Openings around windows and doors sealed (n=23) (100%)
- Knee walls sealed (n=27) (56%)
- Garage walls and ceilings sealed (n=2) (50%)
- Envelope behind tubs and showers sealed (n=34) (53%)
- Attic access openings sealed (n=22) (45%)
- Rim joists sealed (n=24) (42%)
- Other sources of infiltration sealed (n=4) (75%)

C.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:

C.1.4.1 System Profile

- Duct Location in Conditioned Space (percentage):

Supply (n=95): 53% (31 systems located entirely within conditioned space)

Return (n=95): 54% (30 systems located entirely within conditioned space)

- Duct Insulation in Unconditioned Space (R-value):

Supply (n=21): 7.4

Return (n=19): 7.4

- Ducts in Attics (R-value):

Supply (n=31): 7.9

Return (n=28): 7.9

- Air handlers sealed (n=17) (65%)
- Filter boxes sealed (n=21) (75%)

C.1.5 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, there can be significant differences in the two methods.

C.1.5.1 Heating

- Fuel Source (n=66):

Gas (77%)

Electricity (23%)

- System Type (n=95):

Furnace (61%)

Heat Pump (39%)

C.1.5.2 Cooling

- System Type (n=92):

Central AC (60%)

Heat Pump (40%)

C.1.5.3 Water Heating

- Fuel Source (n=62):

Gas (73%) (includes 71% gas and 2% propane)

Electric (27%) (includes 24% electric resistance, 2% heat pump, and 2% unspecified electricity) (round-off issue)

- System Type (n=60):

Storage (68%)

Tankless (32%)

- System Capacity (n=23):

51.9 gallons (observations ranged from 7.5 to 80 gallons for storage systems)

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	38%	44%	0%	15%	3%	0%

- System Efficiency (n=47):

EF 0.82

C.1.5.4 Ventilation

- System Type (n=8):

AHU-Integrated (63%)

ERV (13%)

Exhaust Fan (12%)

Standalone ERV/HRV (12%)

C.1.5.5 Other

- Programmable thermostat installed (n=3) (100%)

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