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Alabama Residential Energy Code Field Study: Baseline Report

January 2017

R Bartlett
M Halverson
V Mendon
J Hathaway
Y Xie
M Zhao

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

A research project in the state of Alabama 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 March 2014, and continued through May 2014. During this period, research teams visited 134 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 nearly $1.3 million in potential savings to Alabama 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 the Institute for Market Transformation (IMT) with support from the Alabama Department of Economic and Community Affairs (ADECA), Cadmus, the Institute for Building Technology and Safety and Calhoun Community College. 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 distributions 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.

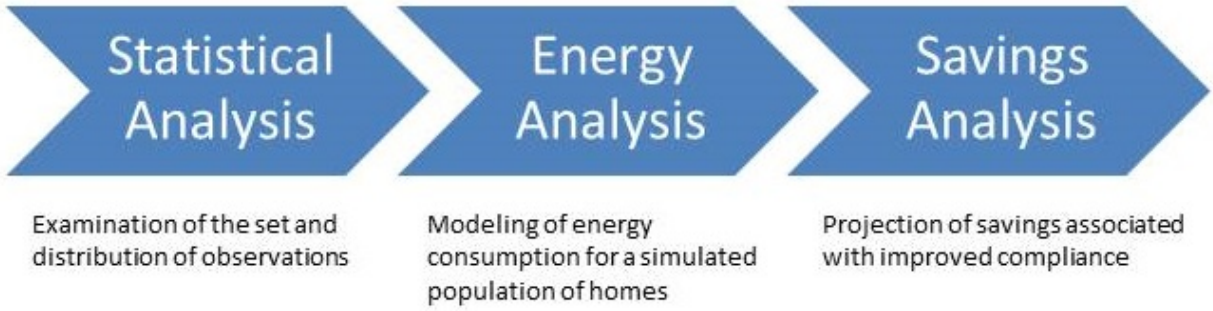

Figure ES.1. Stages of Analysis Applied in the Study

At the time of the study, the state energy code was based on the 2009 International Energy Conservation Code (IECC). Following data collection, the state adopted an updated energy code, known as the 2015

Alabama Residential Energy Code.[1] All data in this study was collected from homes permitted under the 2009 code; potential savings, however, were calculated against the 2015 code, as that is the code that homes will need to comply with in the future, and that will be the focus of ongoing training within the state.

The savings noted in Table ES. 1 and the results noted in Figure ES.2 are based on the 2015 Alabama code. For illustrative purposes, some of the results presented in other sections of this report are based on the 2009 IECC, as noted.

Results

The key items with the greatest potential for savings in Alabama are presented below (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 Alabama (2015 AL Code)

Measure	**Total Energy Savings** (MMBtu)	**Total Energy Cost Savings** ($)	**Total State Emissions Reduction** (MT CO2e)
Duct Leakage	14,420	395,063	2,272
Lighting	10,891	385,451	2,408
Envelope Air Leakage	11,207	263,089	1,417
Exterior Wall Insulation	8,022	201,105	1,116
Window SHGC	1,309	54,674	356
TOTAL	**45,849 MMBtu**	**$1,299,382**	**7,569 MT CO2e**

Simulation analysis of the collected field data indicates an average regulated energy use intensity (EUI) of 19.67 kBtu/ft^2-yr statewide for the homes that are being built in the state today. This compares favorably to the 22.4 kBtu/ft^2-yr that would be expected if homes were constructed to just meet the minimum requirements of the 2009 IECC. Put another way, homes being built in the state today use 12% less energy than expected under the old state code. Compared to the more stringent 2015 Alabama code, however, new homes are using 8% more energy, making it clear that substantial savings opportunities exist as the new code is implemented.

[1] The 2015 Alabama Residential Energy Code is based on the 2015 IECC with state amendments and is available at http://adeca.alabama.gov/Divisions/energy/energycodes/Energy%20Codes/2015%20Alabama%20Residential%20Energy%20Code%20(effective%2010-1-16).pdf

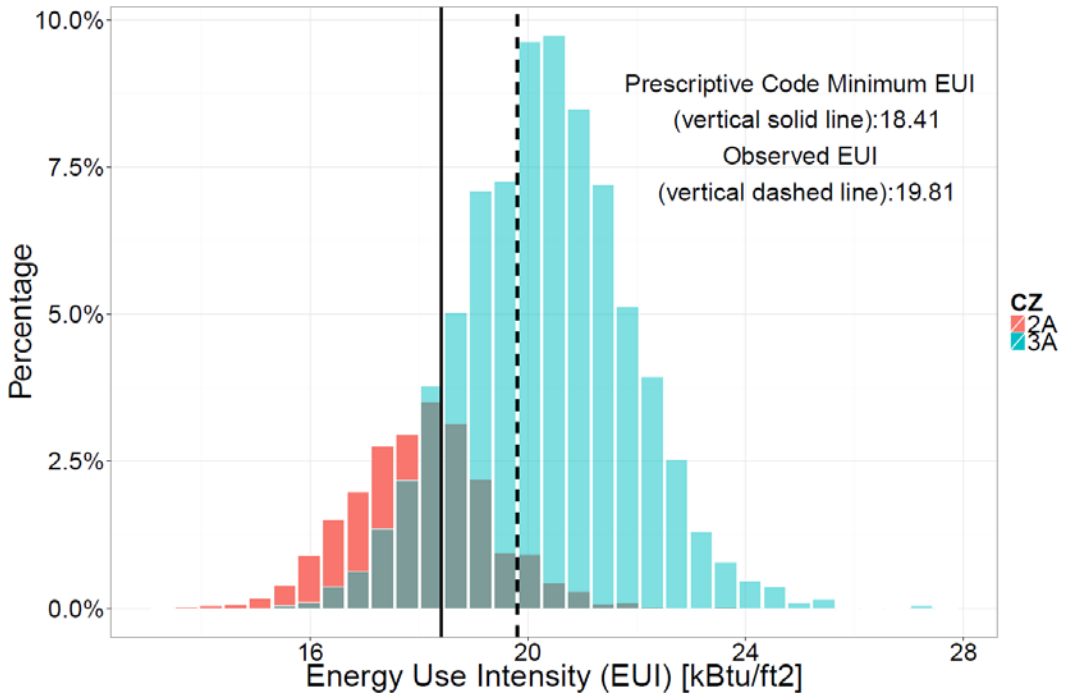

Figure ES.2. Modeled Distribution of Regulated EUI (kBtu/ft^2/year) in Alabama (2015 AL Code)

Acknowledgements

The following members comprised the Alabama project team:

- Ryan Meres, *Institute for Market Transformation (IMT)*
- Heather Goggin, *Alabama Department of Economic and Community Affairs (ADECA)*
- Jeff Domanski, *Institute for Building Technology and Safety*
- Jerry Adams, *Calhoun Community College*
- *Cadmus Group (Cadmus)*

IMT

The Institute for Market Transformation is a Washington, DC-based nonprofit founded in 1996. They promote energy efficiency, green building, and environmental protection in the United States and abroad. The prevailing focus of IMT's work is energy efficiency in buildings. Specific activities include technical and market research, policy and program development, and promotion of best practices and knowledge exchange. In particular, IMT aims to strengthen market recognition of the link between buildings' energy efficiency and their financial value. More information on IMT is available at http://www.imt.org/.

ADECA

The Alabama Department of Economic and Community Affairs was created by the Legislature as an arm of the Governor's Office in 1983. The Legislature established ADECA to streamline the management of a number of programs administered by the state. ADECA is responsible for administering a broad range of state and federal programs that contribute to the department's mission — Building Better Alabama Communities. Find additional information on ADECA at http://adeca.alabama.gov/Pages/default.aspx.

IBTS

The Institute for Building Technology & Safety is a 501(c)(3) nonprofit organization established to provide unbiased professional building code compliance services directly to, or on behalf of, government agencies at all levels. These services include inspections, plan reviews, building department services, education and training, staff augmentation, policy and procedure development, cost evaluation, energy ratings, and auditing. More information is available at http://www.ibts.org/.

Calhoun Community College

Calhoun Community College is a technical college located in Decatur, AL, offering 49 associate degree options and 52 career/certificate programs. The Alabama Center for Excellence in Clean Energy Technology at Calhoun Community College offers students and industry professionals training and education in the latest renewable energy and energy efficiency technologies and practices.

Cadmus

The Cadmus Group, Inc. was founded in 1983 in Watertown, MA. They provide services in the areas of energy, environment, high performance building, sustainability, public health, and strategic communications. See more information on Cadmus at https://www.cadmusgroup.com/.

