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North Carolina Residential Energy Code Field Study: Baseline Report

August 2017

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U.S. DEPARTMENT OF ENERGY

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

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

A research project in the State of North Carolina 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 January 2015 and continued through September 2015. During this period, research teams visited 249 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 $1.5 million in potential annual savings to North Carolina homeowners that could result from increased code compliance. Public and private entities within the state can use this information to justify and catalyze future investments in energy code training and related energy efficiency programs.

Methodology

The project team was led by Appalachian State University. 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 the distribution 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.

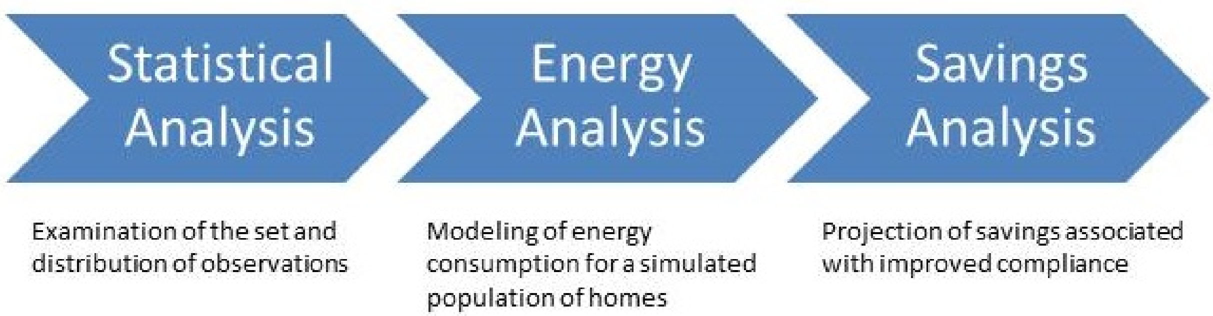

Figure ES.1. Stages of Analysis Applied in the Study

Results

The key items with the greatest potential for savings in North Carolina 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 in North Carolina

Measure	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Total State Emissions Reduction (MT CO2e)
Lighting	13,822	520,839	3,349
Exterior Wall Insulation	20,318	390,827	2,199
Duct Leakage	15,720	334,527	1,935
Envelope Air Leakage	12,174	211,315	1,152
Foundation Insulation	3,925	65,086	349
TOTAL	**65,959 MMBtu**	**$1,522,594**	**8,984 MT CO2e**

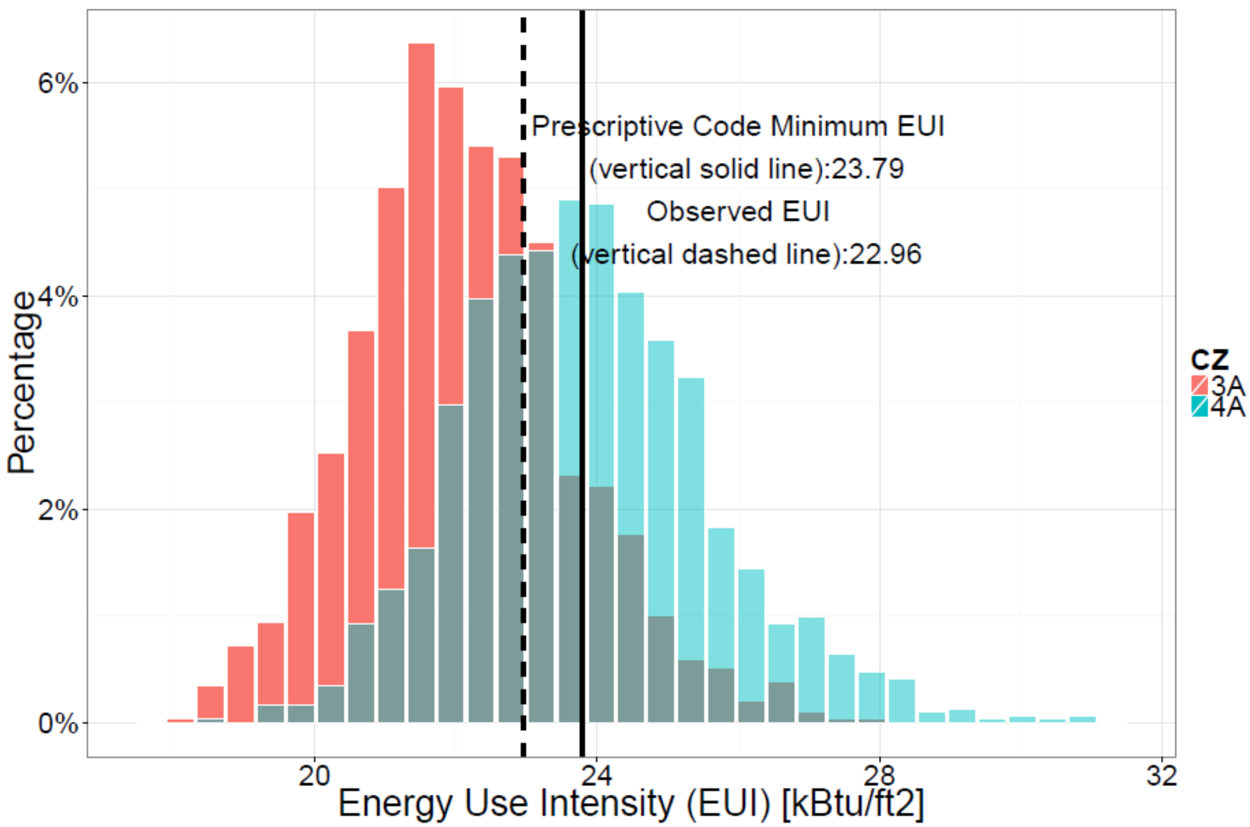

Figure ES.2. Modeled Distribution of Regulated EUI (kBtu/ft^2/year) in North Carolina

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 an average regulated energy use intensity (EUI) of 22.96 kBtu/ft^2-yr statewide compared to 23.79 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 3.5% better than code.

Acknowledgments

The following members comprised the North Carolina project team:

- Janet Miller, Chuck Perry, and Jeff Tiller, *Appalachian State University*
- Joseph Crocker, *Appalachian State University*
- Grace Plummer and Sharon Yates, *Appalachian State University*
- Chase Edge and Jakob Sjostrand, *Appalachian State University*
- Dale Akins, *The Market Edge, LLC*
- John Kidda, *reNew Home*
- Mark Jabaley, *Above and Beyond Energy*
- David Watts, *MSA Marketing*

Appalachian State University Energy Center

The Appalachian Energy Center is housed within the Research Institute for the Environment, Energy, and Economy at Appalachian State University. The mission of the Center is to conduct applied research and to provide services and education in support of the development and deployment of clean energy technologies, policies, and economies. One of the Center's initiatives is the North Carolina Energy Efficiency Alliance (NCEEA) which was established in 2010 as a state-funded non-profit organization with the goal of supporting energy efficient and third party certified construction in NC. The NCEEA is dedicated to educating all the various stakeholders in the home building industry about the benefits of constructing energy efficient homes and buildings. More information is available at https://energy.appstate.edu and http://ncenergystar.org..

The Market Edge, LLC

The Market Edge is a specialized information reporting service that provides leads to building material suppliers, subcontractors, financial institutions, governmental agencies, and other companies that provide goods and services to the residential and commercial construction industry. More information is available at http://www.themarketedge.com.

reNew Home

reNew Home strives to improve existing homes and small commercial buildings by using building science methodology to carry out renovation projects, placing emphasis on occupant safety, energy conservation, sustainable materials, and livability. reNew Home served as a site auditor for the field study. More information is available at http://www.renewhomeinc.com.

Above and Beyond Energy

Above and Beyond Energy was formed by Mark and Marianna Jabaley in 2007, with one mission: to help professionals and laymen alike, to build only the highest performing homes in the Coastal Carolinas. They have built an award winning company that serves clients all across North Carolina. Above and Beyond Energy served as a site auditor for the field study as well as assisted the project team in the Phase 2 training. See http://aboveandbeyondenergy.com for more information.

MSA Marketing

MSA is a full-service marketing firm located in Raleigh, NC. Founded in 1991, MSA is a small, dynamic and growing team with big agency capabilities. They offer a wide range of services for a diverse mix of clients, with a drive to help them achieve results. MSA assisted the project team in the creation of Energy Code videos used in Phase 2 of the project. Visit http://thinkmsa.com for more information.

Acronyms and Abbreviations

AC	air conditioning
ACH	air changes per hour
AFUE	annual fuel utilization efficiency
AHU	air handling unit
AIA	American Institute of Architects
ASU	Appalachian State University
Btu	British thermal unit
cfm	cubic feet per minute
CZ	climate zone
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EUI	energy use intensity
FOA	funding opportunity announcement
HSPF	heating season performance factor
ICC	International Code Council
IECC	International Energy Conservation Code
kBtu	thousand British thermal units
MMBtu	million British thermal units
NA	not applicable
NC	North Carolina
NCBCC	North Carolina Building Code Council
NCECC	North Carolina Energy Efficient Code
PNNL	Pacific Northwest National Laboratory
RFI	request for information
SHGC	solar heat gain coefficient

Contents

Executive Summary iii
Acknowledgments v
Acronyms and Abbreviations vii
1.0 Introduction 1.1
1.1 Background 1.1
1.2 Project Team 1.2
1.3 Stakeholder Interests 1.2
2.0 Methodology 2.1
2.1 Overview 2.1
2.2 State Study 2.2
2.2.1 Sampling 2.2
2.2.2 Data Collection 2.2
2.3 Data Analysis 2.3
2.3.1 Statistical Analysis 2.4
2.3.2 Energy Analysis 2.5
2.3.3 Savings Analysis 2.5
2.4 Limitations 2.6
2.4.1 Applicability of Results 2.6
2.4.2 Determination of Compliance 2.6
2.4.3 Sampling Substitutions 2.6
2.4.4 Site Access 2.6
2.4.5 Analysis Methods 2.7
2.4.6 Presence of Tradeoffs 2.7
3.0 State Results 3.1
3.1 Field Observations 3.1
3.1.1 Key Items 3.1
3.1.2 Additional Data Items 3.16
3.2 Energy Intensity 3.18
3.3 Savings Potential 3.19
4.0 Conclusions 4.1
5.0 References 5.1
Appendix A – Stakeholder Participation A.1
Appendix B – State Sampling Plan B.1
Appendix C – Additional Data C.1

Figures

2.1 Sample Graph 2.4
3.1 Envelope Tightness 3.2
3.2 Window SHGC 3.3
3.3 Window U-Factor 3.4
3.4 North Carolina CZ 3A Wall R-Value Observations 3.5
3.5 North Carolina CZ 4A Wall R-Value Observations 3.6
3.6 North Carolina CZ 3A Wall Assembly Performance, including Wall Insulation Installation Quality... 3.7
3.7 North Carolina CZ 4A Wall Assembly Performance, including Wall Insulation Installation Quality... 3.8
3.8 Ceiling R-Value 3.9
3.9 High-efficacy Lighting Percentage 3.10
3.10 Slab Edge Insulation 3.12
3.11 Floor R-Values for North Carolina 3.13
3.12 Floor Assembly Performance, including Insulation Installation Quality for North Carolina CZ3A3.13
3.13 Floor Assembly Performance, including Insulation Installation Quality for North Carolina CZ4A3.14
3.14 Duct Tightness 3.15
3.15 Statewide EUI Analysis for North Carolina 3.19

Tables

3.1 Envelope Tightness 3.2
3.2 Window SHGC 3.3
3.3 Window U-Factor 3.4
3.4 Wall Assemblies 3.8
3.5 Ceiling R-Value 3.9
3.6 High-efficacy Lighting Percentage 3.10
3.7 Slab Edge Insulation 3.12
3.8 Floors 3.14
3.9 Duct Tightness 3.15
3.10 Insulation Installation Quality 3.16
3.11 Statewide Annual Measure-Level Savings for North Carolina 3.20
3.12 Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings for North Carolina3.21
4.1 Annual Statewide Savings Potential in North Carolina 4.1

1.0 Introduction

A research project in the State of North Carolina 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 North Carolina field study was initiated in January 2015 and continued through September 2015. During this period, research teams visited 249 homes across the state during various stages of construction. At the time of the study, the 2012 North Carolina Energy Conservation Code was in effect, which was an amended version of a draft of the 2012 International Energy Conservation Code (IECC). The study methodology, data analysis and resulting findings are presented throughout this report.

