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Arkansas Residential Energy Code Field Study: Baseline Report

June 2017

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M Zhao

U.S. DEPARTMENT OF ENERGY

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

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

A research project in the State of Arkansas identified opportunities to reduce homeowner utility bills in residential single-family new construction by increasing compliance with the state energy code. The study was initiated in May 2015 and continued through October 2015. During this period, research teams visited 226 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 $300,000 in potential annual savings to Arkansas homeowners that could result from increased code compliance.

Methodology

The project team was led by the Southeast Energy Efficiency Alliance (SEEA). The team applied a methodology prescribed by the U.S. Department of Energy (DOE), which was based on collecting information for the energy code-required building components with the largest direct impact on energy consumption. These *key items* are a focal point of the study, and in turn drive the analysis and savings estimates. The project team implemented a customized sampling plan representative of new construction within the state, which was originally developed by Pacific Northwest National Laboratory (PNNL), and then vetted through public meetings with key stakeholders in the state.

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

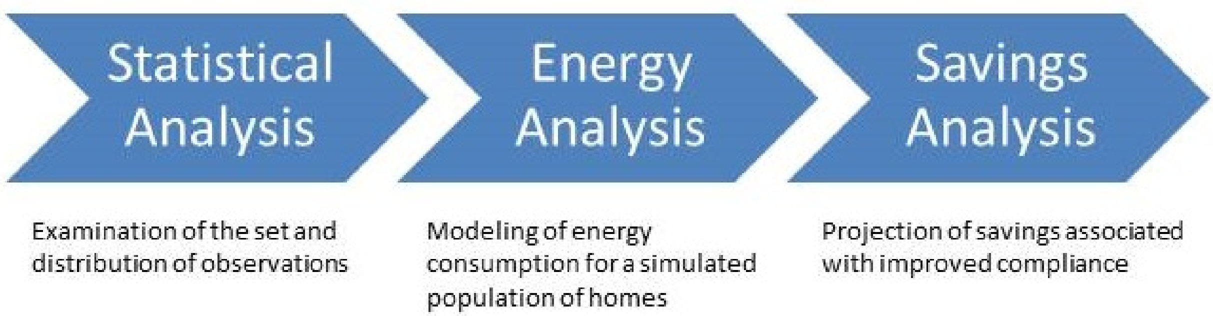

Figure ES.1. Stages of Analysis Applied in the Study

Results

The key items with the greatest potential for savings in Arkansas 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 Arkansas

Measure	**Total Energy Savings** (MMBtu)	**Total Energy Cost Savings** ($)	**Total State Emissions Reduction** (MT CO2e)
Duct Leakage	6,687	110,524	833
Envelope Air Leakage	7,587	104,022	632
Exterior Wall Insulation	4,955	74,792	470
Window SHGC	-63	28,557	242
TOTAL	**19,166 MMBtu**	**$317,895**	**2,060 MT CO2e**

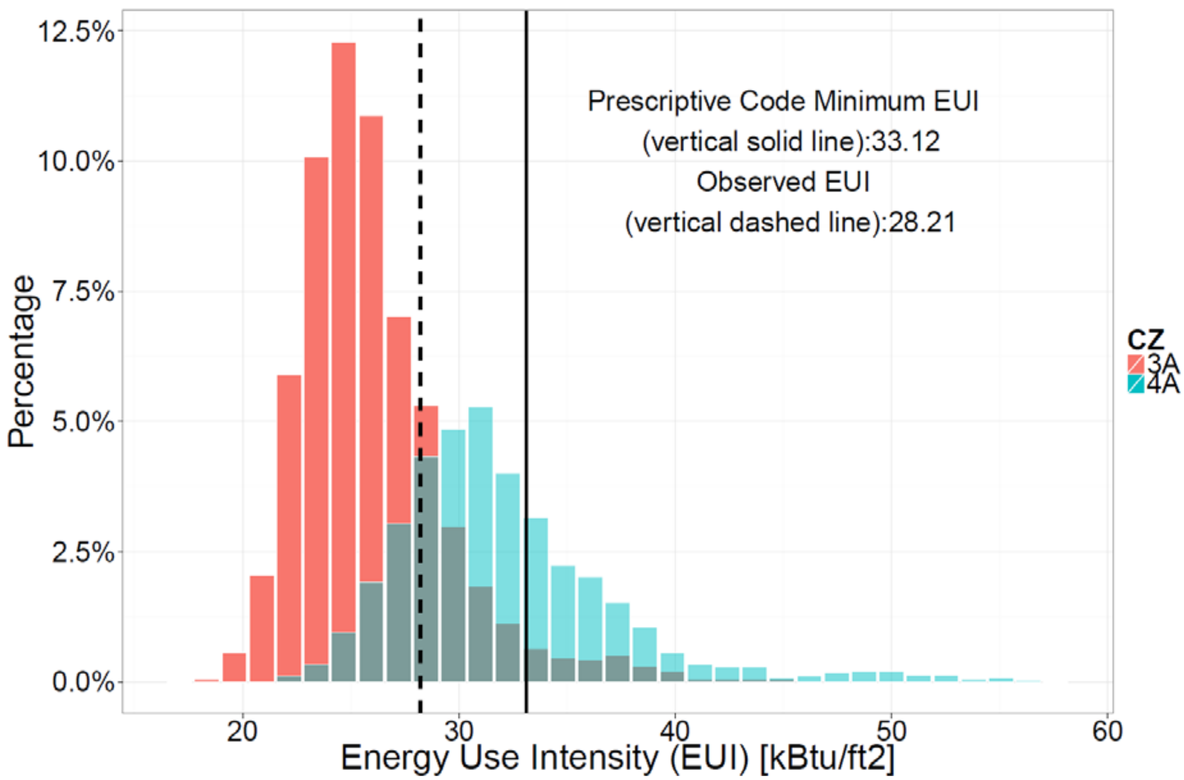

Figure ES.2. Modeled Distribution of Regulated EUI (kBtu/ft^2/year) in Arkansas

In terms of overall energy consumption, the analysis shows that homes within the state use *less* energy than would be expected relative to homes built to the current minimum state code requirements (Figure ES.2). Analysis of the collected field data indicates average regulated energy use intensity (EUI) of 28.21 kBtu/ft^2-yr statewide compared to 33.12 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 8.5% better than code.

Acknowledgments

The following members comprised the Arkansas project team:

- Lauren Westmoreland, *Southeast Energy Efficiency Alliance (SEEA)*
- Amy Dzura, *SEEA*
- Shaun Hassel, *Advanced Energy*
- David Treleven, *Advanced Energy*
- Lisa Poger, *Advanced Energy*
- Lillian Winkler

Southeast Energy Efficiency Alliance (SEEA)

SEEA is a nonprofit founded in 2007 and is one of six regional energy efficiency organizations dedicated to leveraging energy efficiency for the benefit of all citizens. SEEA supports smarter energy policies, stronger local energy codes, resources to upgrade the existing building stock, and opportunities to provide equal access to affordable energy for all communities. SEEA works collaboratively with many different stakeholder groups to service utilities, businesses and communities in 11 southeastern states, including Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia. More information is available at http://seealliance.org/.