Acronyms and Abbreviations

AC	air conditioning
ACH	air changes per hour
ADECA	Alabama Department of Economic and Community Affairs
AERC	Alabama Energy and Residential Codes Board
AL	Alabama
AFUE	annual fuel utilization efficiency
AHU	air handling unit
Btu	British thermal unit
cfm	cubic feet per minute
COAA	Code Officials Association of Alabama
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
HBAA	Home Builders Association of Alabama
HSPF	heating season performance factor
IBTS	Institute for Building Technology and Safety
ICC	International Code Council
IECC	International Energy Conservation Code
IMT	Institute for Market Transformation
kBtu	thousand British thermal units
MMBtu	million British thermal units
MT	metric ton
NA	not applicable
PNNL	Pacific Northwest National Laboratory
RFI	request for information
SHGC	solar heat gain coefficient
TSD	technical support document

Contents

Executive Summary iii
Acknowledgements vii
Acronyms and Abbreviations ix
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 2.7
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 3.11
3.2 Energy Intensity 3.12
3.3 Savings Potential 3.14
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 Alabama Wall Assembly Performance, including Wall Insulation Installation Quality 3.6
3.5 Ceiling R-Value 3.7
3.6 High-efficacy Lighting Percentage 3.8
3.7 Duct Tightness 3.9
3.8 Statewide EUI Analysis for Alabama (2009) 3.13
3.9 Statewide EUI Analysis for Alabama (2015) 3.13

Tables

3.1 Envelope Tightness 3.2
3.2 Window SHGC 3.3
3.3 Window U-Factor 3.5
3.4 Frame Wall Assembly 3.6
3.5 Ceiling R-Value 3.7
3.6 High-efficacy Lighting Percentage 3.8
3.7 Duct Tightness 3.9
3.8 Insulation Installation Quality 3.10
3.9 Statewide Annual Measure-Level Savings for Alabama 3.14
3.10 Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings for Alabama 3.15
4.1 Annual Statewide Savings Potential in Alabama 4.1

1.0 Introduction

A research project in the state of Alabama 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 Alabama field study was initiated in March 2014, and continued through May 2014. During this period, research teams visited 134 homes across the state during various stages of construction. At the time of the study, the state energy code was based on the 2009 International Energy Conservation Code (IECC) with some amendments. Following data collection, the state proceeded in adopting an updated energy code, known as the 2015 Alabama Residential Energy Code.[2] All data in this study was collected from homes permitted under the 2009 code; however, potential savings were calculated against the 2015 code as that is what future homes are required to comply with.

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".[3] 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:

- Conducting a baseline field study to determine installed energy values of code-required items, identify issues, and calculate savings opportunities;
- Implementing education, training, and outreach activities designed to increase code compliance; and
- 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.[4,5] 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.[6]

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[2] The 2015 Alabama Residential Energy Code is based on the 2015 IECC with state amendments and is available at http://adeca.alabama.gov/Divisions/energy/energycodes/Energy%20Codes/2015%20Alabama%20Residential%20Energy%20Code%20(effective%2010-1-16).pdf

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

[4] *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

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

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

1.2 Project Team

The Alabama project was led by the Institute for Market Transformation (IMT), with support from the Alabama Department of Economic and Community Affairs (ADECA), and field data collected by Cadmus. The Institute for Building Technology and Safety and Calhoun Community College provided outreach, education and training efforts. 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 Alabama 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 following analysis, trends and issues are identified, which can inform energy code training and other compliance-improvement programs.

Highlights of the methodology:

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

PNNL identified the code requirements (and associated energy efficiency measures) with the greatest direct impact on residential energy consumption.[7] These *key items* drive sampling, data analysis, and eventual savings projections:

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. Foundation insulation (R-value)[8]
8. 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.

[7] Based on the *mandatory* and *prescriptive* requirements of the International Energy Conservation Code (IECC)
[8] Floor insulation, basement wall insulation, crawlspace wall insulation, and slab insulation are combined into a single category of foundation insulation

The following sections describe how the methodology was implemented as part of the Alabama study, including sampling, data collection, and resulting data analysis. More information on the full DOE protocol is published separately from this report (DOE 2016a). Further details on the PNNL analysis are also available in a technical support document (TSD) (DOE 2016b) and are available on the DOE Building Energy Codes Program website.[9]

2.2 State Study

The prescribed methodology was customized for the State of Alabama 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, statistically representative sampling plan based on the average of the 19 most recent months of Census Bureau permit data[10]. The samples were apportioned to jurisdictions across the state in proportion to their average level of construction compared to the overall construction activity statewide. This approach is known as a proportional random sample. 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 sample plan, the project team began contacting local building departments to identify homes currently in the permitting process. Code officials responded by providing a list of homes at various stages of construction within their jurisdiction. These lists were then sorted using a random number generator and utilized by the team's field personnel to select specific homes to visit and call the builder to gain site access. As prescribed by the methodology, each home was visited only once to avoid any bias associated with multiple site visits. Also, only 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 during the time of the study (the 2009 IECC). The final data collection form is available in spreadsheet format on the DOE Building Energy Codes Program website.[11]

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

[10] Available at http://censtats.census.gov/ (select the "Building Permits" data)

[11] 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.

The form included *all* energy code requirements (i.e., not just the eight key items), as well as additional items required under the prescribed methodology. For example, the field teams were required to conduct a blower door test and duct leakage test on every home where such tests could be conducted, using RESNET[12] protocols.

Field teams gathered substantial information beyond the key items much of which 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, itself, and is therefore used to modify that key item within the later energy modeling and savings calculation. Observed equipment (e.g., fuel type and efficiency rating) and basic home characteristics (e.g., foundation type) help validate the prototype models applied during energy simulation. Other questions, such as whether the home participated in an above-code program, can also assist in understanding whether there may be other influencing factors 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 complied (e.g., via a yes/no response). The current approach provides an improved understanding of how compliance equates to energy consumption, and gives much 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 review 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.[13]

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 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.

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

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

2.3.1 Statistical Analysis

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

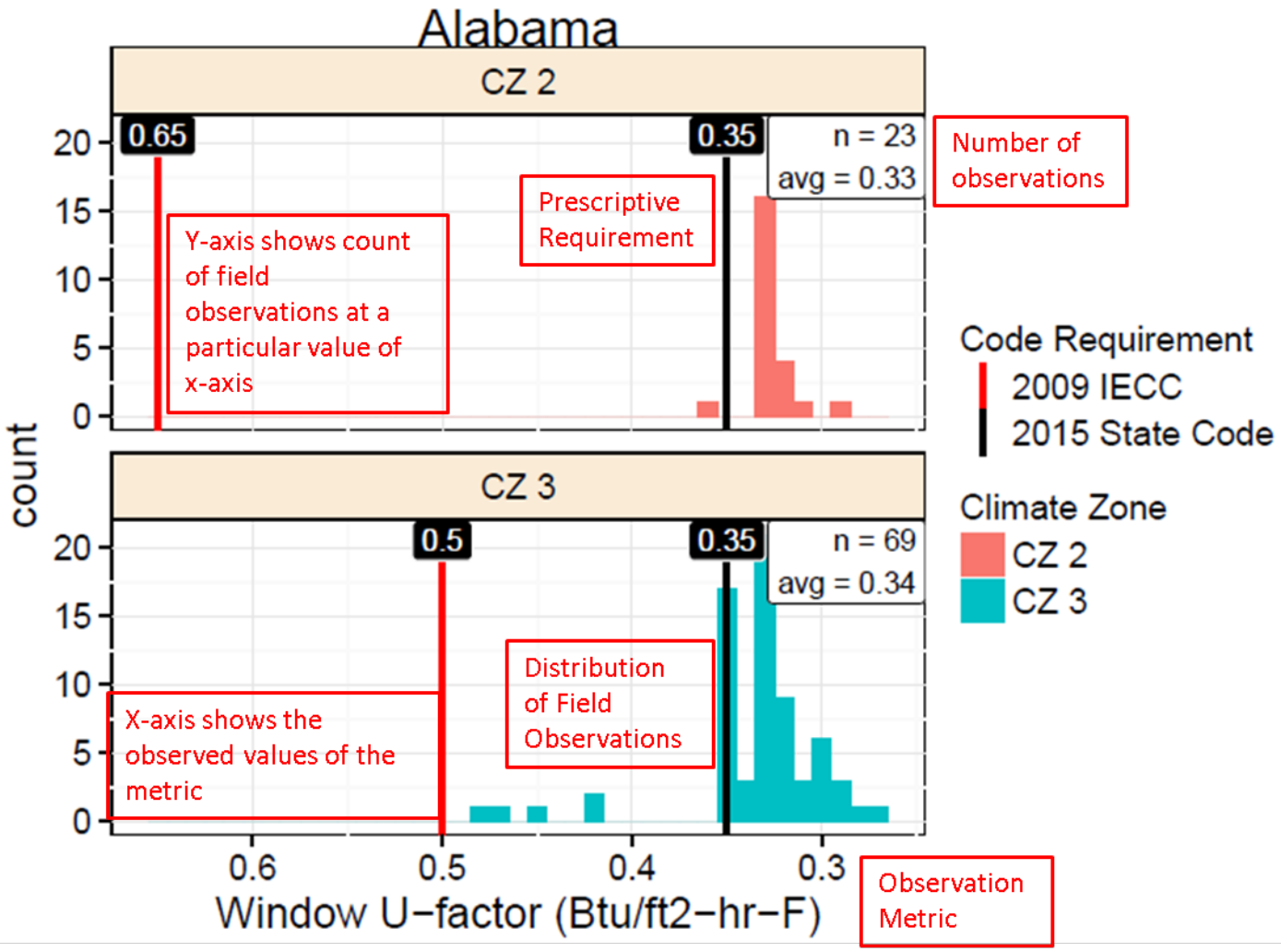

Figure 2.1. Sample Graph

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. In this case, the observations are compared to two codes; the red line represents the requirement of the 2009 IECC, and the black line represents the requirement of Alabama's amended 2015 IECC —values to the right-hand side of this line are *better than code*. Values to the left-hand side of this line 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 sufficient 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.[14] 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 provides perspective on 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 TSD (DOE 2016b).[15]

2.3.3 Savings Analysis

To begin the third phase, each of the key items was examined to determine those where a significant number of observed values did not meet the associated code requirement.[16] For these items, additional models were then 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)[17]. 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

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

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

[16] "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.

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

corresponding prescriptive code value, allowing for the savings potential associated with that key item to be evaluated in isolation.