1.1 Background

The data collected and analyzed for this report was in response to the U.S. Department of Energy (DOE) Funding Opportunity Announcement (FOA), "Strategies to Increase Residential Energy Code Compliance Rates and Measure Results".[1] The goal of the FOA is to determine whether an investment in education, training, and outreach programs can produce a significant, measurable change in single-family residential building code energy use, and therefore energy savings, within 2-3 years. Participating states are:

1. Conducting a baseline field study to determine installed energy values of code-required items, identify issues, and calculate savings opportunities;
2. Implementing education, training, and outreach activities designed to increase code compliance; and
3. Conducting a second field study to measure the post-training values using the same methodology as the baseline study.

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 the FOA and overall DOE interest in compliance is available on the DOE Building Energy Codes Program website.[4]

[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

1.2 Project Team

The North Carolina project and field data collection was led by Appalachian State University (ASU). 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.

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
- 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 North Carolina 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 is 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 North Carolina study, including sampling, data collection, and resulting data analysis. More information on the DOE

[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.

data collection and analysis methodologies is published separately from this report (DOE 2016) and is available on the DOE Building Energy Codes Program website.[3]

2.2 State Study

The prescribed methodology was customized for the State of North Carolina 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 by stakeholders at a project kickoff meeting, such as state-specific construction practices and systematic differences across county or climate zone 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 acquiring permit data. The primary source of data was from The Market Edge, a specialized information reporting service that provided substantial data on new housing starts in most of the counties selected for sampling. In counties where data was not available from The Market Edge, the local building departments were contacted 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 for each county were then sorted using a random number generator and utilized by the team's field personnel in the field survey process. 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 2012 North Carolina Energy Conservation Code (an amended version of a draft of the 2012 IECC). The final data collection form is available in spreadsheet format on the DOE Building Energy Codes Program website.[5] The form included all energy code requirements

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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.

(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[6] 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) 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.

[6] See http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf
[7] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study

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

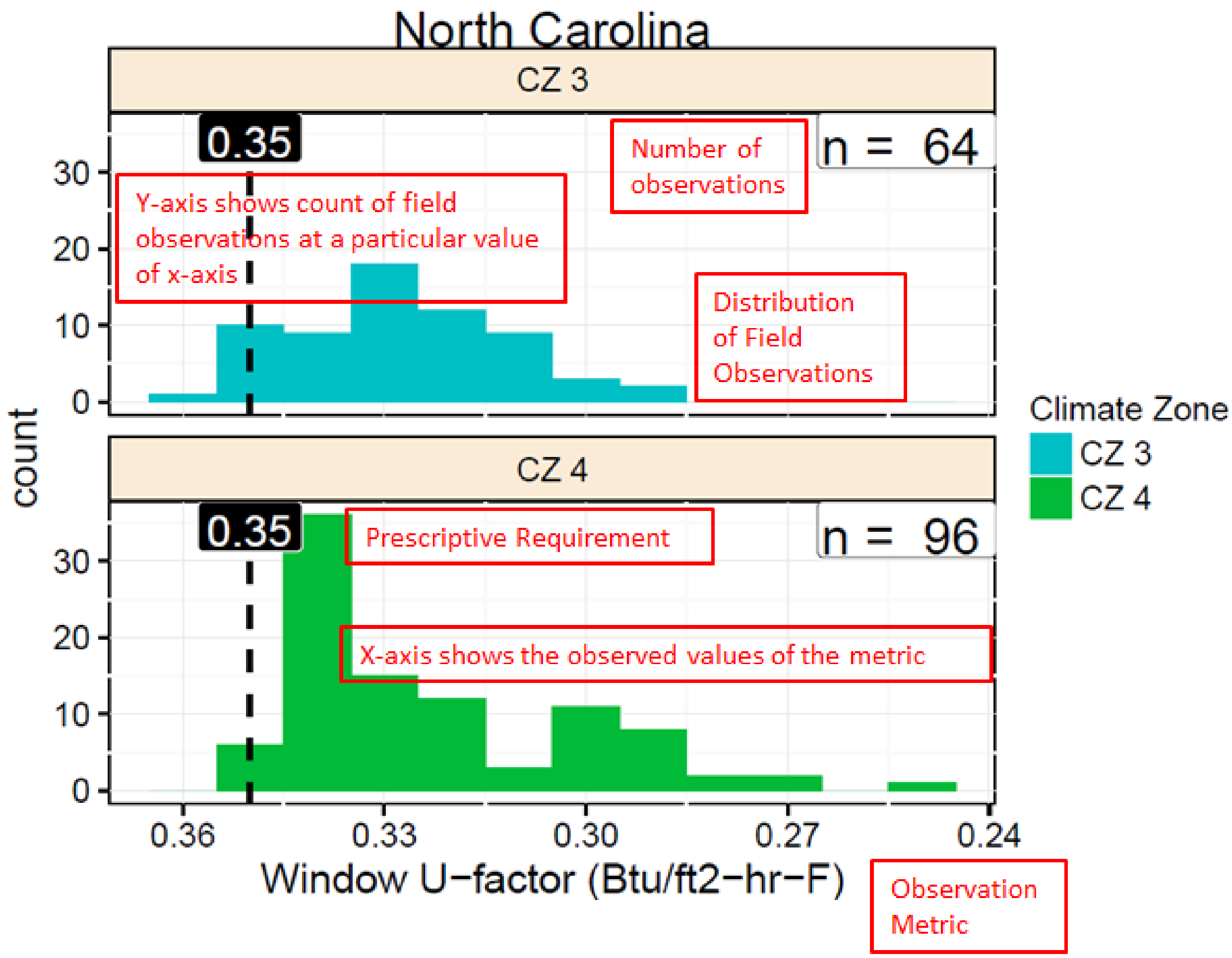

Figure 2.1. Sample Graph

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. This approach is known in statistics as a Monte Carlo analysis.

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 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 a supplemental methodology report (DOE 2016).[9]

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

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

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

[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 better-than-code and worse-than-code results, allowing them to offset each other.

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), *energy cost* ($), and avoided *carbon emissions* (MT CO_2e).

Note that this approach results in the maximum theoretical savings potential for each measure as it does not take "interaction effects" into account such as the increased amount of heating needed in the winter when energy efficient lights are installed. A building's energy consumption is a dynamic and interactive process that includes all the building components present within a given home. In a typical real building, the savings potential might be higher or lower; however, additional investigation indicated that the relative impact of such interactions is very small, and could safely be ignored without changing the basic conclusions of the analysis.

2.4 Limitations

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

2.4.1 Applicability of Results

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

2.4.2 Determination of Compliance

The field study protocol is based 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. North Carolina comprises multiple climate zones (CZ 3, 4 and 5, but only CZ 3 and 4 were selected in the random sample[1]). 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 certain 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. Foundations – slabs (R-value) and floors (assembly U-factor)
8. Duct tightness (expressed in cfm per 100 ft^2 of conditioned floor area at 25 Pascals)

The two main foundation types observed were slabs on grade and CMU foundations with floors over vented crawlspaces. In addition, there were five basement wall observations, but due to that small number, graphics are only provided for slabs and floors.

[1] Due to minimal construction activity in CZ 5

3.1.1.1 Envelope Tightness

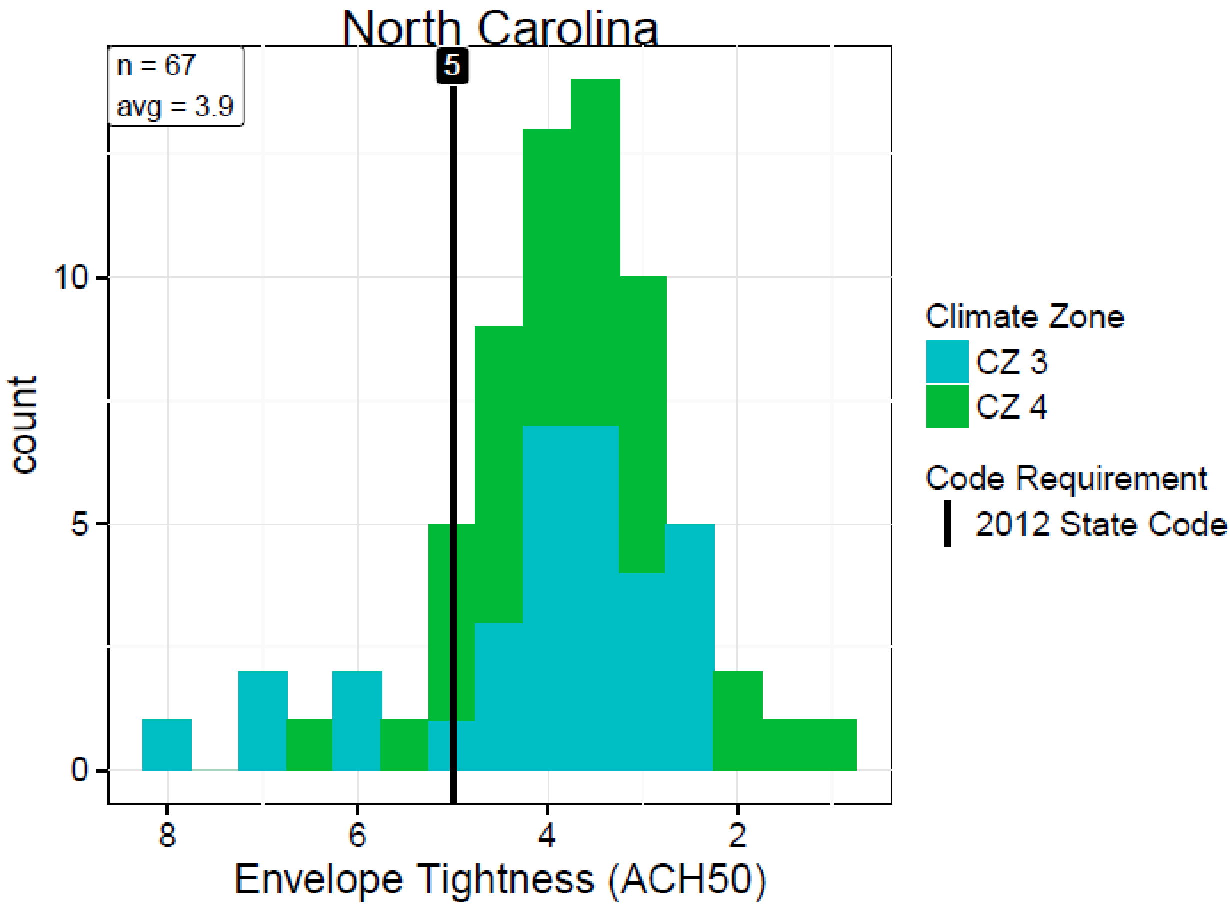

Figure 3.1. Envelope Tightness (ACH50)

Table 3.1. Envelope Tightness

Climate Zone	CZ3	CZ4	Statewide
Number	32	35	67
Range	7.79 to 2.36	6.5 to 1.0	7.79 to 1.0
Average	4.0	3.8	3.9
Requirement	5.0	5.0	5.0
Compliance Rate	27 of 32 (84%)	32 of 35 (91%)	59 of 67 (88%)