Advanced Energy

Advanced Energy, formerly called Alternative Energy Corporation, or AEC was founded in 1980 by the North Carolina Utilities Commission to investigate and implement new technologies for distributed generation, load management, conservation and energy efficiency. The company was set up and still works with member utilities on energy efficiency and conservation projects. Advanced Energy is an independent, non-profit corporation governed by a Board of Directors appointed by the North Carolina governor and member utilities. See more at https://www.advancedenergy.org/.

Acronyms and Abbreviations

AC	air conditioning
ACH	air changes per hour
AEO	Arkansas Energy Office
AFUE	annual fuel utilization efficiency
AHU	air handling unit
AIA	American Institute of Architects
AR	Arkansas
Btu	British thermal unit
cfm	cubic feet per minute
COAR	Code Official Association of Arkansas
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
PNNL	Pacific Northwest National Laboratory
PWC	Parties Working Collaboratively
RFI	request for information
SEEA	Southeast Energy Efficiency Alliance
SHGC	solar heat gain coefficient

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1.0 Introduction

A research project in the State of Arkansas 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 Arkansas field study was initiated in May 2015 and continued through October 2015. During this period, research teams visited 226 homes across the state during various stages of construction. At the time of the study, the state had the 2014 Arkansas Energy Code[1], an amended version of the 2009 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".[2] 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.[3,4] Hence, the importance of ensuring code-intended energy savings, so that consumers reap the benefits of improved codes—something which will happen only through high levels of compliance. More information on the FOA and overall DOE interest in compliance is available on the DOE Building Energy Codes Program website.[5]

[1] Available at http://arkansasenergy.org/sites/default/files/content/pages/ar_energy_code_for_new_building_construction_supplements_and_amendments_2014.pdf.

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

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

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

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

1.2 Project Team

The Arkansas project was led by the Southeast Energy Efficiency Alliance (SEEA), with field data collected by Advanced Energy. 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 Arkansas field study was based on a methodology developed by DOE to identify savings opportunities associated with increased energy code compliance. This methodology involves gathering field data on energy code measures, as installed and observed in actual homes. In the subsequent analysis, trends and issues are identified, which can help to inform energy code training and other compliance improvement programs.

Highlights of the methodology:

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

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

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

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

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

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

collection and analysis methodologies is published separately from this report (DOE 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 Arkansas 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 or 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 contacting local building departments to identify homes currently in the permitting process. Code officials responded by providing lists of homes at various stages of construction within their jurisdiction. These lists were then sorted using a random number generator and utilized by field personnel to contact builders to gain site access. As prescribed by the methodology, each home was visited only once to avoid any bias associated with multiple site visits. Only installed items directly observed by the field teams during site visits were recorded. If access was denied for a particular home on the list, field personnel moved onto the next home on the list.

2.2.2.1 Data Collection Form

The field teams relied on a data collection form customized to the *mandatory* and *prescriptive* requirements of the 2014 Arkansas Energy Code. The final Arkansas data collection form is available in spreadsheet format on the DOE Building Energy Codes Program website.[5] The form included all energy code requirements (i.e., not just the 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.

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[3] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study.
[4] Available at http://censtats.census.gov/ (select the "Building Permits" data).
[5] Available at https://www.energycodes.gov/compliance/residential-energy-code-field-study and based on the forms typically used by the RES*check* compliance software.
[6] See http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf.

The information beyond the key items was used during various phases of the analysis, or to supplement the overall study findings. For example, insulation installation quality impacts the energy-efficiency of insulation and was therefore used to modify that key item during the energy modeling and savings calculation. Equipment, including fuel type and efficiency rating, and basic home characteristics (e.g., foundation type) helped validate the prototype models applied during energy simulation. Other questions, such as whether the home participated in an above-code program, can assist in understanding whether other influencing factors are at play beyond the code requirements.

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

2.2.2.2 Data Management and Availability

Once the data collection effort was complete, the project team conducted a thorough quality assurance review. This included an independent check of raw data compared to the information provided to PNNL for analysis, and helped to ensure completeness, accuracy and consistency across the inputs. Prior to submitting the data to PNNL, the team also removed all personally identifiable information, such as project site locations and contact information. The final dataset is available in spreadsheet format on the DOE Building Energy Codes Program website.[7]

2.3 Data Analysis

All data analysis in the study was performed by PNNL, and was applied through three basic stages:

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

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

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

2.3.1 Statistical Analysis

Standard statistical analysis was performed with distributions of each key item plotted by climate zone. This approach enables a better understanding of the range of data, and provides insight on what energy-

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

efficiency measures are most commonly installed in the field. It also allows for a comparison of installed values to the applicable code requirement, and for identification of any problem areas where potential for improvement exists. The graph below represents a sample key item distribution, and is further explained in the following paragraph.