Once the full compliance models were created, additional energy simulation was carried out using EnergyPlus. All variations of observed heating systems and foundation types were included, and annual electric, gas and total EUIs were extracted for each building. For each key item analyzed, the difference in energy use between the *as-built* and *full compliance* cases represents the potential energy savings that can theoretically be achieved if all homes met the code minimum. To calculate savings, the differences in energy use calculated for each case are weighted by the corresponding frequency of each observation to arrive at an average energy savings potential for each climate zone. For states with multiple climate zones, potential energy savings for each climate zone are 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 can 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 are 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. Alabama is comprised of multiple climate zones; zone 2 (CZ2) and zone 3 (CZ3). Both climate zones are represented in the sampling, data collection, and resulting analysis and statewide savings calculations. A discussion of other findings is also covered in the section, including a description of how certain observations, such as insulation installation quality, are used to modify key item results. (See section 2.3.1 for a sample figure and explanation of how the state result graphs should be interpreted.) For Alabama, the observations are compared to two codes; the red dashed line represents the requirement of the 2009 IECC, and the black dashed line represents the requirement of Alabama's amended 2015 IECC —values to the right-hand side of this line are *better than code*.

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 ft2 of conditioned floor area at 25 Pascals)

Over 90% of the predominant foundation observations were slab-on-grade. Since Alabama has no insulation requirement for slabs under either the 2009 IECC or 2015 Alabama Residential Energy Code and because there were so few observations of the other foundation types, foundation insulation is not included in this section.

3.1.1.1 Envelope Tightness

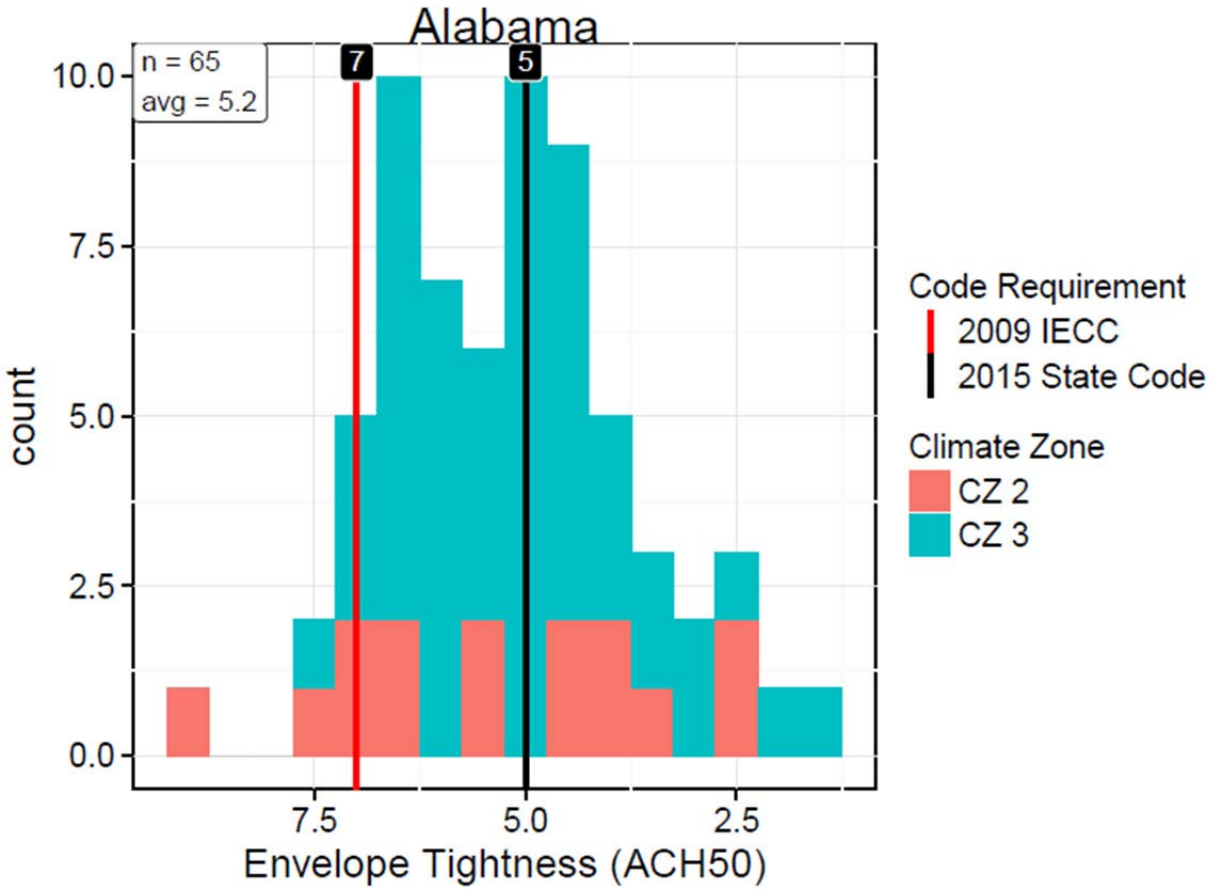

Figure 3.1. Envelope Tightness (ACH50)

Table 3.1. Envelope Tightness (ACH50)

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	15		50		65	
Range	8.9 to 2.65		7.25 to 1.42		8.9 to 1.42	
Average	5.4		5.1		5.2	
Climate Zone and Code	**CZ2** (2009 IECC)	**CZ2** (2015 AL Code)	**CZ3** (2009 IECC)	**CZ3** (2015 AL Code)	**Statewide** (2009 IECC)	**Statewide** (2015 AL Code)
Requirement	7	5	7	5	7	5
Compliance Rate	12 of 15 (80%)	7 of 15 (46%)	48 of 50 (96%)	23 of 50 (46%)	60 of 65 (92%)	30 of 65 (46%)

- **Interpretations:**
  - Overall, the distribution exhibits higher air leakage than allowed by the 2015 Alabama Residential Energy Code, but lower than allowed by the 2009 IECC.
  - Over half of the observations in each CZ met or exceeded the prescriptive code requirement for the 2009 IECC, but that fell to about half compared to the 2015 Alabama Residential Energy Code.

– Reductions in envelope air leakage represent an area for improvement in the state, and should be given attention in future training and enforcement.

3.1.1.2 Window SHGC

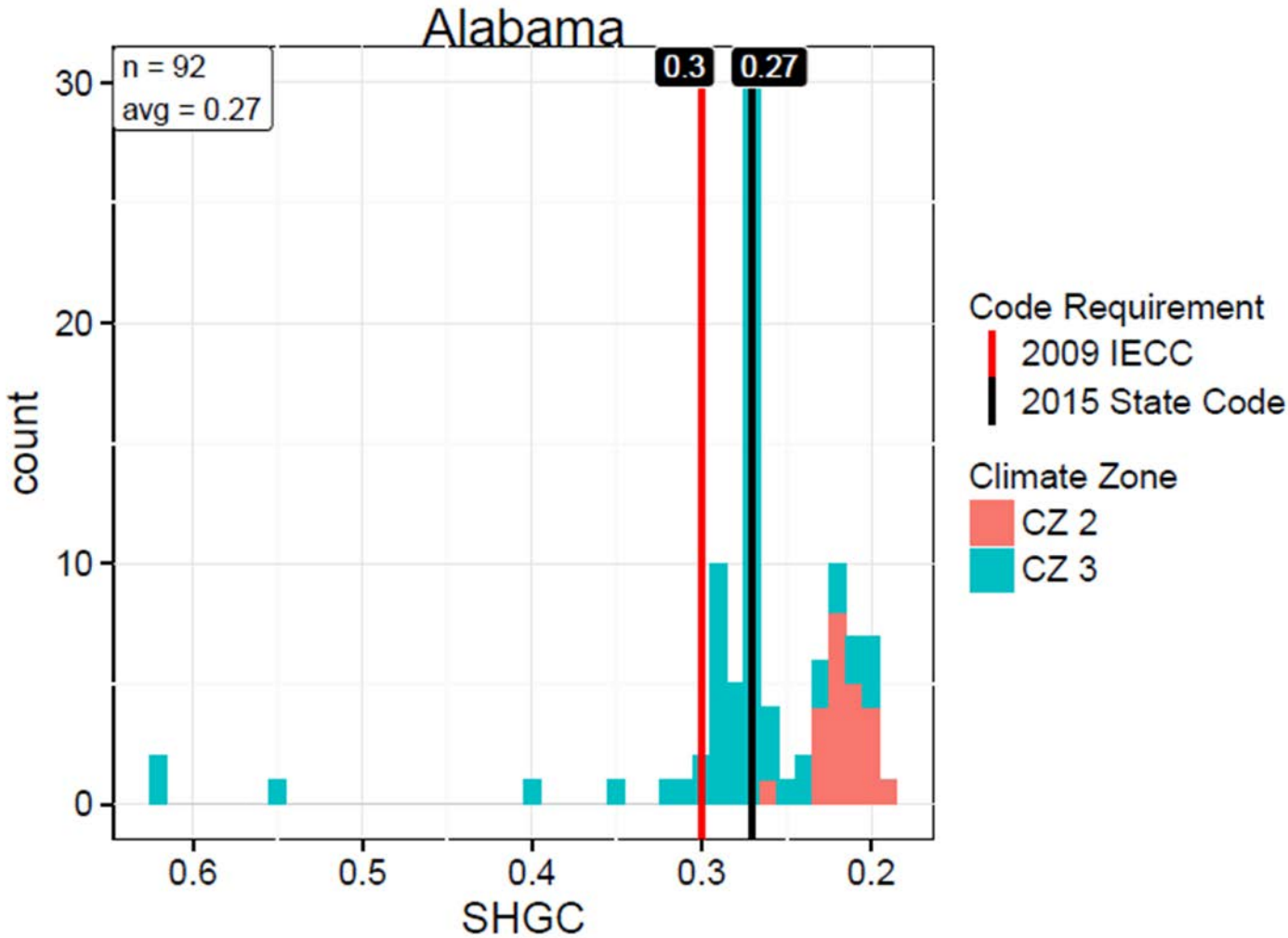

Figure 3.2. Window SHGC

Table 3.2. Window SHGC

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	23		69		92	
Range	0.26 to 0.19		0.62 to 0.2		0.62 to 0.19	
Average	0.22		0.28		0.27	
Climate Zone and Code	**CZ2** (2009 IECC)	**CZ2** (2015 AL Code)	**CZ3** (2009 IECC)	**CZ3** (2015 AL Code)	**Statewide** (2009 IECC)	**Statewide** (2015 AL Code)
Requirement	0.30	0.27	0.30	0.27	0.30	0.27
Compliance Rate	23 of 23 (100%)	23 of 23 (100%)	62 or 69 (90%)	45 of 69 (65%)	85 of 92 (92%)	68 of 92 (74%)