- **Interpretations:**
  - Overall, the distribution exhibits lower average air leakage than the 5.0 ACH50 requirement for homes undergoing air leakage testing.
  - Although the majority of the observations met or exceeded the prescriptive code requirement and most observations were in the 3.0 to 5.0 ACH50 range, there are still significant savings potential, as 12% of the homes surveyed had air leakage rates over 5.0 ACH50

3.1.1.2 Window SHGC

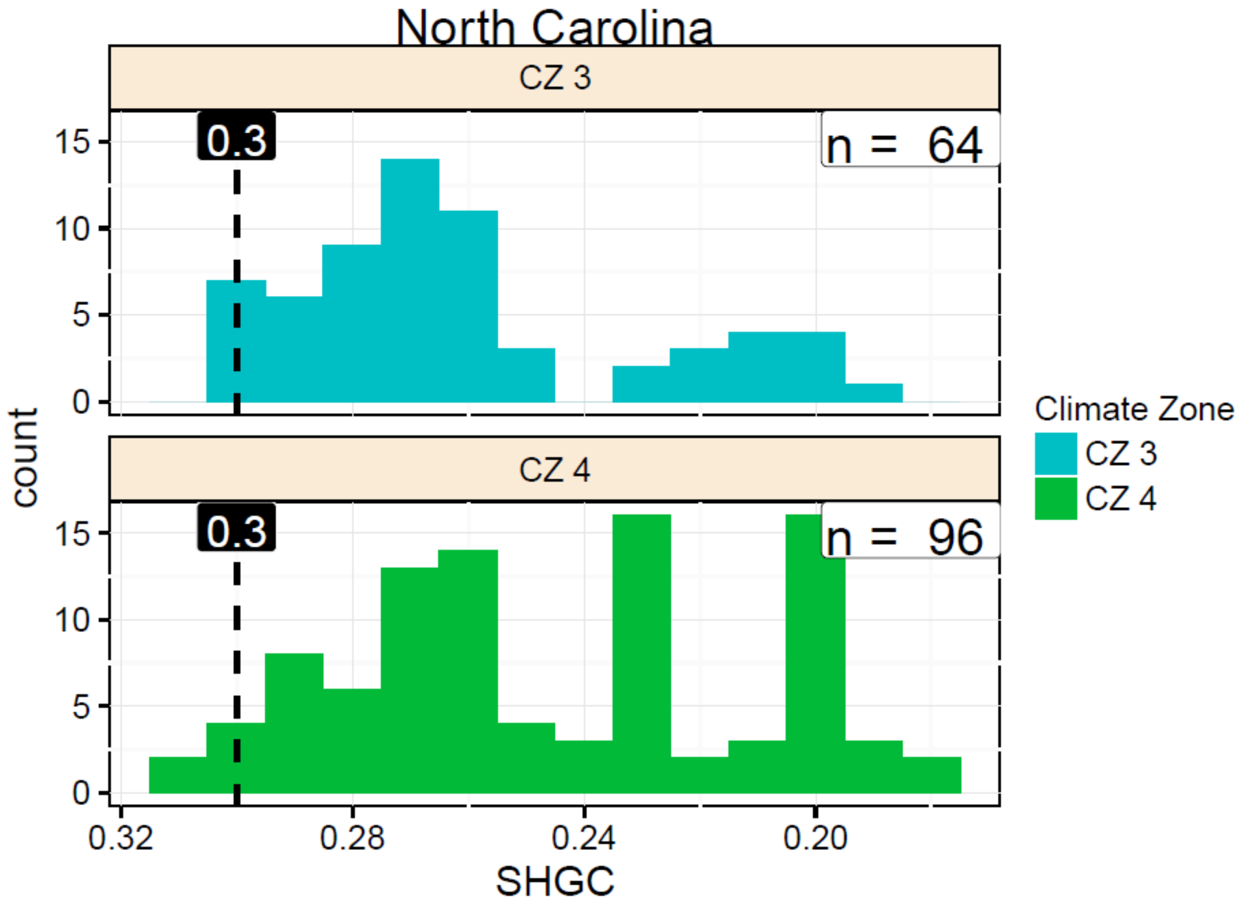

Figure 3.2. Window SHGC

Table 3.2. Window SHGC

Climate Zone	CZ3	CZ4	Statewide
Number	64	96	160
Range	0.30 to 0.19	0.31 to 0.18	0.31 to 0.18
Average	0.26	0.25	0.25
Requirement	0.30	0.30	0.30
Compliance Rate	64 of 64 (100%)	94 of 96 (98%)	158 of 160 (99%)

- **Interpretations:**
  - SHGC values were fully compliant in CZ3, and all but two observations met the prescriptive requirement for CZ4.
  - The vast majority of the observations were in the 0.20 to 0.30 SHGC range.

3.1.1.3 Window U-Factor

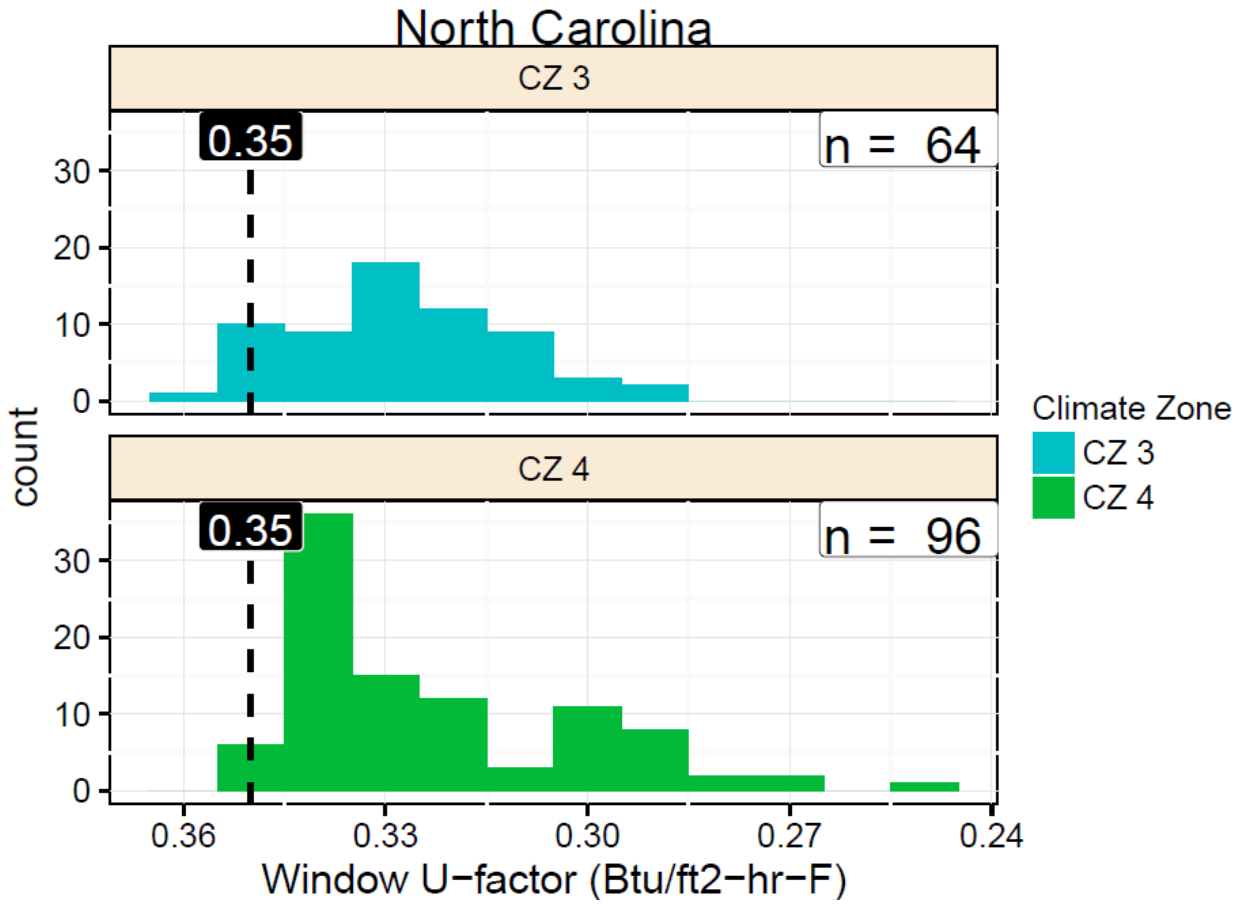

Figure 3.3. Window U-Factor

Table 3.3. Window U-Factor

Climate Zone	CZ3	CZ4	Statewide
Number	64	96	160
Range	0.36 to 0.29	0.35 to 0.25	0.36 to 0.25
Average	0.33	0.32	0.32
Requirement	0.35	0.35	0.35
Compliance Rate	63 of 64 (98%)	96 of 96 (100%)	159 of 160 (99%)

- **Interpretations:**
  - All but one observed fenestration product in the state met or exceeded the U-factor requirements.
  - This represents one of the most significant findings of the field study.
  - Window U-factor requirements appear to have been implemented with a high rate of success across the state.

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 and Figure 3.5 represent the distribution of observed values for wall cavity insulation.