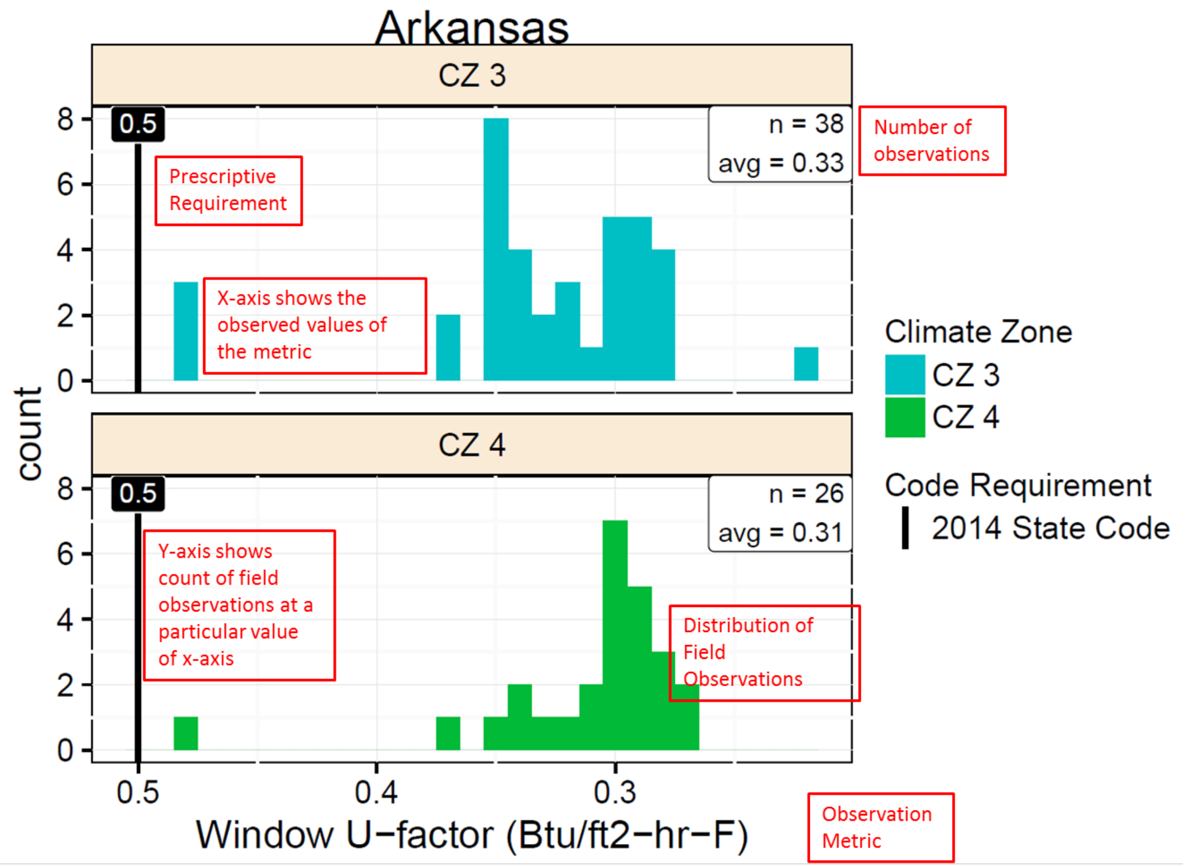

Figure 2.1. Sample Graph

Each graph is set up in a similar fashion, identifying the *state*, *climate zone*, and specific item being analyzed. The total *sample size* (n) is displayed in the top left or right corner of the graph, along with the distribution *average*. The *metric* associated with the item is measured along the horizontal axis (e.g., window U-factor is measured in Btu/ft2-hr-F), and a *count* of the number of observations is measured along the vertical axis. A vertical line is imposed on the graph representing the applicable code requirement—values to the right-hand side of this line are *better than code*. Values to the left-hand side represent areas for improvement.

2.3.2 Energy Analysis

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

Energy simulation was then conducted using the EnergyPlus™ software.[8] Each of the 1,500 models was run multiple times, to represent each combination of heating systems and foundation types commonly found in the state. This resulted in upwards of 30,000 simulation runs for 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). This was done by individually upgrading each worse-than-code observation to the corresponding *prescriptive* code requirement, resulting in a second set of models (*full compliance*) that could be compared to the first (*as-built*). All other components were maintained at the corresponding prescriptive code value, allowing for the savings potential associated with a key item to be evaluated in isolation.

All variations of observed heating systems and foundation types were included, and annual electric, gas and total EUIs were extracted for each building. To calculate savings, the differences in energy use calculated for each case were weighted by the corresponding frequency of each observation to arrive at an average energy savings potential for each climate zone. Potential energy savings for each climate zone were further weighted using construction starts in that zone to obtain the average statewide energy savings potential. State-specific construction volumes and fuel prices are used to calculate the maximum energy savings potential for the state in terms of *energy* (MMBtu), *energy cost* ($), and avoided *carbon emissions* (MT CO2e).

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

[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.

2.4 Limitations

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

2.4.1 Applicability of Results

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

2.4.2 Determination of Compliance

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

2.4.3 Sampling Substitutions

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

2.4.4 Site Access

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

2.4.5 Analysis Methods

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

2.4.6 Presence of Tradeoffs

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

3.0 State Results

3.1 Field Observations

The key items form the basis of the study, and are therefore the focus of this section. Arkansas is comprised of multiple climate zones; zone 3 (CZ3) and zone 4 (CZ4). 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 of how certain observations, such as insulation installation quality, are used to modify key item results. (See Section 2.3.1 for a sample graph and explanation of how they should be interpreted.)

3.1.1 Key Items

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

The following key items were found applicable within the state:

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

Over 90 percent of the predominant foundation observations were slab-on-grade. Among the 66 slab observations, only four had insulation installed. Given the small number of foundation insulation observations, foundation insulation is not included in this section.

3.1.1.1 Envelope Tightness

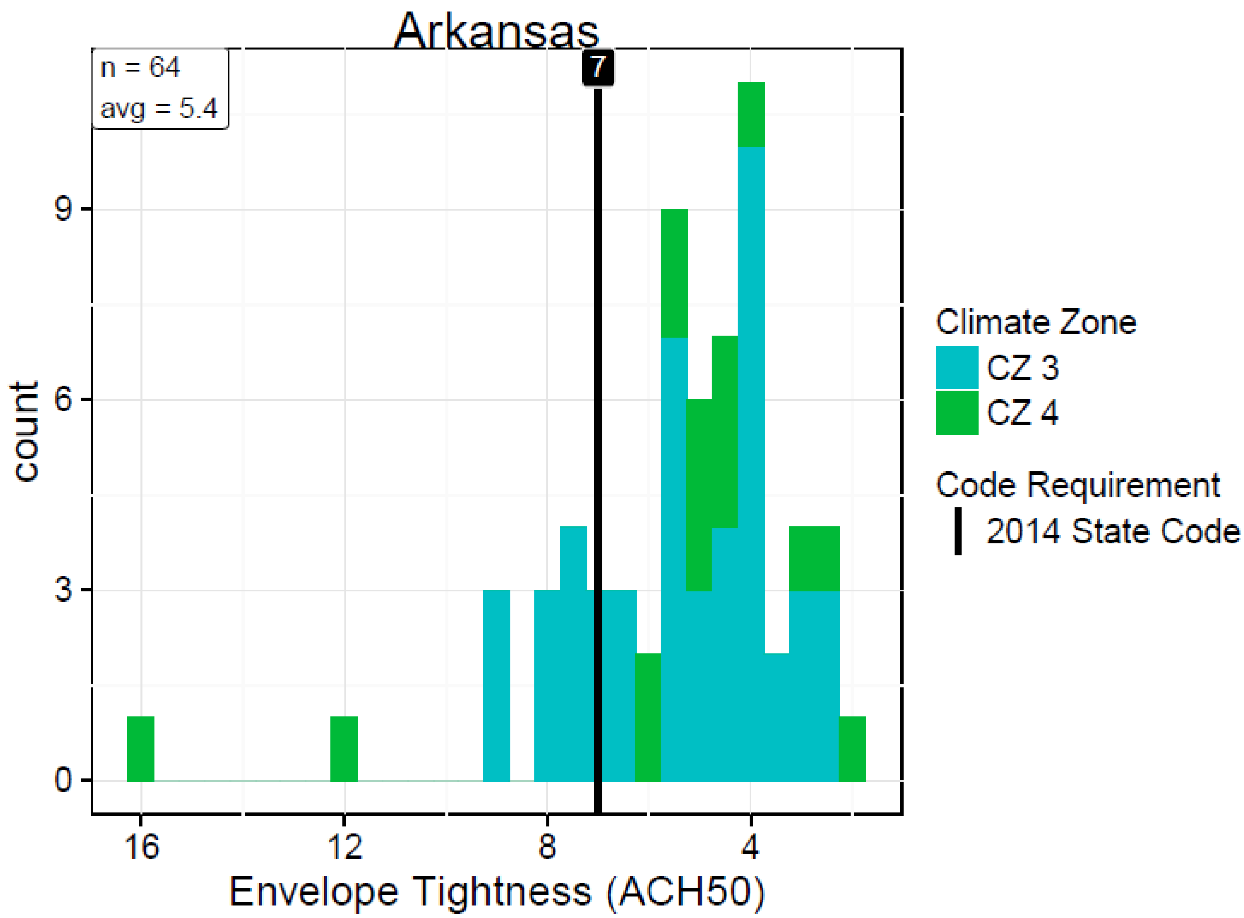

Figure 3.1. Envelope Tightness (ACH50)