- **Interpretations:**
  - SHGC values had a wider range in CZ3 than CZ2.
  - All observations in CZ2 met or exceeded the requirements of both the 2009 IECC and the 2015 Alabama Residential Energy Code.
  - In CZ3, almost all observations met the 2009 IECC requirements, but that fell to about two-thirds under the 2015 Alabama Code.
  - Statewide, almost all instances were observed to be equal to or better than the 2009 IECC requirement, and more than two-thirds of the instances were equal to or better than the 2015 Alabama Code requirement.

3.1.1.3 Window U-Factor

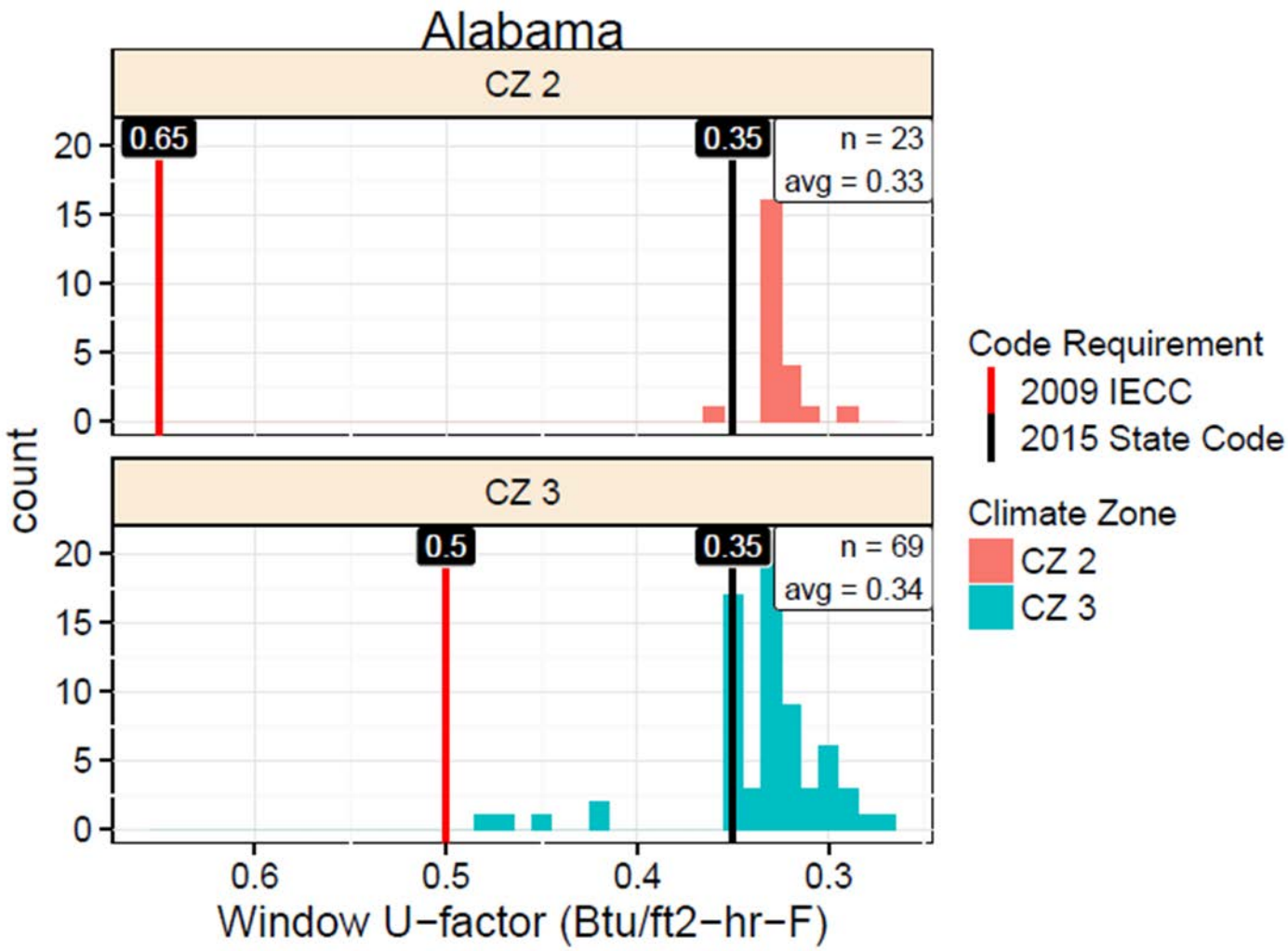

Figure 3.3. Window U-Factor

Table 3.3. Window U-Factor

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	23		69		92	
Range	0.36 to 0.29		0.48 to 0.27		0.48 to 0.27	
Average	0.33		0.34		0.33	
Climate Zone and Code	**CZ2** (2009 IECC)	**CZ2** (2015 AL Code)	**CZ3** (2009 IECC)	**CZ3** (2015 AL Code)	**Statewide** (2009 IECC)	**Statewide** (2015 AL Code)
Requirement	0.65	0.35	0.50	0.35	0.65/0.35	0.35
Compliance Rate	23 of 23 (100%)	22 of 23 (96%)	69 of 69 (100%)	64 of 69 (93%)	92 of 92 (100%)	86 of 92 (94%)

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

3.1.1.4 Wall Assemblies

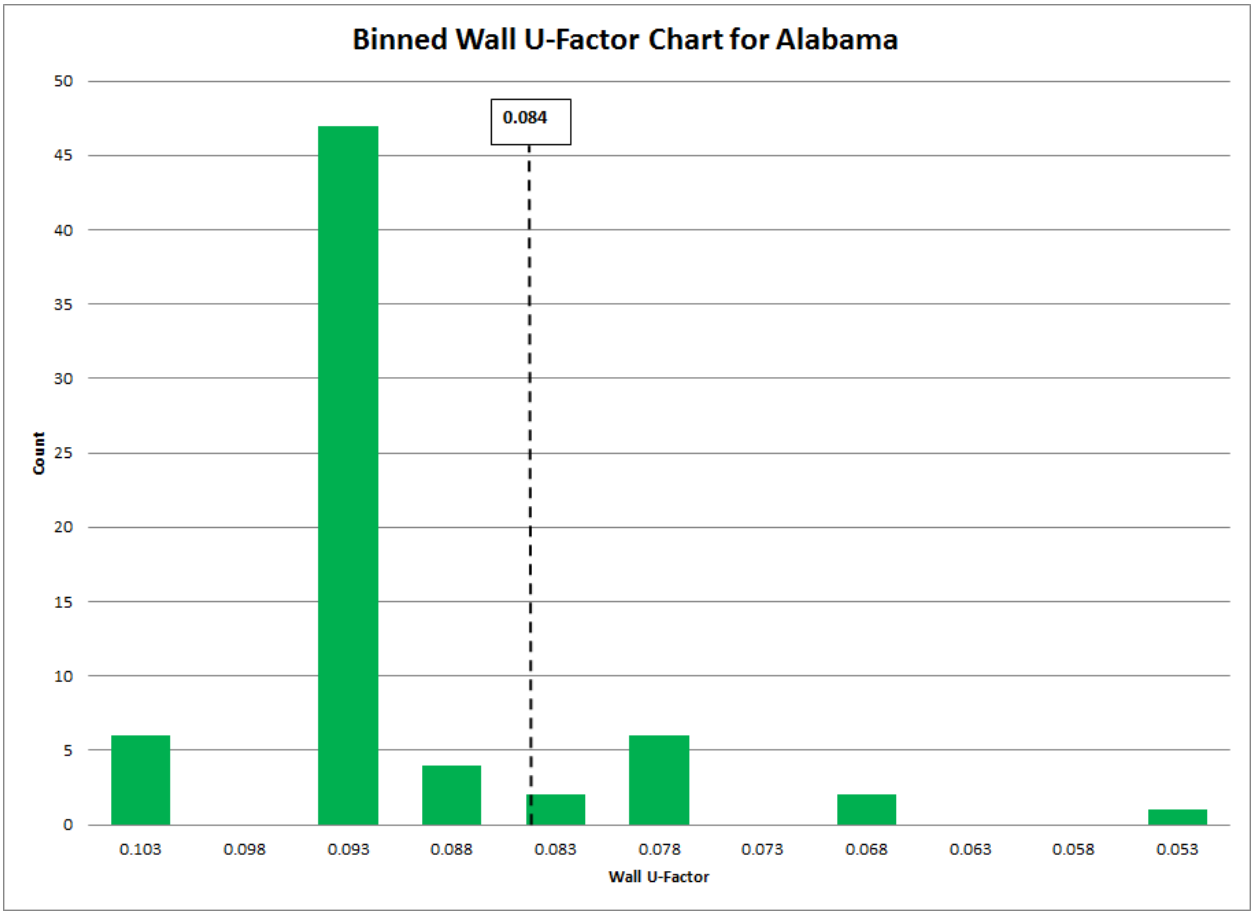

Figure 3.4. Alabama Wall Assembly Performance, including Wall Insulation Installation Quality