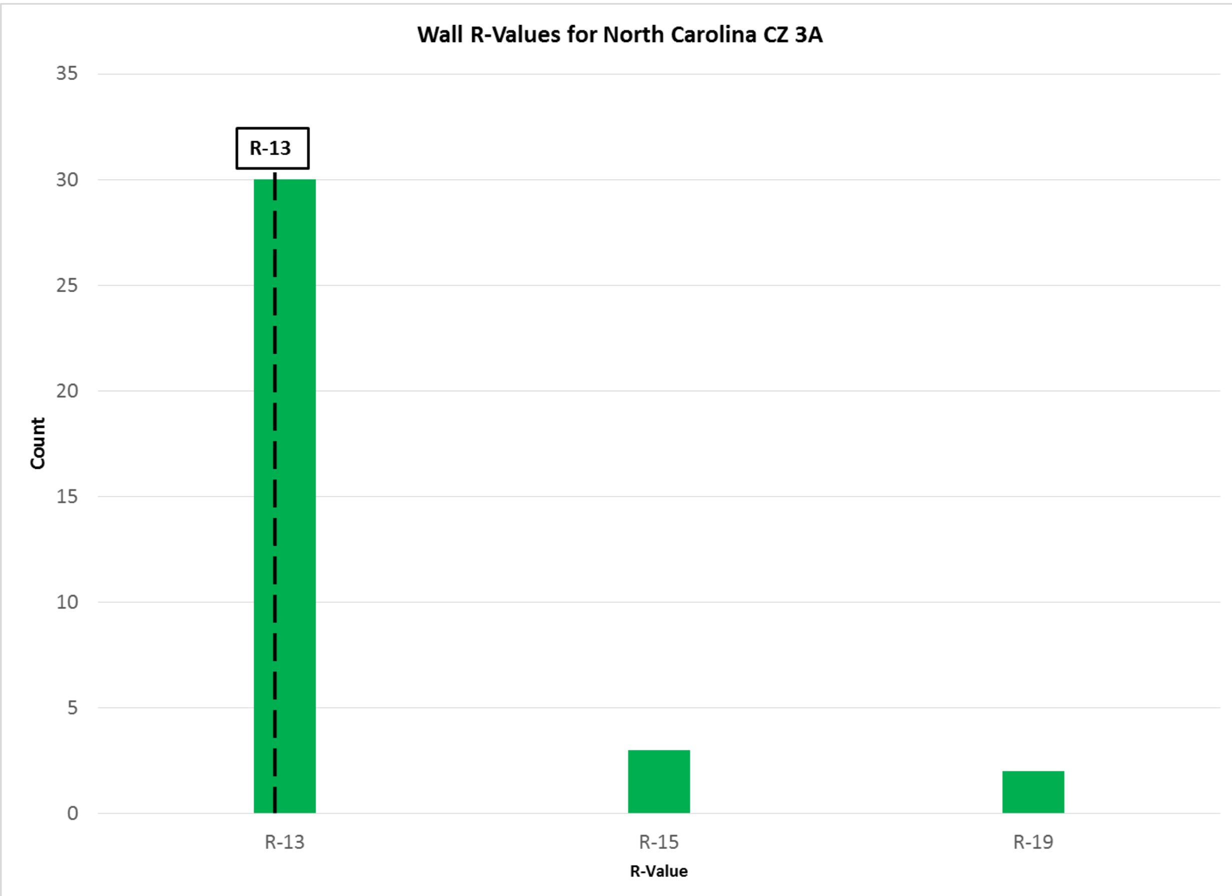

Figure 3.4. North Carolina CZ 3A Wall R-Value Observations

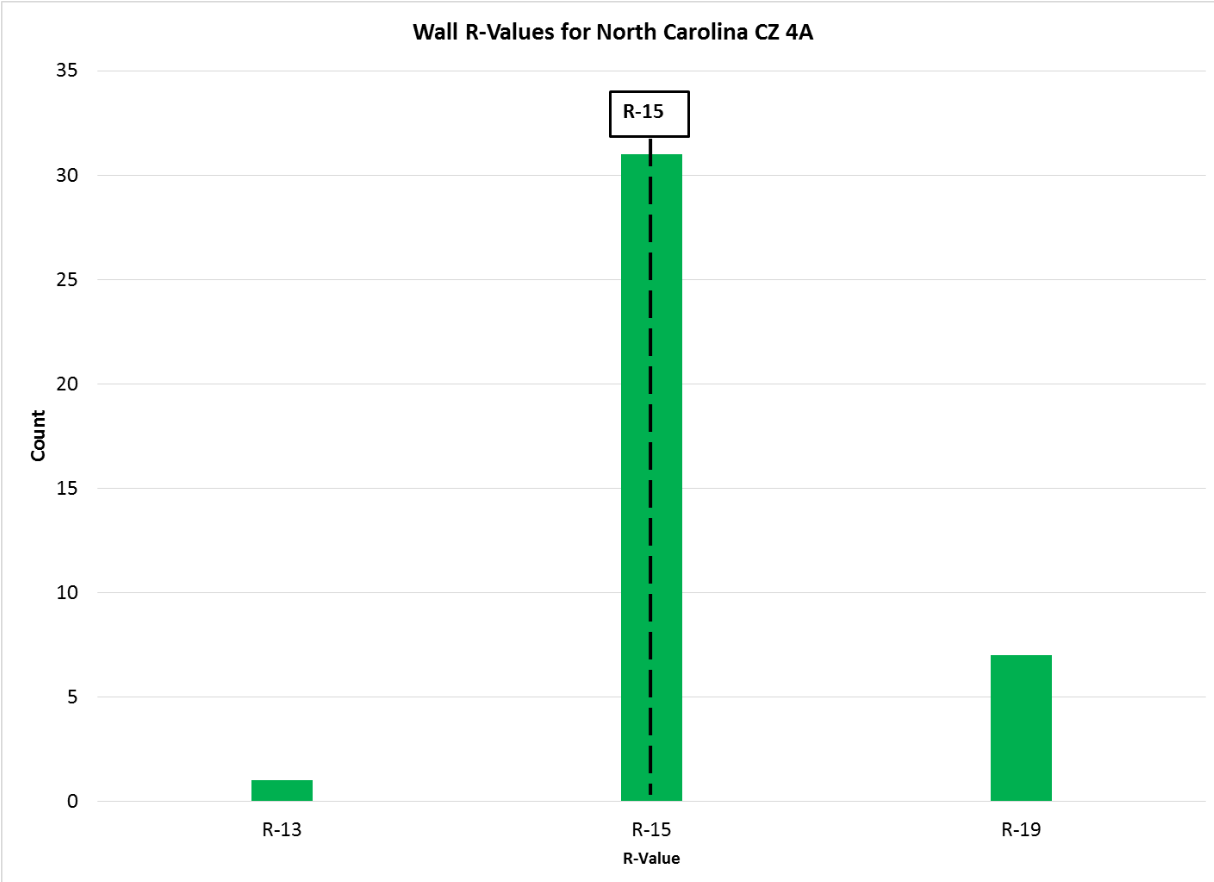

Figure 3.5. North Carolina CZ 4A Wall R-Value Observations

Figure 3.6 and Figure 3.7 represent 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 graphs, observations are binned for clearer presentation based on the most commonly observed combinations.

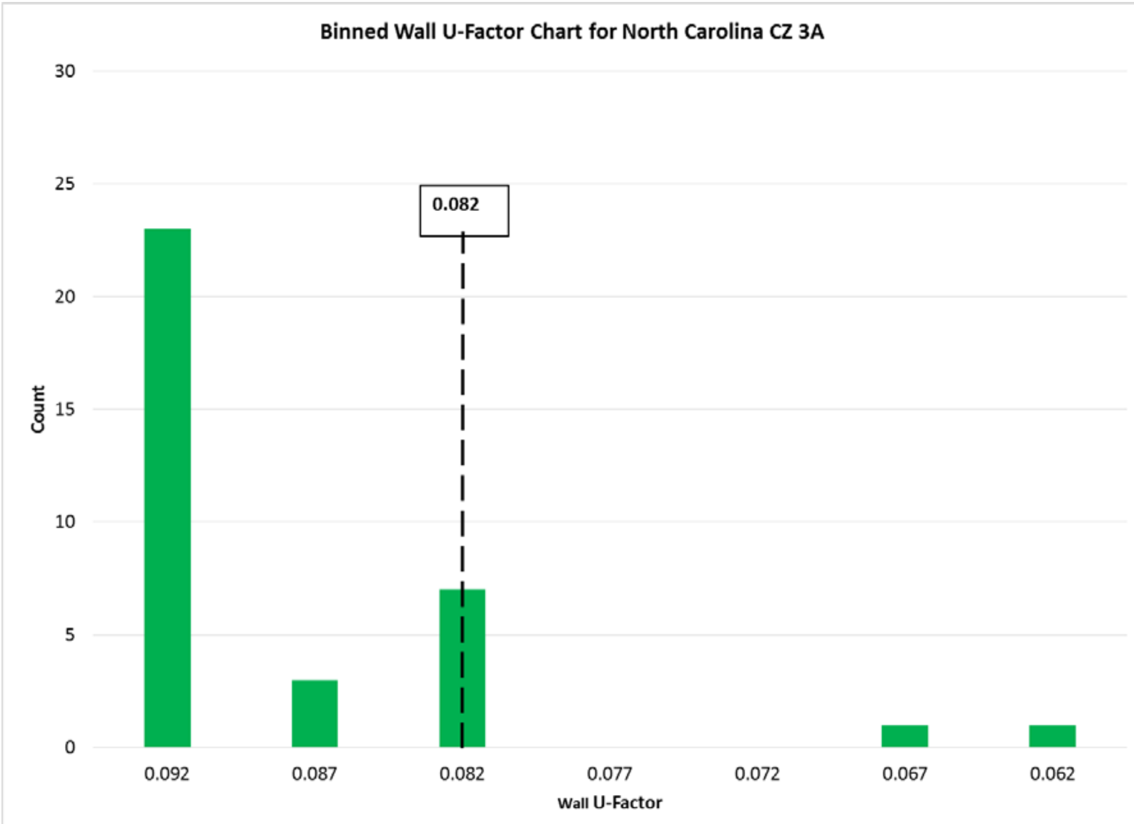

Figure 3.6. North Carolina CZ 3A Wall Assembly Performance, including Wall Insulation Installation Quality

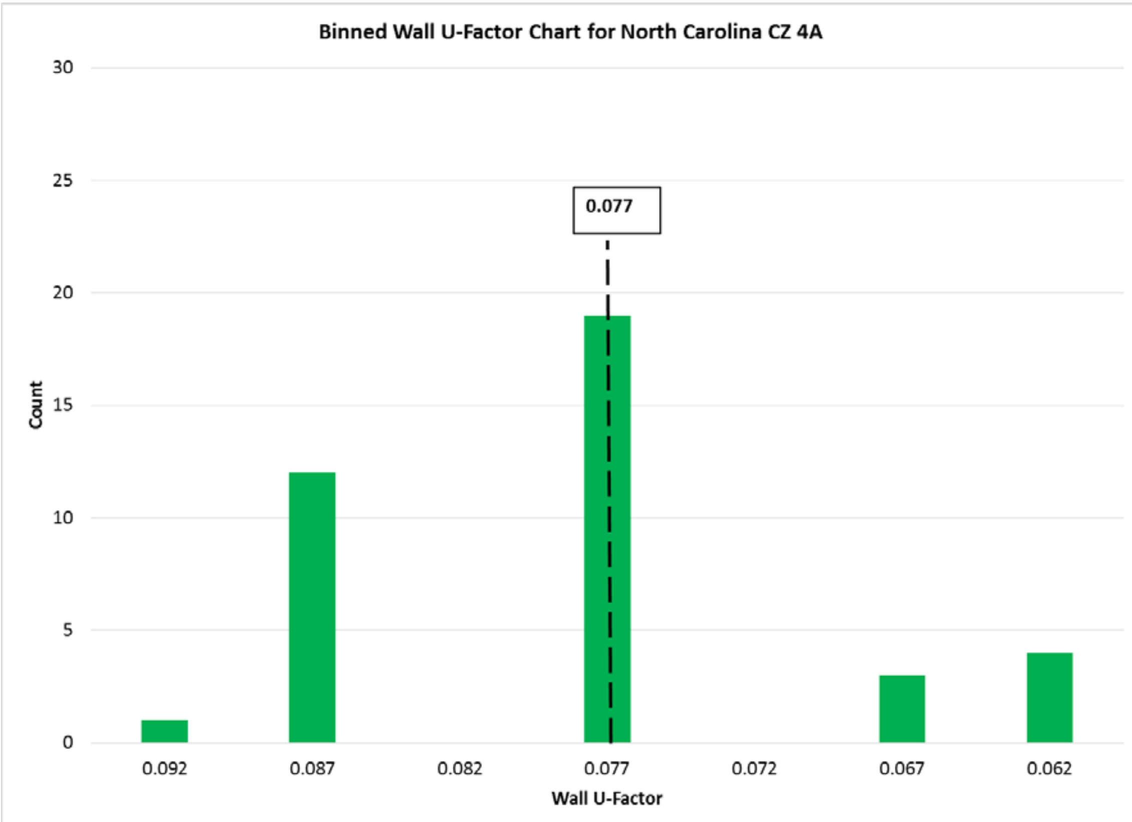

Figure 3.7. North Carolina CZ 4A Wall Assembly Performance, including Wall Insulation Installation Quality

Figure 3.6 and Figure 3.7 combine 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).

Table 3.4. Wall Assemblies

Climate Zone	CZ3	CZ4	Statewide
Number	35	39	74
Range	0.092 to 0.062	0.092 to 0.062	0.092 to 0.062
Average	0.088	0.079	0.083
Assembly U-Factor (expected)	0.082	0.077	0.082 in CZ3 and 0.077 in CZ4
Rate	2 of 35 (6%)	7 of 39 (18%)	9 of 74 (12%)

- **Interpretations:**
  - The cavity insulation requirement is achieved at a high rate—all of the observations in CZ3 and all but one observation in CZ4 meet or exceed the prescriptive code requirement for wall cavity insulation (based on labeled R-value).
  - From an assembly perspective, a majority of observations had Grade II or Grade III insulation installation quality (Table 3.10).

– While the cavity insulation requirement appears to be achieved successfully (R-value), the overall assembly performance (U-factor) exhibits room for improvement—this can be a focal point for future education and training activities in the state.