Table 3.1. Envelope Tightness (ACH50)

Climate Zone	**CZ3**	**CZ4**	**Statewide**
Number	48	16	64
Range	9.0 to 2.3	16.0 to 1.9	16.0 to 1.9
Average	5.3	5.7	5.4
Requirement	7	7	7
Compliance Rate	38 of 48 (79%)	14 of 16 (88%)	52 of 64 (81%)

- **Interpretations:**
  - There was a wider variation in the distribution of observations in CZ4, although the compliance rate in CZ4 exceeded that in CZ3. Overall, the majority of observations were in the 1.9 to 5.7 ACH50 range.
  - 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

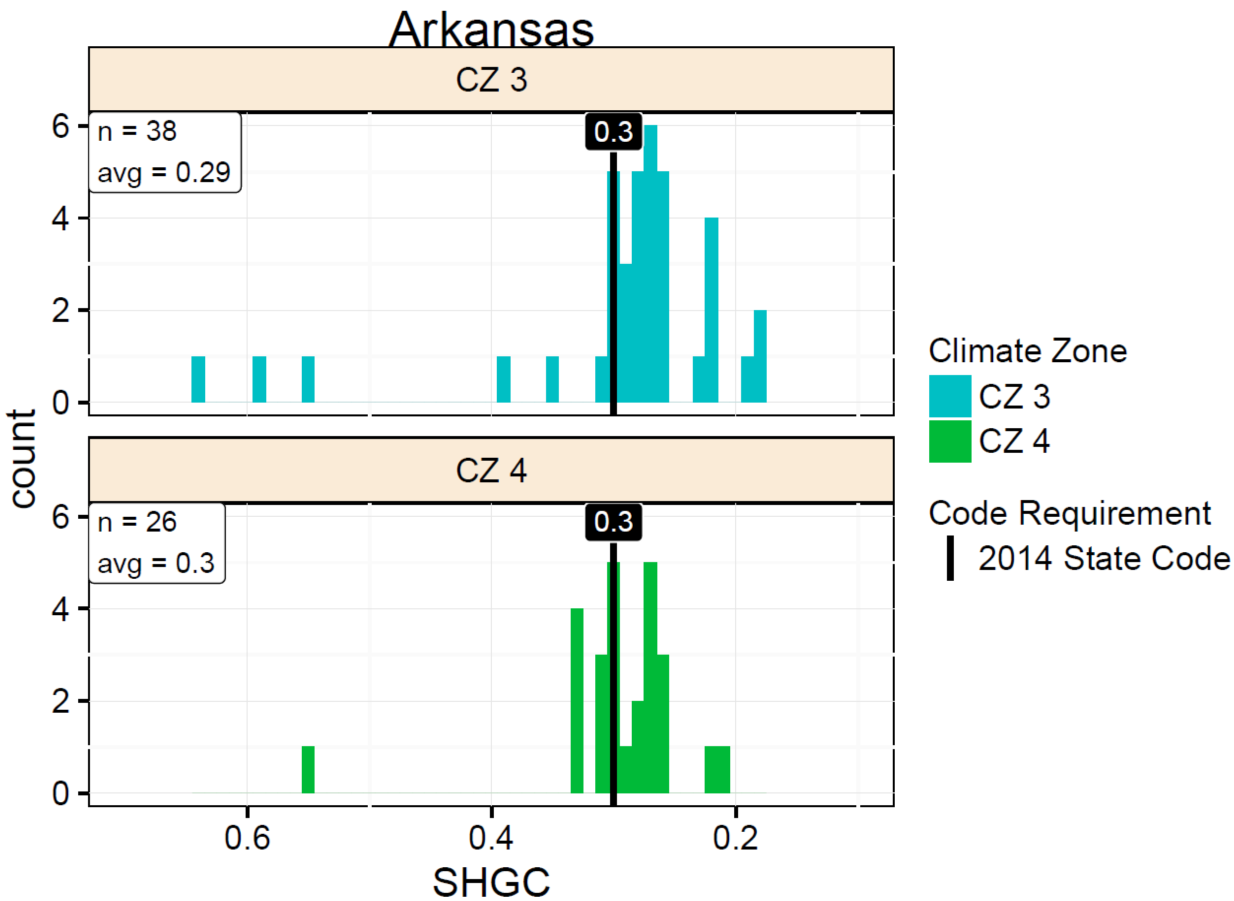

Figure 3.2. Window SHGC

Table 3.2. Window SHGC

Climate Zone	CZ3	CZ4	Statewide
Number	38	26	64
Range	0.64 to 0.18	0.55 to 0.21	0.64 to 0.18
Average	0.29	0.30	0.30
Requirement	0.30	0.30	0.30
Compliance Rate	32 of 38 (84%)	18 of 26 (69%)	50 of 64 (78%)

- **Interpretations:**
  - SHGC values had a wider range in CZ3 than CZ4, but a better overall compliance rate.
  - Statewide, more than two-thirds of the observations were equal to or better than the Arkansas Code requirement.
  - This should be considered an area for improvement in the state, and should be given attention in future training and enforcement.