Figure 3.4 combines all cavity R-value and wall insulation installation quality data observed in the state to generate an "effective U-factor" chart. 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. Frame Wall Assembly

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	14		54		68	
Range	0.091 to 0.054		0.102 to 0.068		0.102 to 0.055	
Average	0.086		0.090		0.089	
Climate Zone and Code	**CZ2** (2009 IECC)	**CZ2** (2015 AL Code)	**CZ3** (2009 IECC)	**CZ3** (2015 AL Code)	**Statewide** (2009 IECC)	**Statewide** (2015 AL Code)
Requirement	0.084	0.084	0.084	0.084	0.084	0.084
Compliance Rate	3 of 14 (21%)	3 of 14 (21%)	8 of 54 (15%)	8 of 54 (15%)	11 of 68 (16%)	11 of 68 (16%)

- **Interpretations:**
  - When looking only at the labeled cavity insulation R-value, all the observations in CZ2 and nearly all the observations in CZ3 meet the prescriptive requirements of the code. This would suggest that wall insulation R-value is not an issue in the state.
  - In terms of insulation installation quality, however, 52 of the 67 (78%) observations[18] were rated as Grades II or III (Table 3.8).
  - There were no observations of continuous insulation in the Alabama sample.

3.1.1.5 Ceilings

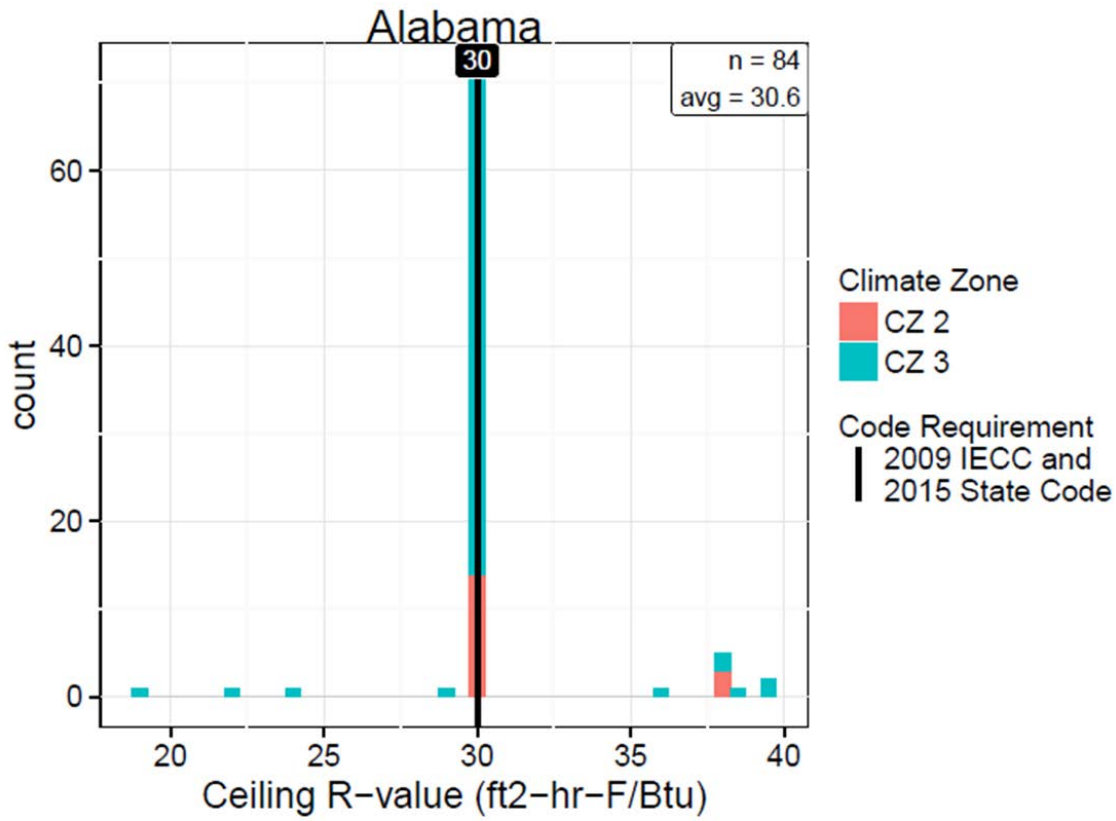

Figure 3.5. Ceiling R-Value

Table 3.5. Ceiling R-Value

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	17		67		84	
Range	30 to 38		19 to 39.6		19 to 39.6	
Average	31		30		31	
Climate Zone and Code	**CZ2** (2009 IECC)	**CZ2** (2015 AL	**CZ3** (2009	**CZ3** (2015 AL	**Statewide** (2009	**Statewide** (2015 AL Code)

[18]While there were 68 total wall observations, only 67 observations of insulation installation quality were noted.

		Code)	IECC)	Code)	IECC)	
Requirement	R-30	R-30	R-30	R-30	R-30	R-30
Compliance Rate	17 of 17 (100%)	17 of 17 (100%)	63 of 67 (94%)	63 of 67 (93%)	80 of 84 (95%)	80 of 84 (95%)

- **Interpretations:**
  - Nearly all the observations meet the code requirements exactly.
  - In terms of insulation installation quality, 58 of 79 (73%) observations were rated Grade I.

3.1.1.6 Lighting

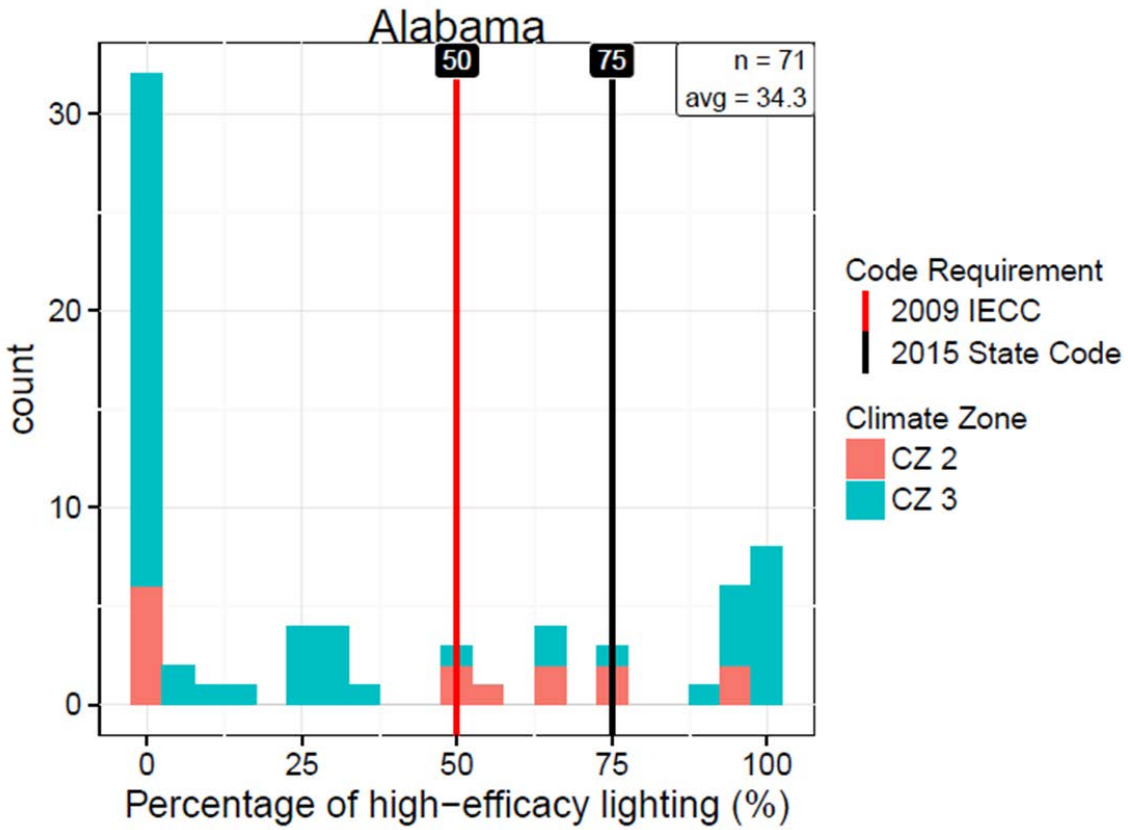

Figure 3.6. High-efficacy Lighting Percentage

Table 3.6. High-efficacy Lighting Percentage

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	15		56		71	
Range	0 to 94		0 to 100		0 to 100	
Average	41		33		34	
Climate Zone and Code	**CZ2** (2009 IECC)	**CZ2** (2015 AL Code)	**CZ3** (2009 IECC)	**CZ3** (2015 AL Code)	**Statewide** (2009 IECC)	**Statewide** (2015 AL Code)
Requirement	50	75	50	75	50	75

Compliance Rate	8 of 15 (53%)	4 of 15 (27%)	17 of 56 (30%)	13 of 56 (23%)	25 of 71 (35%)	15 of 71 (21%)

- **Interpretations:**
  - There are a significant quantity and wide range of observations that do not meet either the 2009 or the 2015 minimum code requirements.
  - A little more than half of the field observations meet the 2009 IECC requirement in CZ2, but that drops to just over one-quarter under the 2015 Alabama Code.
  - In CZ3, nearly one-third of the field observations meet the 2009 IECC requirement, but less than one-quarter meets the 2015 Alabama Code.
  - This should be considered an area for increased attention in future training and enforcement within the state.