3.1.1.5 Ceiling R-Value

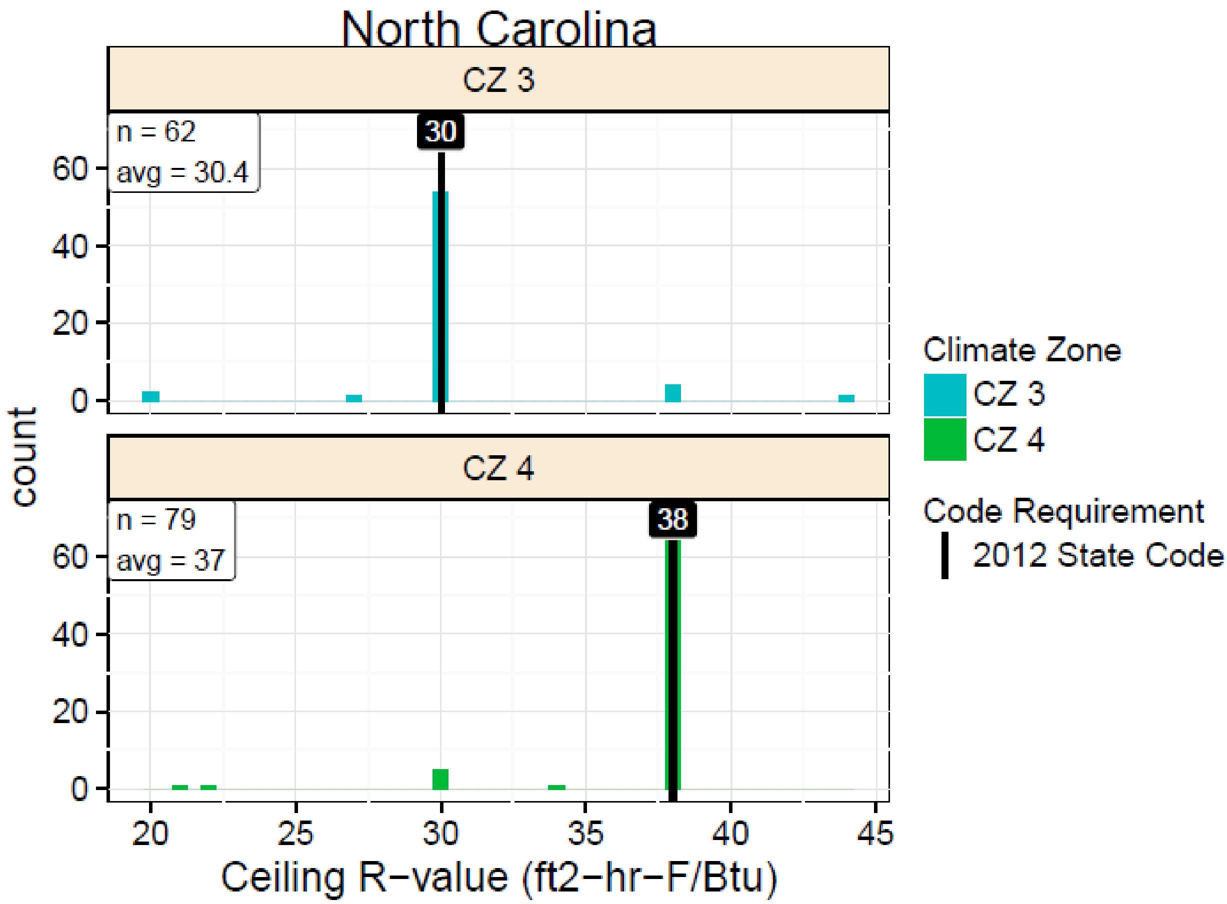

Figure 3.8. Ceiling R-Value

Table 3.5. Ceiling R-Value

Climate Zone	CZ3	CZ4	Statewide
Number	62	79	141
Range	20 to 44	21 to 38	20 to 44
Average	30.4	37.0	34.1
Requirement	30.0	38.0	30.0 in CZ3 and 38.0 in CZ4
Compliance Rate	59 of 62 (95%)	71 of 79 (90%)	130 of 141 (92%)

- **Interpretations:**
  – Nearly all of the observations met the code requirement exactly.

– The cause of the instances of other values in the field is unclear (i.e., product of a performance tradeoff or non-compliance).

– Overall, ceiling insulation does not appear to be an issue in the state, although approximately 30% of observations were noted as Grade II or Grade III on insulation installation quality. Insulation installation quality is an area for improvement which can be addressed through future training and education efforts.

3.1.1.6 Lighting

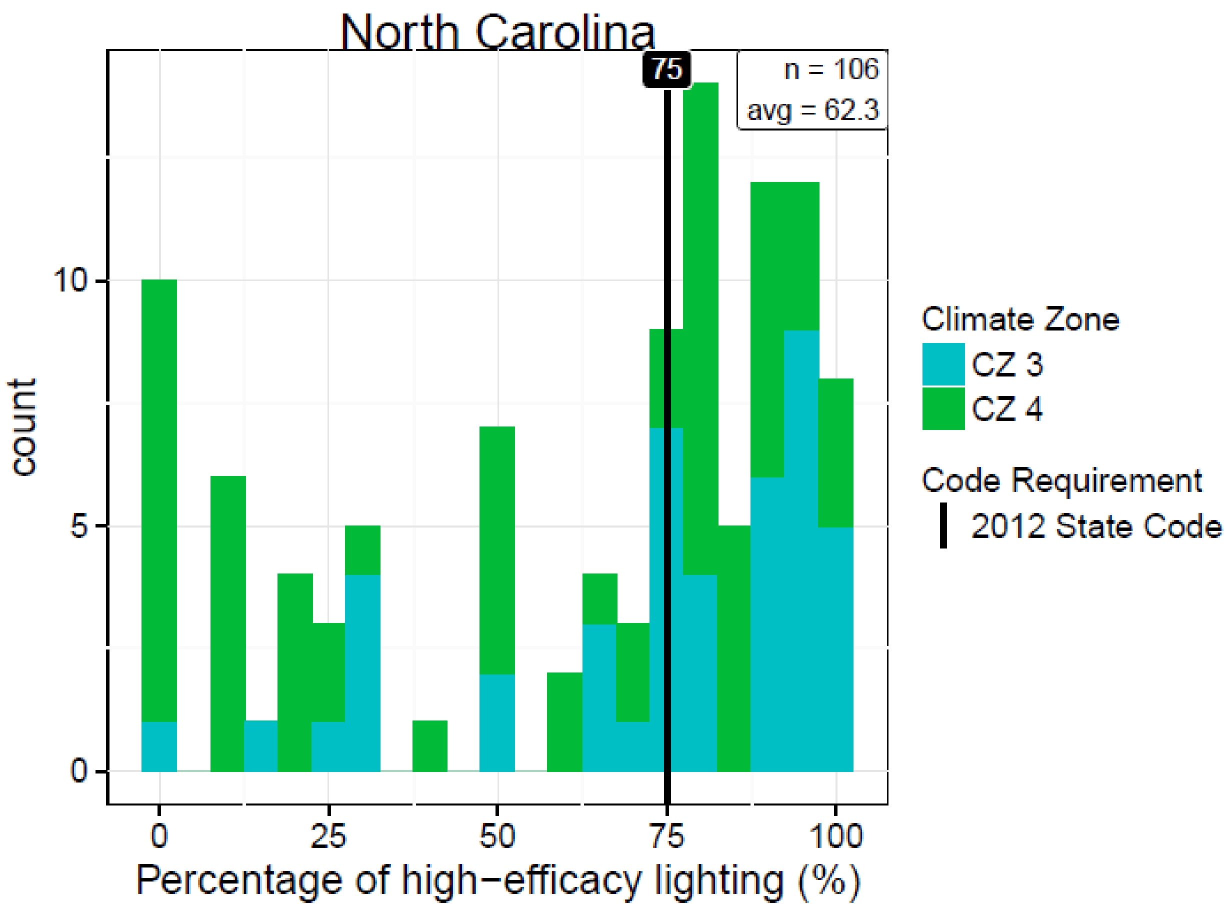

Figure 3.9. High-efficacy Lighting Percentage

Table 3.6. High-efficacy Lighting Percentage

Climate Zone	CZ3	CZ4	Statewide
Number	44	62	106
Range	0 to 100	0 to 100	0 to 100
Average	74.2	53.8	62.3
Requirement	75	75	75
Compliance Rate	31 of 44 (70%)	29 of 62 (47%)	60 of 106 (57%)

- **Interpretations:**
  - A little more than half of the observations met the requirement; a much lower number than expected based on the current code.
  - The most common observations are in the 85-100% range, but there were a significant quantity and wide range of non-compliant observations. Of the 106 total observations, 10 (over 9%) had no high-efficacy lighting whatsoever.
  - Lighting is an area for increased attention in future training and enforcement within the state.

3.1.1.7 Foundations

There were two predominant foundation types observed in North Carolina, slabs on grade and floors. Floors include those observations where floor insulation is installed, such as over vented crawlspaces and unconditioned basements. Two graphs are shown for each climate zone for floors, insulation (R-value) and binned assembly (U-factor). The R-value graph shows the insulation R-values observed. The binned 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. The U-factors are binned to reduce the number of bars in the chart since 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.

Slabs

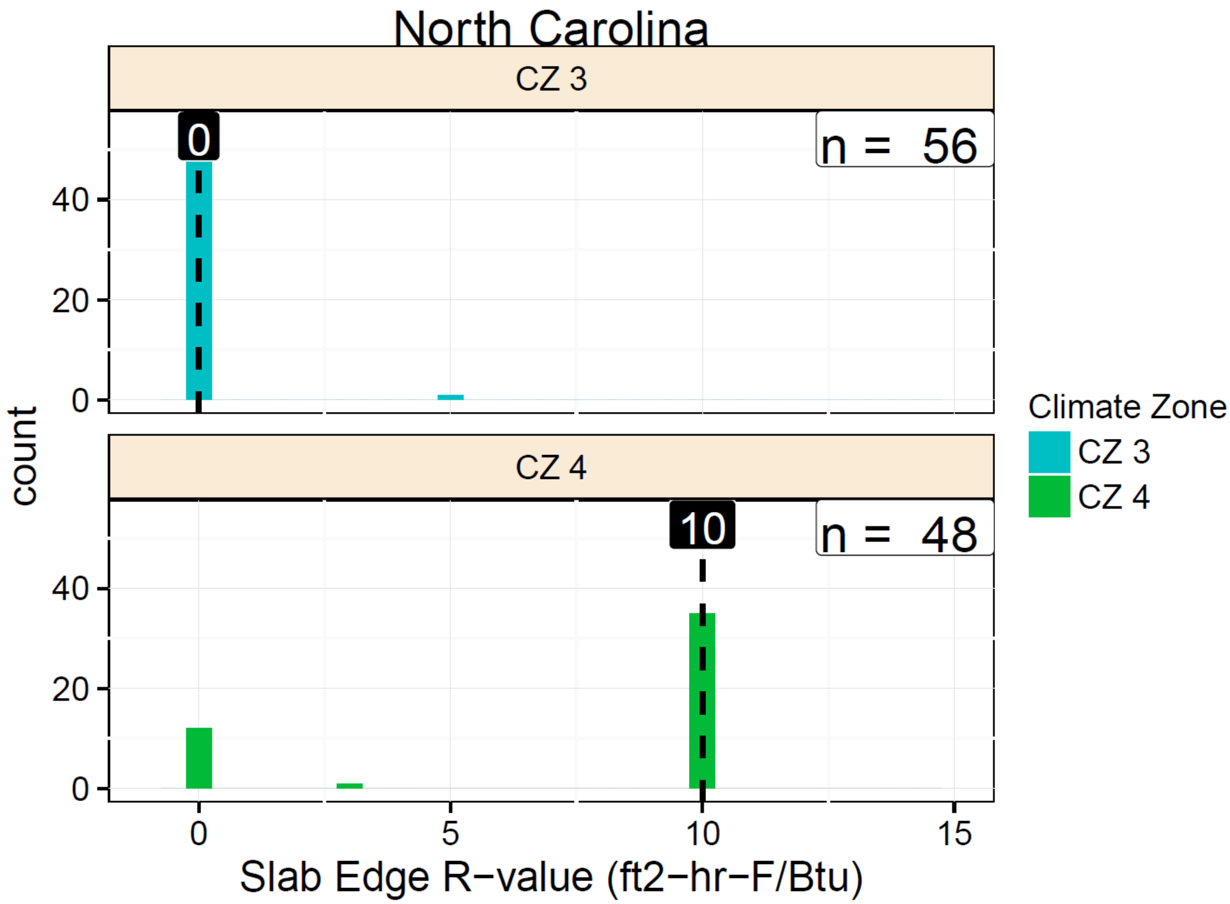

Figure 3.10. Slab Edge Insulation

Table 3.7. Slab Edge Insulation

Climate Zone	CZ3	CZ4	Statewide
Number	56	48	104
Range	0.0 to 5.0	0.0 to 10.0	0.0 to 10.0
Average	0.09	7.4	3.4
Requirement	0*	10.0	10.0
Compliance Rate	56 of 56 (100%)	35 of 48 (73%)	91 of 104 (88%)

*The NC Energy Code lists the requirement in CZ3 as R-0.