3.1.1.3 Window U-Factor

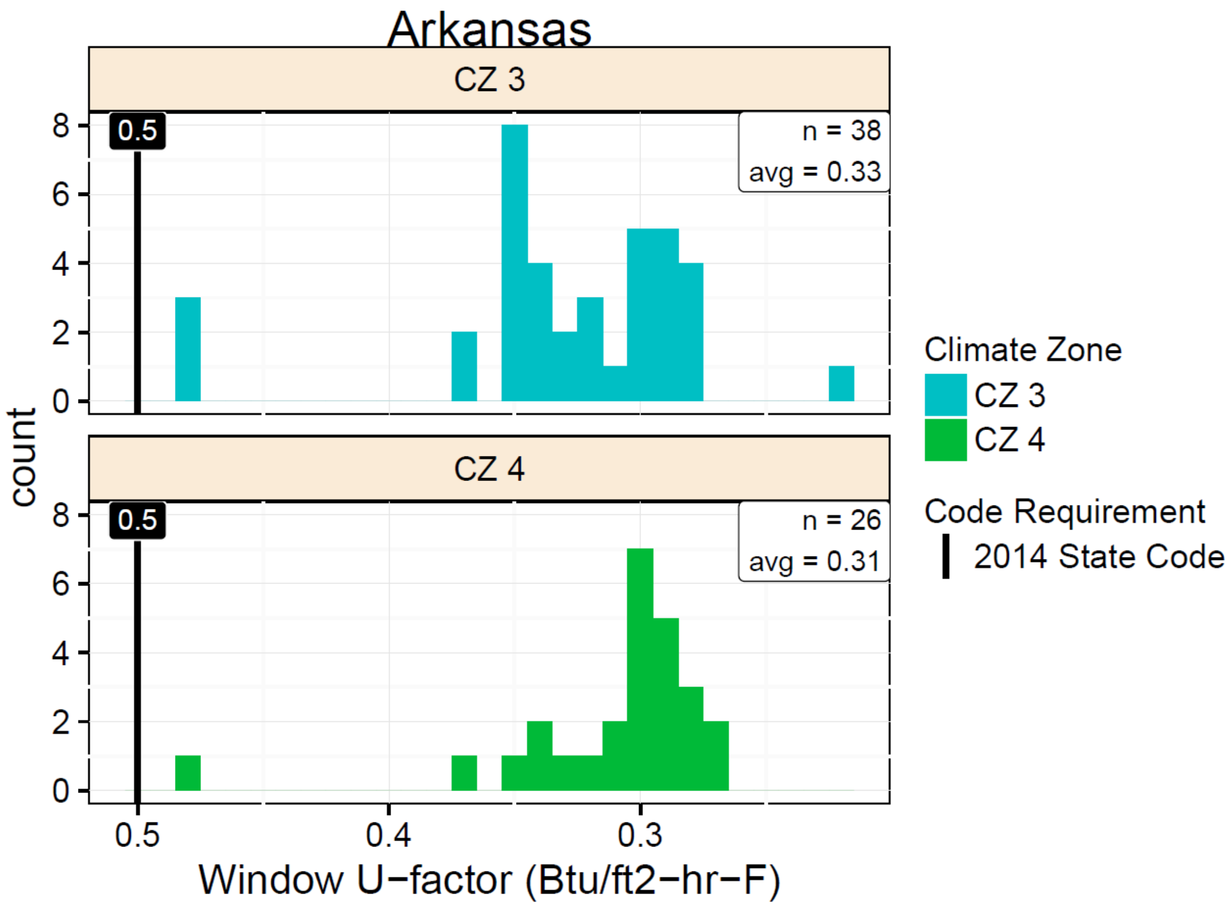

Figure 3.3. Window U-Factor

Table 3.3. Window U-Factor

Climate Zone	CZ3	CZ4	Statewide
Number	38	26	64
Range	0.48 to 0.22	0.48 to 0.27	0.48 to 0.22
Average	0.33	0.31	0.32
Requirement	0.50	0.50	0.50
Compliance Rate	38 of 38 (100%)	26 of 26 (100%)	64 of 64 (100%)

- **Interpretations:**
  - Window U-factor requirements appear to have been implemented with a high rate of success across 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.

3.1.1.4 Wall Insulation

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

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

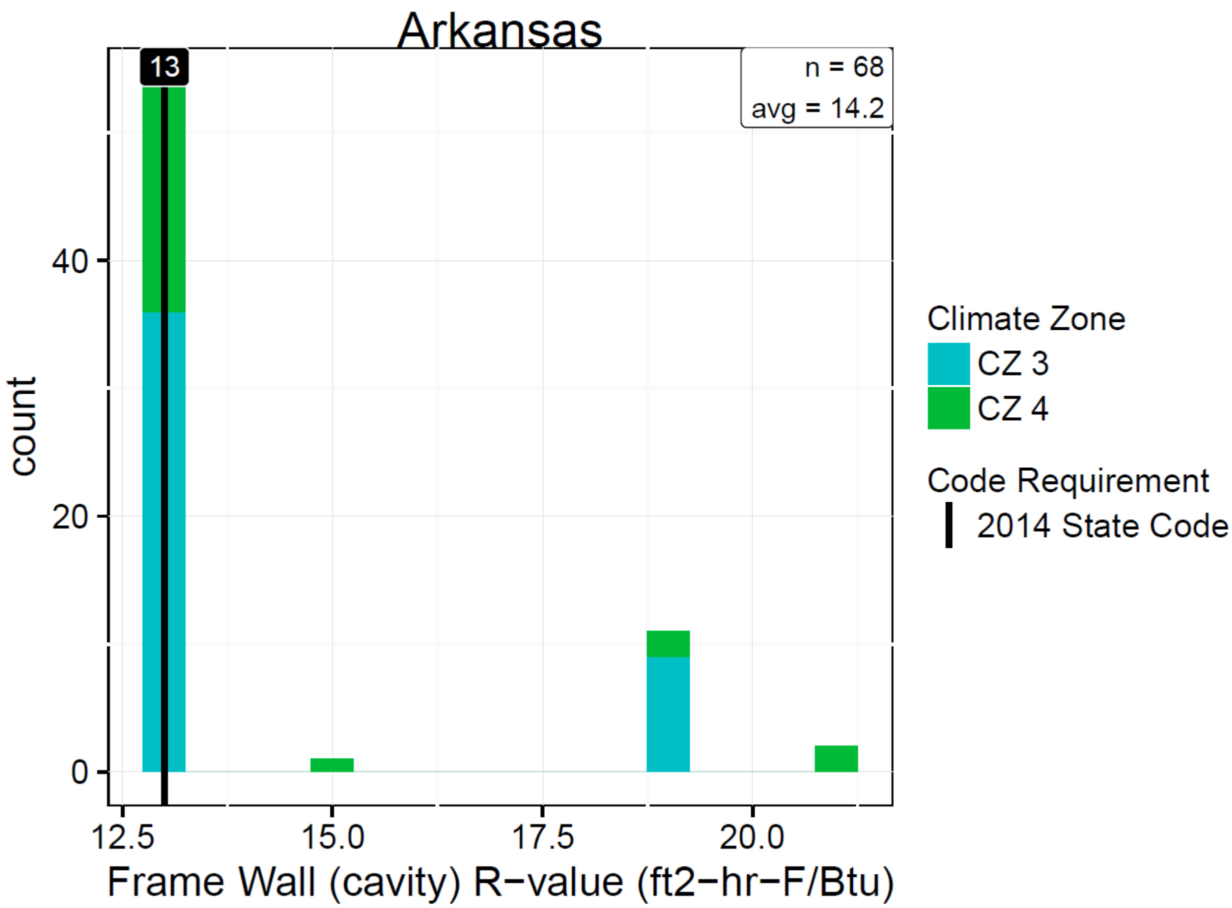

Figure 3.4. Frame Wall R-Value (Cavity)