3.1.1.7 Duct Tightness

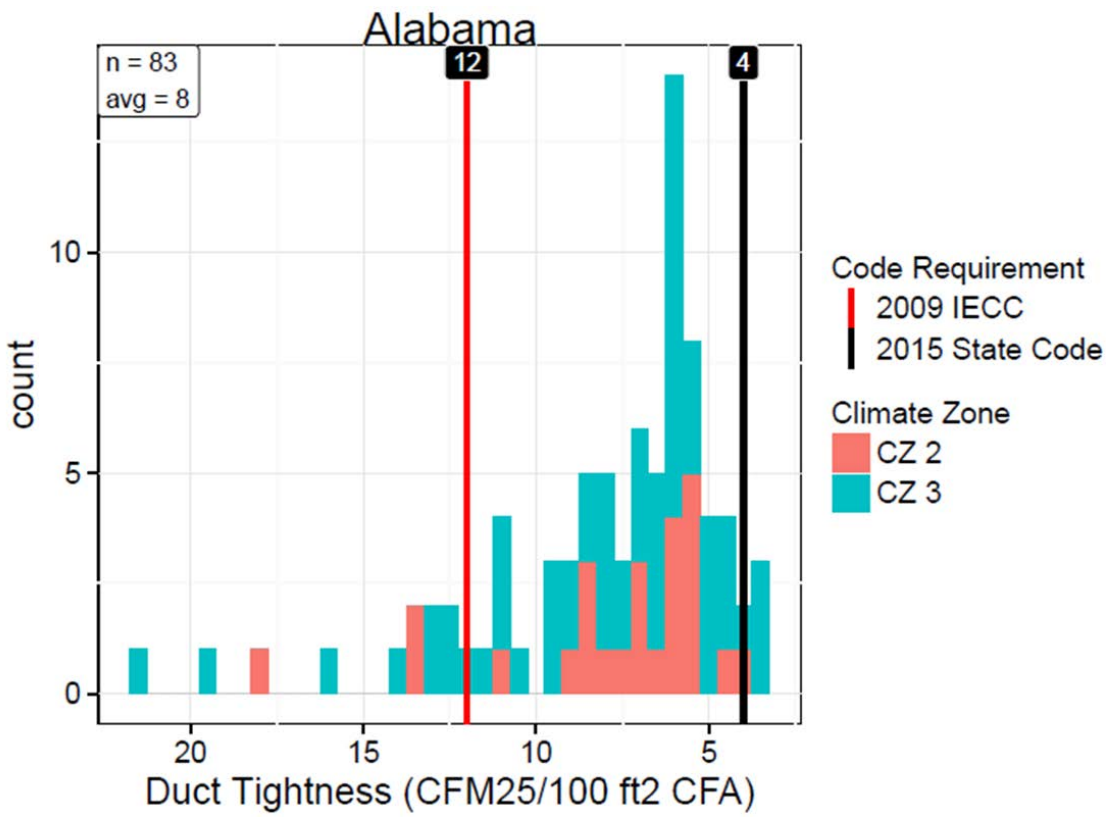

Figure 3.7. Duct Tightness (CFM25/100ft^2 CFA)

Table 3.7. Duct Tightness (CFM25/100ft^2 CFA)

Climate Zone	**CZ2**		**CZ3**		**Statewide**	
Number	25		58		83	
Range	18.1 to 4.2		21.3 to 3.5		21.3 to 3.5	
Average	7.5		8.3		8.1	
Climate Zone and	**CZ2**	**CZ2**	**CZ3**	**CZ3**	**Statewide**	**Statewide**

Code	(2009 IECC)	(2015 AL Code)	(2009 IECC)	(2015 AL Code)	(2009 IECC)	(2015 AL Code)
Requirement	12	4	12	4	12	4
Compliance Rate	22 of 25 (88%)	4 of 25 (16%)	50 of 58 (86%)	7 of 58 (12%)	72 of 83 (87%)	11 of 83 (13%)

- **Interpretations:**
  - The average duct leakage is 8.13 CFM 25/100 ft2 (in unconditioned space); 6.97 for ducts entirely in conditioned space.
  - The majority of observations meets or exceeds the 2009 IECC requirement for duct leakage.
  - However, the trend is reversed compared to the 2015 Alabama Code, with the vast majority of observations not meeting the requirement.
  - Reductions in duct leakage represent a significant area for improvement within the state, and should be given increased attention in future training and enforcement.

Based on visual inspection, ducts were observed as sealed the vast majority of the time (91%). This appears consistent with the testing results relative to the 2009 IECC requirement. However, while the code requires ducts, air handlers and filter boxes to be sealed, it does not provide a comprehensive list of inspection points (as it does with envelope air sealing, in comparison). It may be necessary to utilize more advanced sealing methods in order to meet the testing threshold required in the 2015 Alabama Code.

3.1.1.8 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[19] assessment protocol which has three grades, Grade I being the best quality installation and Grade III being the worst.

Table 3.8 shows the insulation installation quality levels for framed envelope assemblies, as observed in the state. The majority of the observations (144 of 213) were classified as Grades II and III, indicating that there is considerable room for improvement in installation quality.

Table 3.8. Insulation Installation Quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Roof Cavity	58	19	2	**79**
Floor	2	5	1	**8**
Above Grade Wall	8	52	7	**67**
Basement Wall	0	5	0	**5**
Knee Wall	1	53	0	**54**
Crawlspace Wall	0	0	0	**0**

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

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.[20]

3.1.2.1 Average Home

- Size: 2552 ft^2 and 1.52 stories

3.1.2.2 Compliance

- None of the homes (0%) participated in an above-code program

3.1.2.3 Envelope

- **Profile:**
  - Walls: All were wood-framed walls with a preponderance of 4" studs (93%) and a few 6" studs (7%)
  - Foundations: Mostly slab-on-grade (90%), with the remainder split between basements (5%)[21] and crawlspaces (5%)
- **Successes:**
  - Openings around doors and windows were almost always sealed (97%)
  - Narrow cavities were almost always sealed and insulated (91%)
- **Areas for Improvement:**
  - A significant number of attic hatches & doors did not exhibit the required insulation value (83%)
  - Knee walls were often not sealed (54%)
  - Envelope areas behind bathroom tubs & showers were often not sealed (47%)
  - Recessed lighting was often not sealed and insulated (63%)
  - Rim joists were often not sealed (52%)

3.1.2.4 Duct & Piping Systems

- **Profile:**

[20] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study
[21] Five of the seven basements observed in the study were conditioned

- Ducts were generally not located within conditioned space (percentage of duct system):
  - Supply: 17% (12 homes entirely within conditioned space)
  - Return: 24% (22 homes entirely within conditioned space)
- About 12% of homes located *supply* ducts entirely within conditioned space
- About 20% of homes located *return* ducts entirely within conditioned space
- Pipe Insulation (R-value): 2.4 (mix of R-2 and R-3)

- **Successes:**
  - Building cavities were almost never used as ducts (97%)
- **Areas for Improvement:**
  - Air handlers (82%) and filter boxes (77%) were not always sealed

3.1.2.5 HVAC Equipment

- **Profile:**
  - Heating: Mostly heat pumps with an average efficient of 13 HSPF
  - Cooling: Mostly heat pumps with an average efficiency of 13 SEER
  - Water Heating: Mix of gas (54%) and electric (46%) storage with an average capacity of 52 gallons and average efficiency rating of EF 0.82
  - Ventilation: Majority exhaust-only (99%). All homes relied solely upon the bathroom fan; none had dedicated exhaust.
- **Areas for Improvement:**
  - User manuals for mechanical systems were provided just over half of the time (56%)

3.2 Energy Intensity

The statewide energy analysis results are shown in the figures below, which compare 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 within the state appear to use *less* energy relative to the previous 2009 IECC, 19.8 kBtu/ft^2-yr statewide compared to 22.4 kBtu/ft^2 (Figure 3.8), but *more* than the current minimum state code requirements, 19.81 kBtu/ft^2 compared to 18.41 kBtu/ft^2 (Figure 3.9). This suggests that on average the typical home EUI in the state is about 13% better than the 2009 code and about 7.6% worse than the current Alabama energy code.