- **Interpretations**
  - There appears to be some room for improvement in CZ4 as 12 of the 48 observations had no slab insulation.

The project team noted that slab insulation quality was not an observation on the field study input form; however, field observations and supporting photos reveal that in a number of cases, slab insulation was installed poorly. Energy code training efforts should highlight key steps for quality installation.

Floors

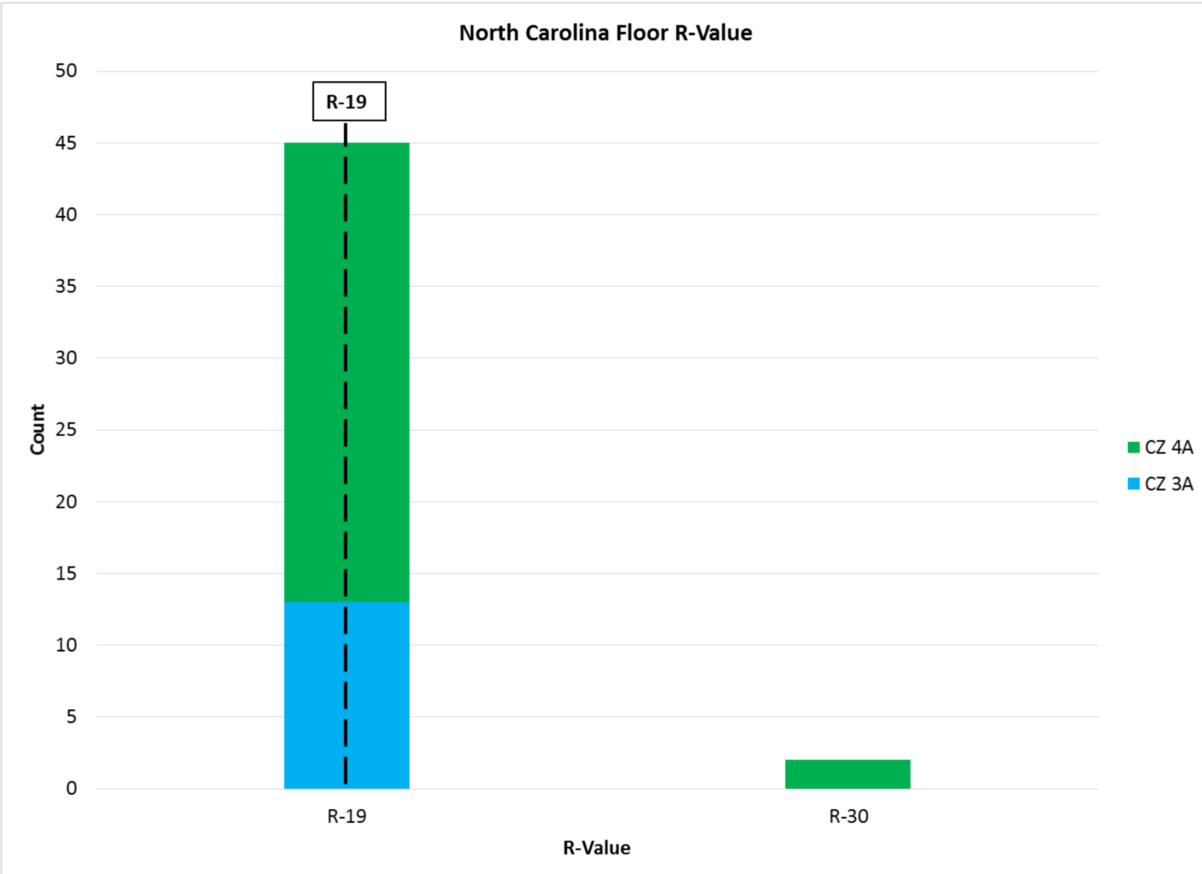

Figure 3.11. Floor R-Values for North Carolina

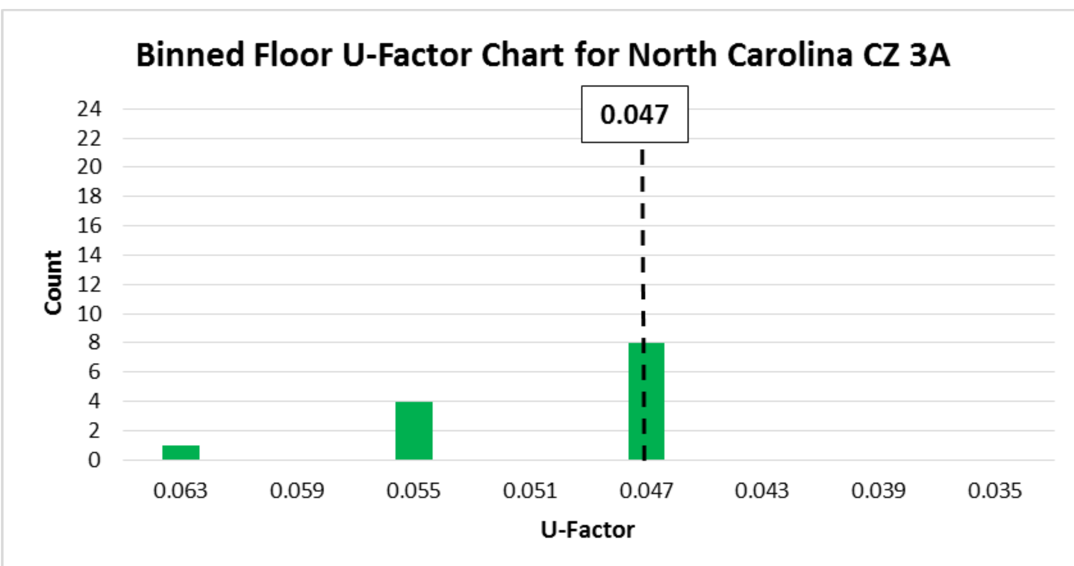

Figure 3.12. Floor Assembly Performance, including Insulation Installation Quality for North Carolina CZ3A

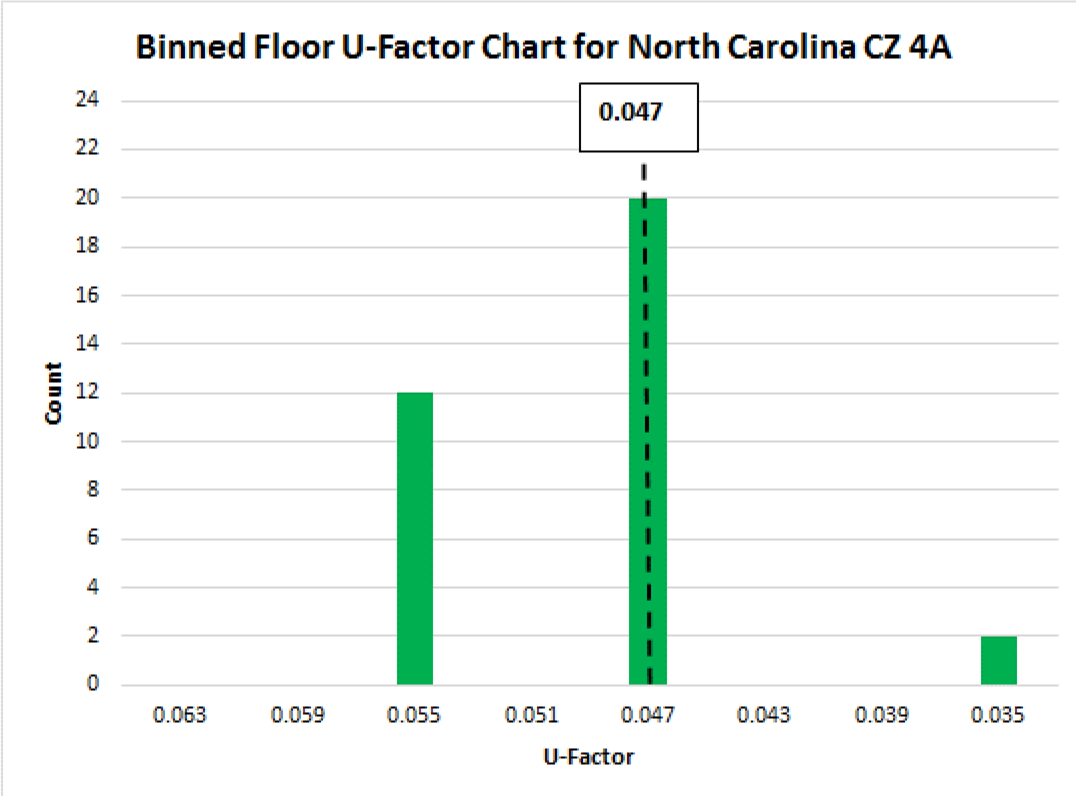

Figure 3.13. Floor Assembly Performance, including Insulation Installation Quality for North Carolina CZ4A

Table 3.8. Floors

Climate Zone	CZ3	CZ4	Statewide
Number	13	34	47
Range	0.064 to 0.047	0.055 to 0.037	0.064 to 0.037
Average	0.051	0.050	0.050
Assembly U-Factor (expected)	0.047	0.047	0.047
Rate	8 of 13 (62%)	20 of 34 (59%)	28 of 47 (60%)

- **Interpretations**
  - The cavity insulation requirement is achieved at a high rate—all observed instances met or exceeded the prescriptive code requirement for wall cavity insulation (based on labeled R-value).
  - From an assembly perspective, the overall assembly performance (U-factor) exhibits room for improvement as over half of the homes with floor insulation had installation quality levels of 2 or 3. Improved installation of floor insulation can be a focal point for future education and training activities in the state.