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

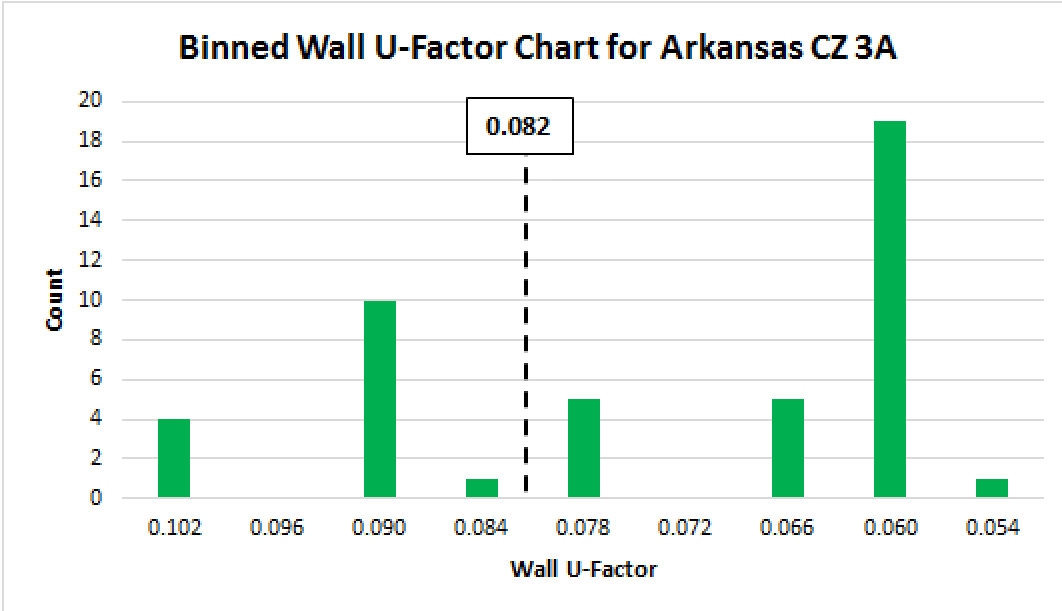

Figure 3.5. Wall Assembly Performance, including Wall Insulation Installation Quality in CZ3

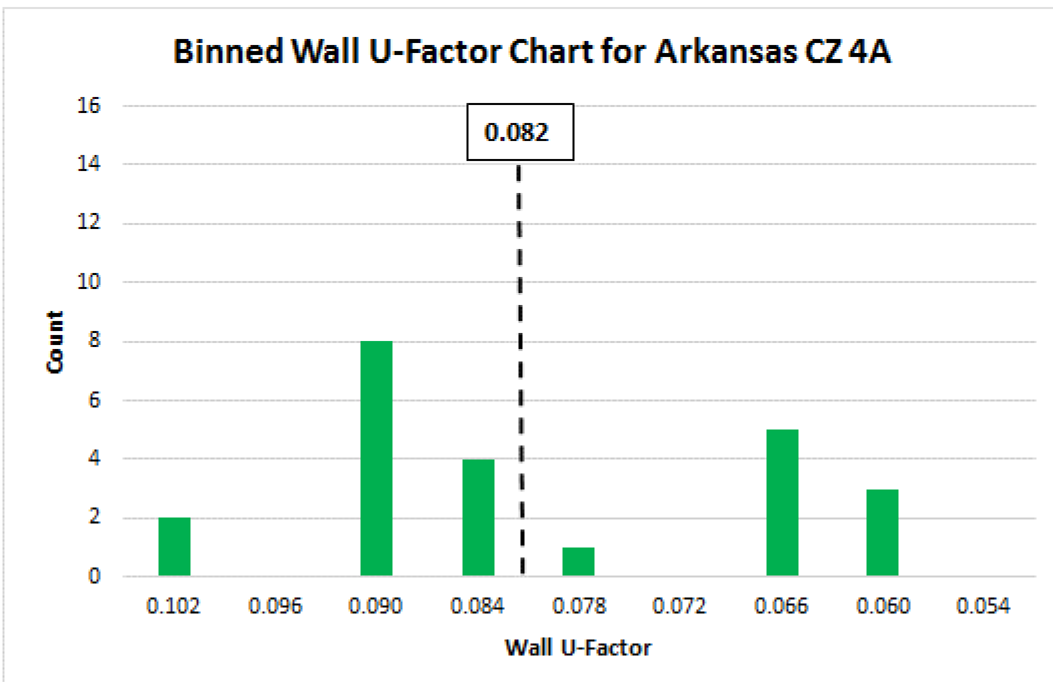

Figure 3.6. Wall Assembly Performance, including Wall Insulation Installation Quality in CZ4

Figure 3.5 and Figure 3.6 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. Frame Wall Assembly

Climate Zone	CZ3	CZ4	Statewide
Number	45	23	68
Range	7.59 to 1.88	1.71 to 8.85	8.85 to 1.71
Average	0.074	0.081	0.077
Assembly U-Factor (expected)	0.082	0.082	0.082
Rate	30 of 45 (67%)	9 of 23 (39%)	39 of 68 (57%)

- **Interpretations:**
  - Cavity insulation 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, a majority of observations had below Grade I insulation installation quality—39 of 68 (57%) were rated as Grades II or III (Table 3.8).
  - While cavity insulation 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