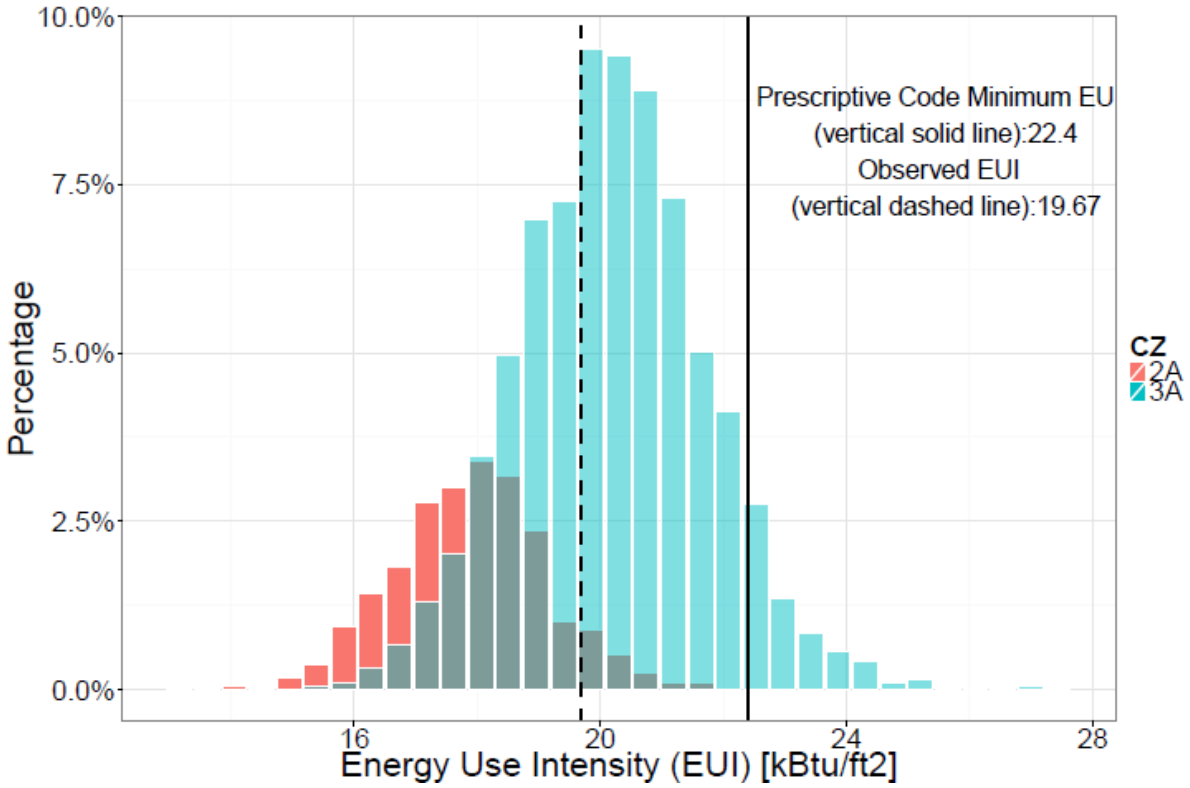

Figure 3.8. Statewide EUI Analysis for Alabama (2009 IECC)

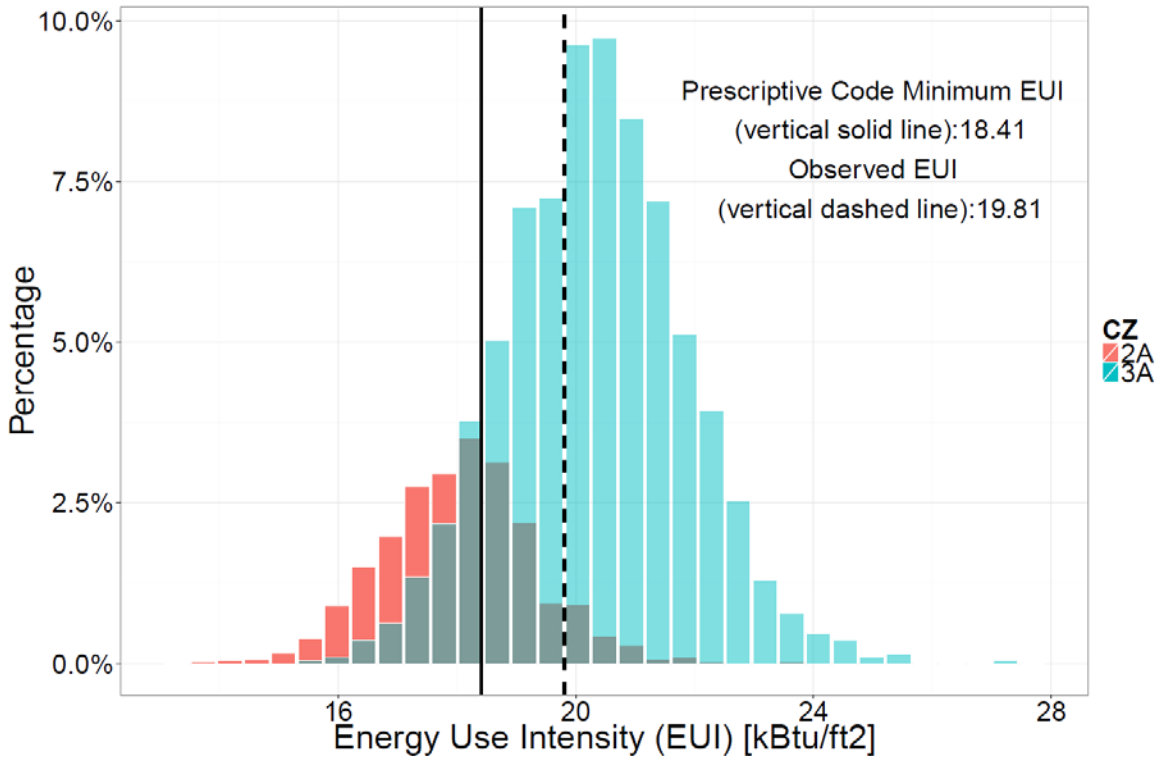

Figure 3.9. Statewide EUI Analysis for Alabama (2015 AL Code)

3.3 Savings Potential

All data in this study was collected from homes permitted under the 2009 code; potential savings, however, were calculated against the 2009 code and also against the 2015 code. Several key items exhibit the potential for improvement, although the specific key items vary by code. Due to the EUI results noted in the previous section, there were less savings opportunities when compared to the 2009 code, although some savings do exist for lighting, exterior wall insulation, and duct leakage. However, the current code is the 2015 Alabama code, which is the basis of the savings noted in Table 3.9 and Table 3.10.

Those key items with the greatest potential[22], shown below followed by the percent that did *not* meet code, were analyzed further to calculate the associated savings potential, including energy, cost and carbon savings.

- Duct Leakage (87%),
- Lighting (79%),
- Envelope Tightness (54%),
- Wall Insulation (2%), and
- Window SHGC (26%).

For analytical details refer to section 2.3.3 (Savings Analysis) or the methodology TSD (2016b).

Estimated savings resulting from the analysis are shown below in order of highest to lowest total energy, cost and carbon savings (Table 3.9). As can be seen, there are significant savings opportunities, with the greatest total savings potential associated with these measures. In addition, Table 3.10 shows the total savings and emissions reductions that will accumulate over 5, 10, and 30 years of construction.

Table 3.9. Statewide Annual Measure-Level Savings for Alabama (2015 AL Code)

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	2A	330	4	1,539	2,053	3,160	88,351	512
	3A	307	5	1,511	7,453	11,258	306,577	1,759
	State Total	**312**	**5**	**1,517**	**9,506**	**14,420**	**395,063**	**2,272**
Lighting	2A	396	-1	1,237	2,053	2,540	88,164	548
	3A	374	-2	1,119	7,453	8,343	297,068	1,859
	State Total	**379**	**-1**	**1,146**	**9,506**	**10,891**	**385,451**	**2,408**
Envelope Air Leakage	2A	143	5	946	2,053	1943	46,517	253
	3A	178	6	1,246	7,453	9,286	217,033	1,166
	State Total	**170**	**6**	**1,179**	**9,506**	**11,207**	**263,089**	**1,417**
Exterior Wall Insulation	2A	121	3	679	2,053	1,395	35,824	201
	3A	149	4	891	7,453	6642	165,622	917
	State Total	**143**	**4**	**844**	**9,506**	**8,022**	**201,105**	**1,116**
Window SHGC	2A	67	-0.4	182	2,053	375	14,166	90
	3A	57	-0.7	124	7,453	930	40,403	265
	State Total	**59**	**-0.6**	**138**	**9,506**	**1,309**	**54,674**	**356**
TOTAL		**1,064**	**12**	**4,823**	**9,506**	**45,849**	**$1,299,382**	**7,569**

[22] Defined here as those items where more than 15% of observations did not meet the prescriptive code requirement

Table 3.10.Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings for Alabama (2015 AL Code)

	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
Measure	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Duct Leakage	216,300	793,100	6,705,300	5,925,945	21,728,465	183,704,295	34,080	124,960	1,056,480
Lighting	163,365	599,005	5,064,315	5,781,765	21,199,805	179,234,715	36,120	132,440	1,119,720
Envelope Air Leakage	168,105	616,385	5,211,255	3,946,335	14,469,895	122,336,385	21,255	77,935	658,905
Exterior Wall Insulation	120,330	441,210	3,730,230	3,016,575	11,060,775	93,513,825	16,740	61,380	518,940
Window SHGC	19,635	71,995	608,685	820,110	3,007,070	25,423,410	5,340	19,580	165,540
TOTAL	**687,735**	**2,521,695**	**21,319,785**	**19,490,730**	**71,466,010**	**604,212,630**	**113,535**	**416,295**	**3,519,585**

4.0 Conclusions

The Alabama field study provides an enhanced understanding of statewide code implementation, and suggests that high levels of compliance were achieved relative to the former state energy code (2009 IECC with Alabama amendments). During the course of the study, the state updated its energy code, with the new code based on the 2015 IECC (with Alabama amendments). As a result, the project team requested that the analysis be done not only against the former statewide code, the 2009 IECC, but also the new 2015 Alabama Residential Energy Code. This report contains findings relative to both codes, which help portray levels of compliance under the former code, as well as potential savings the state will realize by achieving full compliance with the updated energy code.

As a result of the successful levels of compliance achieved against the 2009 IECC, there are limited potential savings under the previous code through increased compliance. However, it should be noted that savings were available for lighting and exterior wall insulation, and duct leakage to a lesser degree, under the 2009 IECC.