3.1.1.8 Duct Tightness

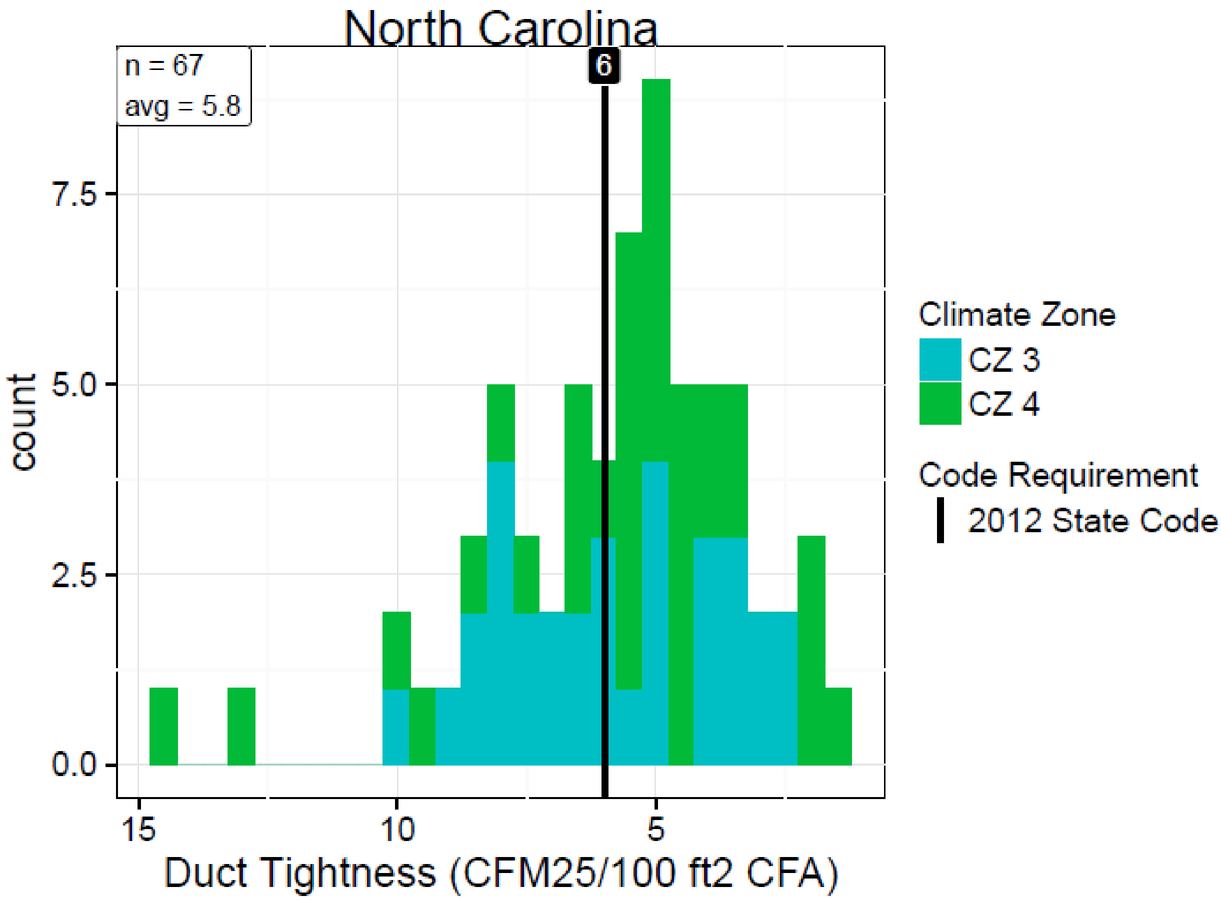

Figure 3.14. Duct Tightness (CFM25/100ft2 CFA)

Table 3.9. Duct Tightness

Climate Zone	CZ3	CZ4	Statewide
Number	32	35	67
Range	9.9 to 2.49	14.4 to 1.70	14.4 to 1.70
Average	5.8	5.3	5.8
Requirement	6.0	6.0	6.0
Compliance Rate	18 of 32 (56%)	25 of 35 (71%)	43 of 67 (64%)

- **Interpretations:**
  - The average total duct leakage was 5.8 CFM25/100 ft^2 for ductwork located in unconditioned space) and 4.8 CFM25/100 ft^2 for ducts located entirely in conditioned space.
  - Overall, 36% of the observations fail to meet the NC Energy Code requirement for duct leakage based on the total duct leakage test.
  - Reductions in duct leakage represent an area for improvement and should be given increased attention in future training and enforcement.

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[2] assessment protocol which has three grades, Grade I being the best quality installation and Grade III being the worst.

Table 3.10 shows the insulation installation quality levels for framed envelope assemblies, as observed in the state. The majority of the observations (196 of 336) were classified as Grade I, indicating that there are areas for improvement.

Table 3.10. Insulation Installation Quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Roof Cavity	98	36	5	**139**
Floor	42	35	1	**78**
Above Grade Wall	31	38	0	**69**
Basement Wall	1	1	1	**3**
Knee Wall	22	21	2	**45**
Crawlspace Wall	2	0	0	**2**

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 C. The full data set is also available on the DOE Building Energy Codes Program website.[3] *The percentages provided in the section below represent percentages of total observations or the percentage of observations that complied.*

3.1.2.1 Average Home

- Size: 2730 ft^2 and 1.80 stories
- Bedrooms: 3.7

[2] See http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf
[3] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study

3.1.2.2 Compliance

- The majority of homes were permitted under the NC 2012 Code (n=248) (99.6%)
- Approximately a third of the homes (32%) participated in an above-code program (n=31)
- Eleven homes were noted as participating in a wide variety of above-code programs such as the Duke Energy HERO and ENERGY STAR for Homes.

3.1.2.3 Envelope

- **Profile:**
  - Walls: All were wood-framed walls with a mix of 4” (86%) and 6” (14%) studs
  - Foundations: Mix of basements (8%), slab-on-grade (55%) and crawlspaces (37%)
- **Successes:**
  - Insulation labeled (n=114) (88%)
  - IC-rated light fixtures sealed (n=97) (93%)
  - Utility penetrations sealed (n=79) (89%)
  - Sealed under knee walls (n=55) (95%)
  - Envelope areas behind bathroom tubs & showers sealed (n=91) (81%)

3.1.2.4 Duct & Piping Systems

- **Profile:**
  - Ducts located within conditioned space (percentage of duct system):
    - Supply: 30% (13 homes entirely within conditioned space) (n=154)
    - Return: 32% (17 homes entirely within conditioned space) (n=178)
  - About 7% of homes located *supply* ducts entirely within conditioned space
  - About 10% of homes located *return* ducts entirely within conditioned space
  - Pipe Insulation (R-value): 3.3 (n=8)
- **Successes:**
  - Building cavities not used as ducts (95%)
  - Air ducts (97%), air handlers (90%), and filter boxes (95%) sealed.
- **Areas for Improvement:**
  - None

3.1.2.5 HVAC Equipment

- **Profile:**
  - Heating: Almost evenly split between gas furnaces with an average efficiency of 84 AFUE and heat pumps with an HSPF of 12.6. All furnaces observed in the study had an efficiency of 80 AFUE or better.

- Cooling: Central AC (60%) and heat pumps (40%) with an average efficiency of 14 SEER
- Water Heating: Mix of gas (42%) and electric (58%) storage with an average capacity of 53 gallons
- Ventilation: Wide variety of systems including exhaust-only (28%) or AHU-integrated (33%), Stand-alone ERV or ERV/HRV (17%) or none (22%).

- **Successes (percentage of observations that complied):**
  - Programmable thermostats installed (100%)
  - User manuals for mechanical systems provided (86%)

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, homes in North Carolina appear to use *more* 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 (dotted line in Figure 3.15) of approximately 22.96 kBtu/ft^2-yr compared to 23.79 kBtu/ft^2-yr for homes exactly meeting minimum *prescriptive* energy code requirements (black line in Figure 3.15). This suggests the EUI for a "typical" home in the state is about 3.5% better than code.

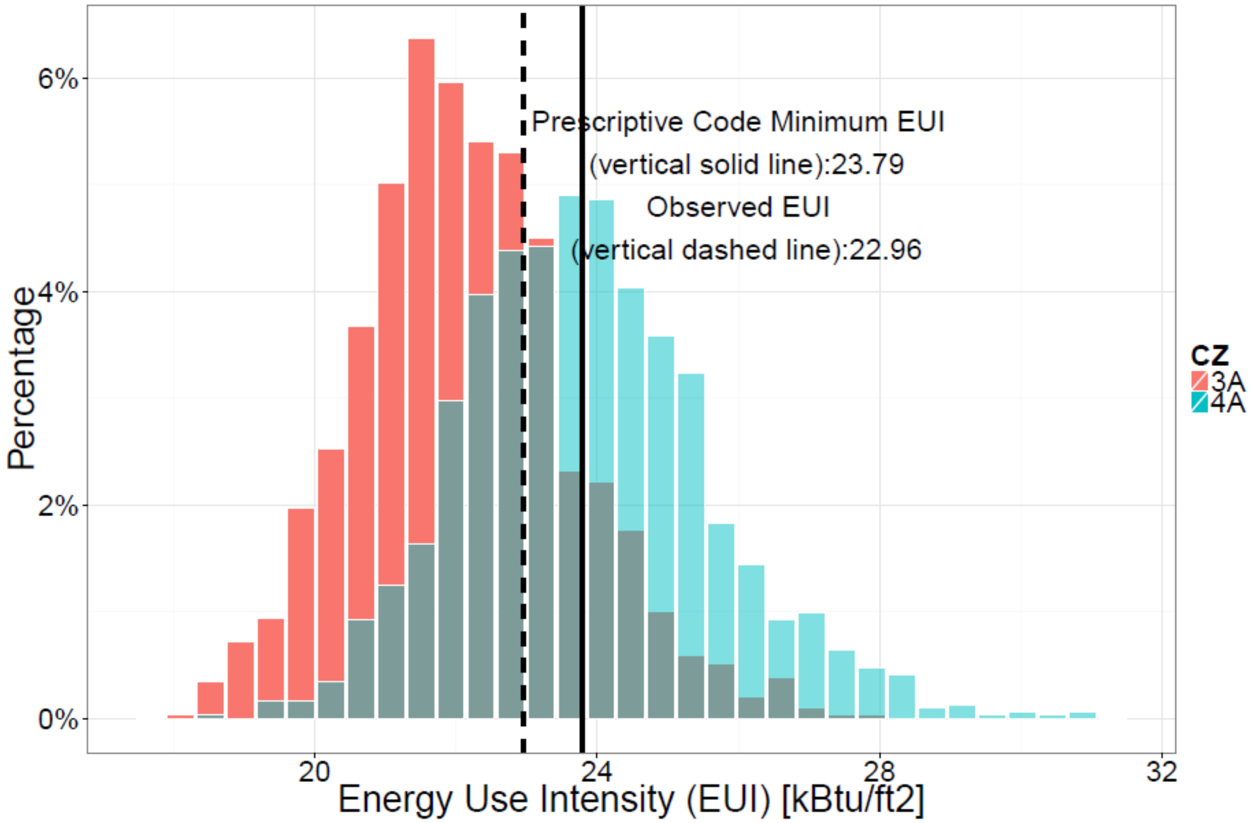

Figure 3.15. Statewide EUI Analysis for North Carolina

3.3 Savings Potential

Those key items with the greatest potential[4], shown below followed by the percent that met code, were analyzed further to calculate the associated savings potential, including energy, cost and carbon savings.

- Envelope Air Leakage (88%),
- Exterior Wall Insulation (48%),
- Duct Leakage (62%),
- Lighting (57%), and
- Foundations
  - Slabs (87%), and
  - Floor Insulation (60%).

For analytical details refer to Section 2.3.3 (Savings Analysis) or the methodology report (DOE 2016).

Estimated savings resulting from the analysis are shown below in order of highest to lowest total energy, cost and carbon savings (Table 3.11). As can be seen, there are significant savings opportunities, with the

[4] Defined here as those items with less than 85% of observations meeting the prescriptive code requirement. Some insulation measures were also included when a significant number of observations had insulation installation quality of Grades II or III.

greatest total savings potential associated with these measures. In addition, Table 3.12 shows the total savings and emissions reductions that will accumulate over 5, 10, and 30 years of construction.