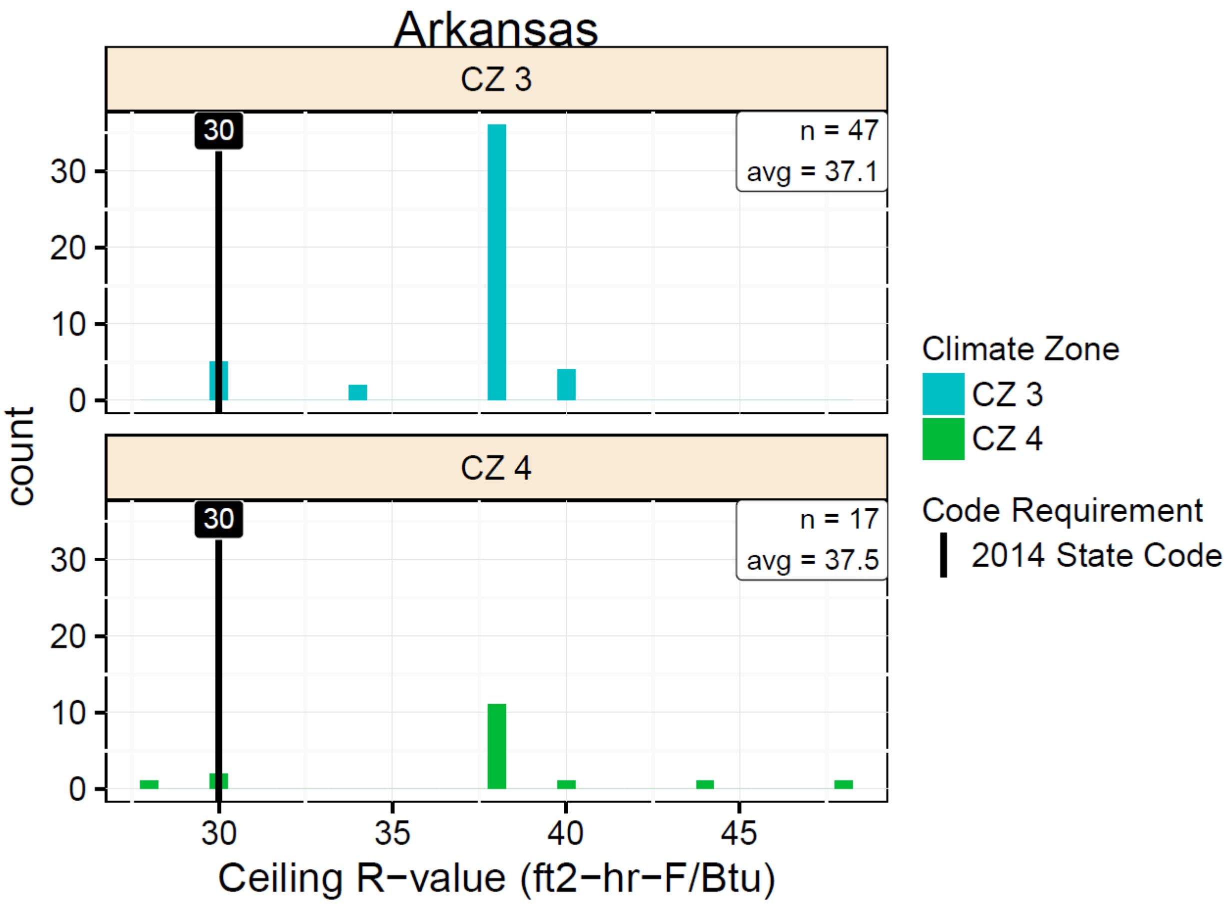

Figure 3.7. Ceiling R-Value

Table 3.5. Ceiling R-Value

Climate Zone	CZ3	CZ4	Statewide
Number	47	17	64
Range	30 to 40	28 to 48	28 to 48
Average	37.1	37.5	37.3
Requirement	30	30	30
Compliance Rate	47 of 47 (100%)	16 of 17 (94%)	63 of 64 (98%)

- **Interpretations:**
  - All observations but one meet or exceed the code requirement.
  - In terms of insulation installation quality, 49 of 64 (77%) observations were rated Grade I.
  - Ceiling insulation appears to have been successfully implemented in the state.

3.1.1.6 Lighting

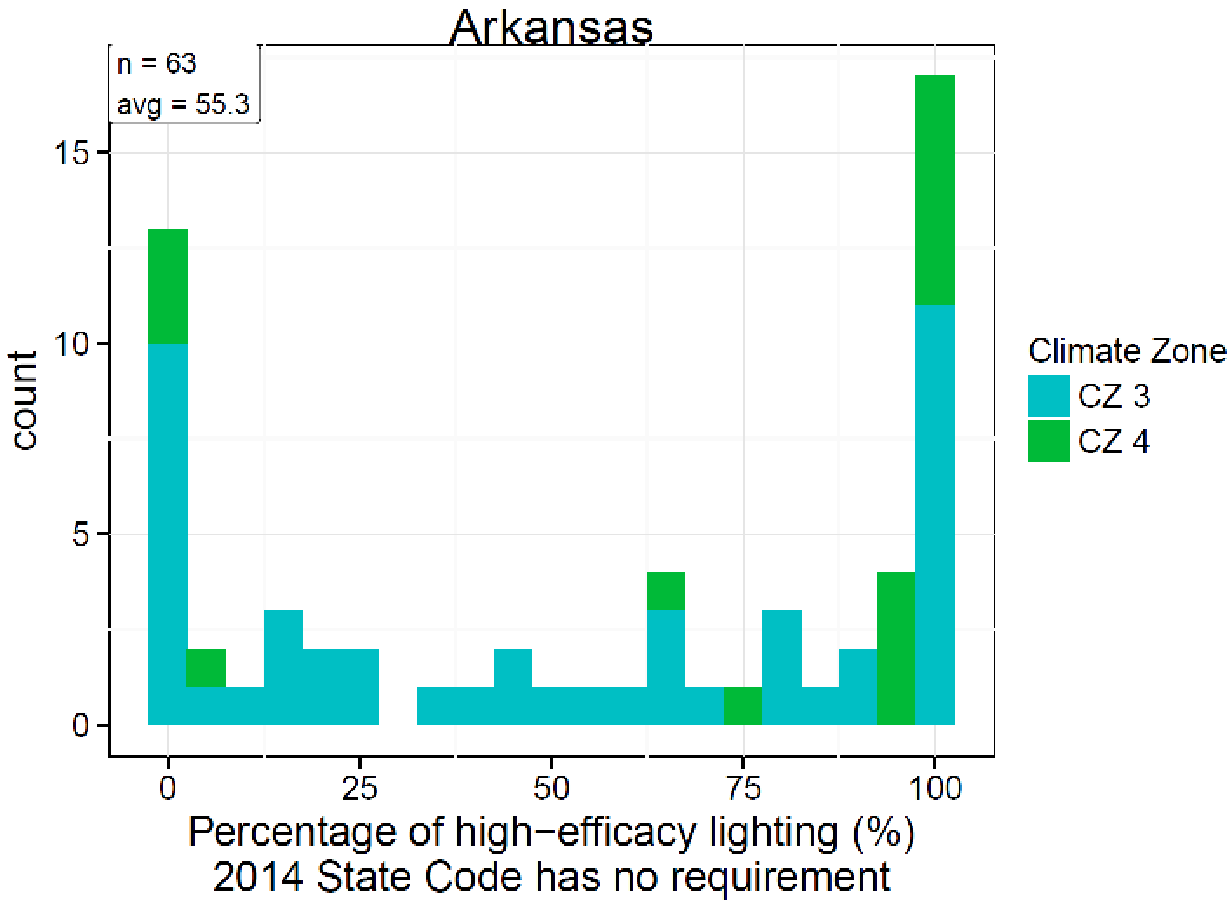

Figure 3.8. High-Efficacy Lighting Percentage

Table 3.6. High-Efficacy Lighting Percentage

Climate Zone	CZ3	CZ4	Statewide
Number	47	16	63
Range	0 to 100	0 to 100	0 to 100
Average	50.1	70.6	55.3
Requirement	NA	NA	NA
Compliance Rate	NA	NA	NA

- **Interpretations:**
  - The Arkansas Energy Code does not have a high-efficacy lighting requirement. However, the observations show that 12 of 16 (75%) of observations in CZ3 and 24 of 47 (51%) in CZ4, or 57% statewide, would meet or exceed the 50% requirement in the 2009 IECC.