Significant savings can be achieved in the state through full compliance with the 2015 Alabama Residential Energy Code. Potential statewide annual energy savings are 45,849 MMBtu, which equates to $1,299,382 in cost savings, and emission reductions of 7,569 MT CO2e. Over a 30-year period, these impacts grow to 21,300,000 MMBtu, $604 million, and over 3,500,000 MT 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:

Table 4.1. Annual Statewide Savings Potential in Alabama (2015 AL Code)

		Annual Savings		
	Key Measure	**Energy** (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
1	Duct Leakage	14,420	395,063	2,272
2	Lighting	10,891	385,451	2,408
3	Envelope Tightness	11,207	263,089	1,417
4	Wall Insulation	8,022	201,105	1,116
5	Window SHGC	1,309	54,674	356
	Total	**45,849 MMBtu**	**$1,299,382**	**7,569 MT CO2e**

When compared to the 2009 IECC, the average home in Alabama uses about 13% less energy than a home exactly meeting the code. The average home uses about 7.6% more energy than a home exactly meeting the new state energy code, the 2015 Alabama Residential Energy Code. In terms of particular measures, fenestration (U-factor & SHGC) was better than code across the board, with the average window exceeding the requirement of any U.S. climate zone. Other measures had varying degrees of savings potential.

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
Home Builders Association of Alabama (HBAA)	Trade organization representing builders, remodelers, developers and affiliated professionals.
Southeast Energy Efficiency Alliance (SEEA)	Regional energy efficiency advocacy organization.
Alabama Department of Economic and Community Affairs (ADECA)	State agency responsible for overseeing adoption of the energy and residential building codes.
Code Officials Association of Alabama (COAA)	A charter chapter of the International Code Council.
Shelby County – Permits and Inspections	Government agency responsible for local code administration and enforcement in Shelby County.
Tuscaloosa Inspection Department	Government agency responsible for local code administration and enforcement in Tuscaloosa.
Lee County Building Inspection	Government agency responsible for local code administration and enforcement in Lee County.
Alabama Board of Heating, Air Conditioning, & Refrigeration Contractors	State board responsible for the oversight of heating, air conditioning and refrigeration contractors.
Alabama Energy and Residential Codes Board,	State board, administered by ADECA, with the responsibility of adopting statewide residential and commercial energy codes.
Central Alabama Electric Cooperative	A not-for-profit, member-owned electric distribution utility serving more than 42,000 meters in a 10-county area of central Alabama.
Home Builders Licensure Board	The Board enforces the provisions of The Home Building and Home Improvement Industries Act that provides for the licensure of persons engaged in residential construction in the State of Alabama.
Alabama General Contractors Board	The Board licenses and regulates commercial/industrial contractors in the major and specialty classifications that constitute the industry. Currently there are more than 10,000 general contractors licensed to work in the state.

Appendix B

State Sampling Plan

Appendix B

State Sampling Plan

B.1 State Sampling Plan

Location (City, County)	Sample	Actual
Huntsville, Madison	6	6
Madison County Unincorporated Area, Madison	3	3
Mobile County Unincorporated Area, Mobile	7	7
Auburn, Lee	5	5
Baldwin County Unincorporated Area, Baldwin	2	2
Hoover, Jefferson	2	2
Tuscaloosa, Tuscaloosa	7	7
Madison, Madison	5	5
Montgomery, Montgomery	2	2
Fairhope, Baldwin	1	1
Jefferson County Unincorporated Area, Jefferson	1	1
Dothan, Houston	1	1
Foley, Baldwin	1	1
Opelika, Lee	2	2
Phenix City, Russell	1	1
Vestavia Hills, Jefferson	3	3
Pell City, St. Clair	1	1
Mobile, Mobile	1	1
Shelby County Unincorporated Area, Shelby	1	1
Millbrook, Elmore	1	1
Athens, Limestone	1	1
Helena, Shelby	1	1
Moody, St. Clair	1	1
Saraland, Mobile	2	2
Troy, Pike*	1	1
Pelham, Shelby	1	1
Wetumpka, Elmore	1	1
Cullman, Cullman	1	1
Irondale, Jefferson	1	1
Total	**63**	**63**

*Enterprise in Coffee County substituted for Troy in Pike County

B.2 Substitutions

In the Alabama study, the project team had to make one substitution in the final sampling plan, substituting Enterprise in Coffee County for Troy in Pike County. This was due to an inability to obtain permit data from a single jurisdiction selected in the random sample. The project team discussed this challenge, and ultimately identified an adequate alternative (i.e., a jurisdiction in the same region of the state with a similar population, residential construction starts and socio-economic conditions).

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 Alabama 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=128): 2252 ft^2
- Number of Stories (n=133): 1.5

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 %	33 %	43 %	15 %	9 %

Table C.2. Number of Stories

No. of Stories	1	2	3	4+
Percentage	50 %	49 %	1%	0 %

C.1.1.2 Wall Profile

- Framing Type (n=134):

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

  - *All* were framed construction (100 %)
- Framing Material (n=134):
  - Wood (100%)
  - Steel (0%)
- Framing Depth (n=134):
  - 4” (93%)
  - 6” (7%)
- Type of Wall Insulation (n=68)
  - Cavity Only (100%)
  - Cavity + Continuous (0%)
  - Continuous Only (0%)

C.1.1.3 Foundation Profile

- Foundation Type (n= 134):
  - Basement (5%)
  - Slab on Grade (90%)
  - Crawlspace (5%)
- Basement Type (n=7):
  - Conditioned (71%)
  - Unconditioned (29%)
- Type of Wall Insulation (n=68)
  - Cavity Only (100%)
  - Cavity + Continuous (0%)
  - Continuous Only (0%)

C.1.1.4 Other

- *None* had a pool or spa (n=0)
- *None* had a sunroom (n=110)

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:

- Was the home participating in an above-code program (n=16)?
  - Yes (0%)
  - No (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=90)?
  - Yes (77%)
  - No (23%)

C.1.3.2 Ceilings

- Did the attic hatch/door exhibit the correct insulation value (n=47)?
  - Yes (17%)
  - No (83%)

C.1.3.3 Air Sealing[1]

- Was the thermal envelope sealed (n=69)?
  - *About half* of the responses were reported to comply (48%)
- Was fenestration sealed (n=18)?
  - *Most* responses were reported to comply (94%)
- Were openings around windows and doors sealed (n=61)?
  - *Most* responses were reported to comply (97%)
- Were utility penetrations sealed (n=108)?
  - Yes (80%)
  - No (20%)
- Were dropped ceilings sealed (n=56)?
  - Yes (36%)
  - No (64%)
- Were knee walls sealed (n=48)?
  - Yes (46%)
  - No (54%)
- Were garage walls and ceilings sealed (n=63)?
  - Yes (70%)
  - No (30%)

[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.

- Was the envelope behind tubs and showers sealed (n=60)?
  - Yes (53%)
  - No (47%)
- Were IC-rated light fixtures sealed (n=104)?
  - Yes (81%)
  - No (19%)

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=103): 17% (12 homes with systems located entirely within conditioned space)
  - *Return* (n=111): 24% (22 homes with systems located entirely within conditioned space)
- Duct Insulation (R-value):
  - *Supply* (n=39): 8.0
  - *Return* (n=35): 7.8
- Ducts in Attics (R-value):
  - *Supply* (n=106): 8.1
  - *Return* (n=98): 7.9
- Pipe Insulation (R-value):
  - Average of responses a value of R-2.4 (64% of observations were R-2, the rest R-3) (n= 108)
- Were building cavities used as ducts (n=116)?
  - Yes (97%)
  - No (3%)
- Were air ducts sealed (n=122)?
  - Yes (91%)
  - No (9%)
- Were air handlers sealed (n=113)?
  - Yes (82%)
  - No (18%)
- Were filter boxes sealed (n=106)?
  - Yes (77%)

- No (23%)

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=129):
  - Gas (36%)
  - Electricity (64%)
- System Type (n=131):
  - Furnace (37%)
  - Heat Pump (60%)
  - Electric Resistance (3%)
- Average System Capacity (n=122):
  - Furnace: 73,300 Btu
  - Heat Pump: 43,200 Btu
  - Electric Resistance: 59,500
- Average System Efficiency (n=80):
  - Furnace: 83 AFUE (*all* observed furnaces had an efficiency of 80 AFUE or better)
  - Heat Pump: 13 HSPF

C.1.5.2 Cooling

- System Type (n=125):
  - Central AC (31%)
  - Air Conditioning (unspecified) (2%)
  - Heat Pump (67%)
- Average System Capacity (n=117):
  - Central AC: 41,300 Btu
  - Air Conditioning: 51,000 Btu
  - Heat Pump: 43,000 Btu
- Average System Efficiency (n=72):
  - Central AC: 13 SEER
  - Air Conditioning: 13 SEER
  - Heat Pump: 13.4 SEER

C.1.5.3 Water Heating

- Fuel Source (n=110):
  - Gas (54%)
  - Electric (46%)
- System Type (n= 17):
  - Storage (74%)
  - Tankless (26%)
- System Capacity (n=65):
  - Average Storage: 52 gallons (observations ranged from 4.9 to 100 gallons)

Table C.3. Water Heating System Storage Capacity Distribution

Capacity	< 50 gal	50-59 gal	60-69 gal	70-79 gal	80-89 gal	90+ gal
Percentage	5 %	89 %	2 %	0 %	0 %	5 %

- Average System Efficiency (n=61):
  - Electricity Storage: EF 0.96
  - Gas Storage: EF 0.69
  - Gas Tankless: EF 0.86

C.1.5.4 Ventilation

- System Type (n=101):
  - Exhaust Only (99%)
  - AHU-Integrated (1%)
- Exhaust Fan Type (n=100):
  - Dedicated Exhaust (0%)
  - Bathroom Fan (100%)

C.1.5.5 Other

- Were mechanical manuals provided? (n=43)
  - Yes (56%)
  - No (44%)

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