Table 3.11. Statewide Annual Measure-Level Savings for North Carolina

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)
Lighting	3A	172	-1	467	15,585	7,278	272,595	1,751
	4A	170	-1	453	14,444	6,545	248,239	1,597
	State Total	**171**	**-1**	**460**	**30,029**	**13,822**	**520,839**	**3,349**
Exterior Wall Insulation	3A	43	2	390	15,585	6,074	117,542	663
	4A	106	6	987	14,444	14,252	273,428	1,537
	State Total	**73**	**4**	**677**	**30,029**	**20,318**	**390,827**	**2,199**
Duct Leakage	3A	69	3	514	15,585	8,016	168,649	973
	4A	75	3	533	14,444	7,704	165,886	962
	State Total	**72**	**3**	**523**	**30,029**	**15,720**	**334,527**	**1,935**
Envelope Air Leakage	3A	30	3	371	15,585	5,777	99,705	542
	4A	37	3	443	14,444	6,398	111,627	609
	State Total	**33**	**3**	**405**	**30,029**	**12,174**	**211,315**	**1,152**
Foundation Insulation*	3A	0	0	0	8,869	0	0	0
	4A	34	4	478	8,219	3,929	65,143	349
	State Total	**16**	**2**	**230**	**17,088**	**3,925**	**65,086**	**349**
TOTAL		**365**	**11**	**2,295**	**Varies**	**65,959**	**1,522,594**	**8,984**

*For North Carolina, foundation insulation is represented by slab-on-grade insulation.

Table 3.12. Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings for North Carolina

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
	5yr	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Lighting	207,334	760,226	6,427,365	7,812,578	28,646,119	242,189,912	50,233	184,186	1,557,210
Exterior Wall Insulation	304,775	1,117,508	9,448,021	5,862,405	21,495,485	181,734,554	32,989	120,961	1,022,672
Duct Leakage	235,797	864,589	7,309,708	5,017,899	18,398,965	155,554,884	29,028	106,435	899,859
Envelope Air Leakage	182,605	669,553	5,660,763	3,169,726	11,622,328	98,261,500	17,275	63,342	535,530
Foundation Insulation	58,879	215,891	1,825,259	976,297	3,579,756	30,265,206	5,238	19,205	162,371
TOTAL	**989,391**	**3,627,766**	**30,671,115**	**22,838,905**	**83,742,652**	**708,006,057**	**134,763**	**494,130**	**4,177,641**

4.0 Conclusions

The North Carolina field study provides an enhanced understanding of statewide code implementation, and suggests that significant savings are available through increased compliance with the North Carolina energy code. From a statewide perspective, the average home in North Carolina uses about 3.5% 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 65,959 MMBtu, which equates to $1,522,594 in cost savings, and emission reductions of 8,984 MT CO2e. Over a 30-year period, these impacts grow to over 30 million MMBtu, over $700 million, and over 4.1 million metric tons CO2e in avoided emissions.

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

Table 4.1. Annual Statewide Savings Potential in North Carolina

		Annual Savings		
	Key Measure	**Energy** (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
1	Lighting	13,822	520,839	3,349
2	Exterior Wall Insulation	20,318	390,827	2,199
3	Duct Leakage	15,720	334,527	1,935
4	Envelope Air Leakage	12,174	211,315	1,152
5	Foundation Insulation	3,925	65,086	349
	Total	**65,959 MMBtu**	**$1,522,594**	**8,984 MT CO2e**

5.0 References

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Appendix A

Stakeholder Participation

Appendix A

Stakeholder Participation

Table A.1. Stakeholder Participation in Project Kickoff Meeting

Stakeholder	Description
Appalachian State Energy Center	The mission of the Appalachian Energy Center (AEC) is to conduct applied research and to provide services and education in support of the development and deployment of clean energy technologies, policies, and economies. The AEC team coordinated and held the meeting.
Duke Energy	An electric power holding company headquartered in Charlotte, North Carolina.
NC Homebuilders Association	A trade association consisting of builder and associate member-firms and a network of local builder associations and chapters throughout North Carolina; affiliated with the National Association of Home Builders.
NC Department of Insurance	A state agency that regulates the insurance industry and also houses the Office of State Fire Marshal. The Insurance Commissioner serves as State Fire Marshal and duties include helping to improve building codes.
NC Building Performance Association	A not-for-profit association of North Carolina home and building performance professionals and companies seeking to lead high performance construction in the state through quality construction, workforce development, political advocacy, public education and more.
North Carolina Clean Energy Technology Center	A UNC System-chartered Public Service Center administered by the College of Engineering at North Carolina State University. Its mission is to advance a sustainable energy economy by educating, demonstrating and providing support for clean energy technologies, practices, and policies.
North Carolina Sustainable Energy Association	A non-profit membership organization working on public policy change and driving market development.
Greenville Utilities	A municipal electric utility company in eastern North Carolina.
PSNC Energy	A natural gas utility company with offices in Raleigh.
Piedmont Natural Gas	A natural gas utility company with offices in Charlotte.
Yellow Dot	A major HVAC contractor for new homes in North Carolina.
Energy efficient builders	Several homebuilders who specialize in high efficiency homes attended.
Above and Beyond Energy	Eastern and central NC Home Energy Rating company
Environmental Solutions Group	Central NC Home Energy Rating company

Appendix B

State Sampling Plan

Appendix B

State Sampling Plan

Table B.1. State Sampling Plan

Location	Sample	Actual
Asheville, Buncombe	1	1
Beaufort County Unincorporated Area, Beaufort	1	1
Brunswick County Unincorporated Area, Brunswick	1	1
Burlington, Alamance	1	1
Cabarrus County, Cabarrus	3	3
Cary town, Wake	4	4
Cumberland County Unincorporated Area, Cumberland	2	2
Durham, Durham	3	3
Fayetteville, Cumberland	1	1
Forsyth County Unincorporated Area, Forsyth	3	3
Fuquay-Varina town, Wake	2	2
Gaston County Unincorporated Area, Gaston	1	1
Greensboro, Guilford	2	2
Guilford County Unincorporated Area, Guilford	1	1
Haywood County Unincorporated Area, Haywood	1	1
Henderson County, Henderson	1	1
High Point, Guilford	1	1
Iredell County, Iredell	2	2
Jacksonville, Onslow	1	1
Leland town, Brunswick	1	1
Mecklenburg County, Mecklenburg	6	6
Montgomery County, Montgomery	1	1
Morrisville town, Wake	1	1
New Hanover County Unincorporated Area, New Hanover	2	2
Onslow County Unincorporated Area, Onslow	3	3
Pender County Unincorporated Area, Pender	1	1
Raleigh, Wake	3	3
Southern Pines town, Moore	1	1
Southport, Brunswick	1	1
Transylvania County, Transylvania	1	1
Union County Unincorporated Area, Union	1	1
Wake County Unincorporated Area, Wake	3	3
Wake Forest town, Wake	3	3
Waxhaw town, Union	2	2
Winston-Salem, Forsyth	1	1
Totals	**63**	**63**

Appendix C

Additional Data

Appendix C

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 North Carolina 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=231): 2730 ft^2
- Number of Stories (n=246): 1.8
- Number of Bedrooms (n=137): 3.7

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	0.4%	21.6%	44.2%	25.1%	8.7%

Table C.2. Number of Stories

No. of Stories	1	1.5	2	2.5	3	4+
Percentage	15.9%	16.7%	61.8%	2.0%	3.3%	0.4%

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

Table C.3. Number of Bedrooms

No. of Bedrooms	1	2	3	4	5+
Percentage	12%	0%	7%	77%	0.5%

C.1.1.2 Wall Profile

- Framing Type (n=238):
  - *All* were framed construction (100%)
- Framing Material (n=223):
  - Wood (100%)
  - Steel (0%)
- Framing Depth (n=207):
  - 4” (86%)
  - 6” (14%)
- Type of Wall Insulation (n= 74)
  - Cavity Only (100%)
  - Cavity + Continuous (0%)
  - Continuous Only (0%)

C.1.1.3 Foundation Profile

- Foundation Type (n=249):
  - Basement (8%)
  - Slab on Grade (55%)
  - Crawlspace (37%)
- Basement Type (n=15):
  - Conditioned (47%)
  - Unconditioned (53%)

C.1.1.4 Other

- *Very few* (2%) had a pool or spa (n=84)
- *None* had a sunroom (n=61)

C.1.1.5 Builder Profile

- Average number of Homes Built Annually (n=227): 90 homes

Table C.4. Number of Homes Built by Builder (annually)

No. of Homes per Year	< 10	10 to 50	50 to 99	100+
Percentage	4%	32%	10%	55%

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= 248):

Table C.5. Energy Code Used

Energy Code	2009 IECC	NC 2012
Percentage	0.4%	99.6%

- Was the home participating in an above-code program (n=31)?
  - Yes (32%)*
  - No (69%)

  * Six different above code programs were listed - ENERGY STAR for Homes program[1] (2 homes), HERS rating (2 homes), Eco Select (1 home), NAHB Green (1 homes), System Vision (1 home), and Duke Energy HERO program (4 homes)

C.1.2.2 Compliance Path Used (n=45)

- Prescriptive (89%)
- RES*check* (9%)
- Performance (2%)

C.1.3 Envelope

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

C.1.3.1 Insulation Labels

- Insulation labeled (n=114) (88%)

[1] *See* https://www.energystar.gov/index.cfm?c=new_homes.hm_index

C.1.3.2 Air Sealing[1]

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

- Openings around windows and doors sealed (n=74) (92%)
- Utility penetrations sealed (n=79) (89%)
- Dropped ceilings sealed (n=70) (86%)
- Ceiling systems under knee walls sealed (n=55) (95%)
- Garage walls and ceilings sealed (n=74) (81%)
- Envelope behind tubs and showers sealed (n=91) (81%)
- Other sources of infiltration sealed (n=86) (74%)
- IC-rated fixtures sealed (n=97) (93%)

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=184): 30% (13 homes with systems located entirely within conditioned space)
  - *Return* (n=178): 32% (17 homes with systems located entirely within conditioned space)
- Duct Insulation (R-value):
  - *Supply* (n=190): 8
  - *Return* (n=191): 8
- Pipe Insulation (R-value):
  - *Most* responses a value of R3.3 (n=8)
- Building cavities not used as ducts (n=78) (95%)
- Air ducts sealed (n=156) (97%)
- Air handlers sealed (n=162) (90%)
- Filter boxes sealed (n=59) (95%)

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

C.1.5 HVAC Equipment

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

C.1.5.1 Heating

- Fuel Source (n=177):
  - Gas (54%)
  - Electricity (46%)
- System Type (n=177):
  - Furnace (56%)
  - Heat Pump (44%)
- Average System Capacity (n=28):
  - Furnace: 72,000 Btu/hr
  - Heat Pump: 42,700 Btu/hr
- Average System Efficiency (n=79):
  - Furnace: 84 AFUE (*all* observed furnaces had an efficiency of 80 AFUE or better)
  - Heat Pump: 12.6 HSPF

C.1.5.2 Cooling

- System Type (n=164):
  - Central AC (60%)
  - Heat Pump (40%)
- Average System Capacity (n=47):
  - 45,300 Btu/hr
- Average System Efficiency (n=52):
  - 13.9 SEER (observations ranged from 13 to16.25 SEER)

C.1.5.3 Water Heating

- Fuel Source (n=112):
  - Gas (42%)
  - Electric (58%)
- System Type (n=108):
  - Storage (85%)
  - Tankless (15%)
- System Capacity (n=88):
  - Average Storage: 53 gallons (observations ranged from 40 to 80 gallons)

Table C.6. Water Heating System Storage Capacity Distribution

Capacity	< 50 gal	50-59 gal	60-69 gal	70-79 gal	80-89 gal	90+ gal
Percentage	7%	80%	0%	2%	10%	0%

C.1.5.4 Ventilation

- System Type (n=18):
  - Exhaust Only (28%)
  - AHU-Integrated (33%)
  - Standalone ERV/HRV (11%)
  - Standalone ERV (6%)
  - None (22%)
- Exhaust Fan Type (n=3):
  - Dedicated Exhaust (0%)
  - Bathroom Fan (100%)

C.1.5.5 Other

- Mechanical manuals provided (n=102) (86%)
- Programmable thermostat installed (n=65) (100%)

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