3.1.1.7 Duct Tightness

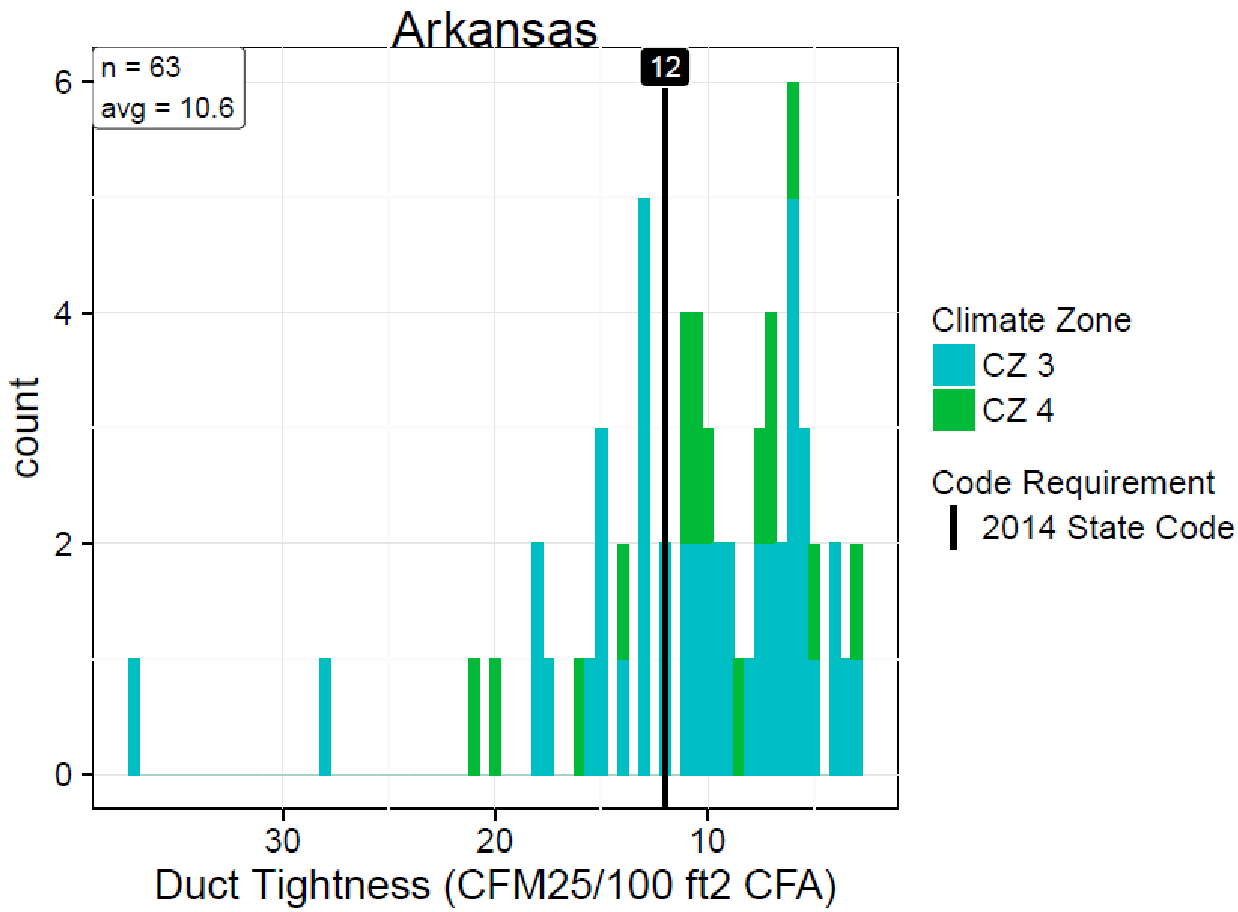

Figure 3.9. Duct Tightness (CFM25/100ft2 CFA)

Table 3.7. Duct Tightness

Climate Zone	CZ3	CZ4	Statewide
Number	47	16	63
Range	37.0 to 3.6	20.9 to 3.0	37.0 to 3.0
Average	10.6	10.5	10.6
Requirement	12	12	12
Compliance Rate	32 of 47 (68%)	12 of 16 (75%)	46 of 63 (73%)

- **Interpretations:**
  - The average duct leakage is 10.56 CFM 25/100 ft2 (in unconditioned space). There were no homes with ducts entirely in conditioned space.
  - Reductions in duct leakage represent an area for improvement within the state, and should be given increased attention in future training and enforcement.

The project team noted that the Arkansas Energy Code removed the requirement for duct leakage testing, allowing permit holders to choose between testing and visual observation. They added that it will be important to ensure that future education efforts include resources that target the visual observation option.

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[1] 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 (79 of 144) were classified as Grade I, indicating that insulation installation quality is generally good.

Table 3.8. Insulation Installation Quality

Assembly	Grade I	Grade II	Grade III	Total Observations
Roof Cavity	49	12	3	64
Above Grade Wall	29	28	11	68
Knee Wall	0	6	0	6

3.1.2 Additional Data Items

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

The following represents a summary of this data and outlines some of the more significant findings, in many cases including the observation or compliance rate associated with the specified item. The full data set, including some additional data that did not have enough observations to be deemed meaningful, is also available on the DOE Building Energy Codes Program website.[2]

3.1.2.1 Average Home

- Size: 1904 ft^2 (n=31) and 1.3 stories (n=57)

Table 3.9. Conditioned Floor Area (ft^2)

Conditioned Floor Area (ft^2)	< 1000	1000 to 1999	2000 to 2999	3000 to 3999	4000+
Percentage	0 %	65 %	32 %	3 %	0 %

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

Table 3.10. Number of Stories

No. of Stories	1	1.5	2	2.5	3	4+
Percentage	70 %	7 %	21 %	2%	0 %	0 %

3.1.2.2 Envelope

- Foundations (n=119): Mix of slab-on-grade (91%) and crawlspaces (9%)

3.1.2.3 Duct & Piping Systems

- Ducts were often not located within conditioned space (percentage of duct system):
  - Supply (n=59): 31%
  - Return (n=59): 12%
- Ducts located entirely in conditioned space:
  - Supply (n=59): 17% of homes
  - Return (n=59): 0% of homes

3.1.2.4 HVAC Equipment

- Heating (n=56): Split between gas furnace (59%) and electric heat pump (41%)
- Cooling (n=44): Split between central AC (68%) and heat pump (32%)

3.2 Energy Intensity

The statewide energy analysis results are shown in the Figure 3.10, 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 Arkansas appear to use less energy than would be expected relative to homes built to the current minimum state code requirements.

Analysis of the collected field data indicates an average regulated EUI (dashed line in Figure 3.10) of approximately 28.21 kBtu/ft^2-yr compared to 33.12 kBtu/ft^2-yr for homes exactly meeting minimum *prescriptive* energy code requirements (black line in Figure 3.10). This suggests the EUI for a “typical” home in the state is about 8.5% better than the Arkansas Energy Code.

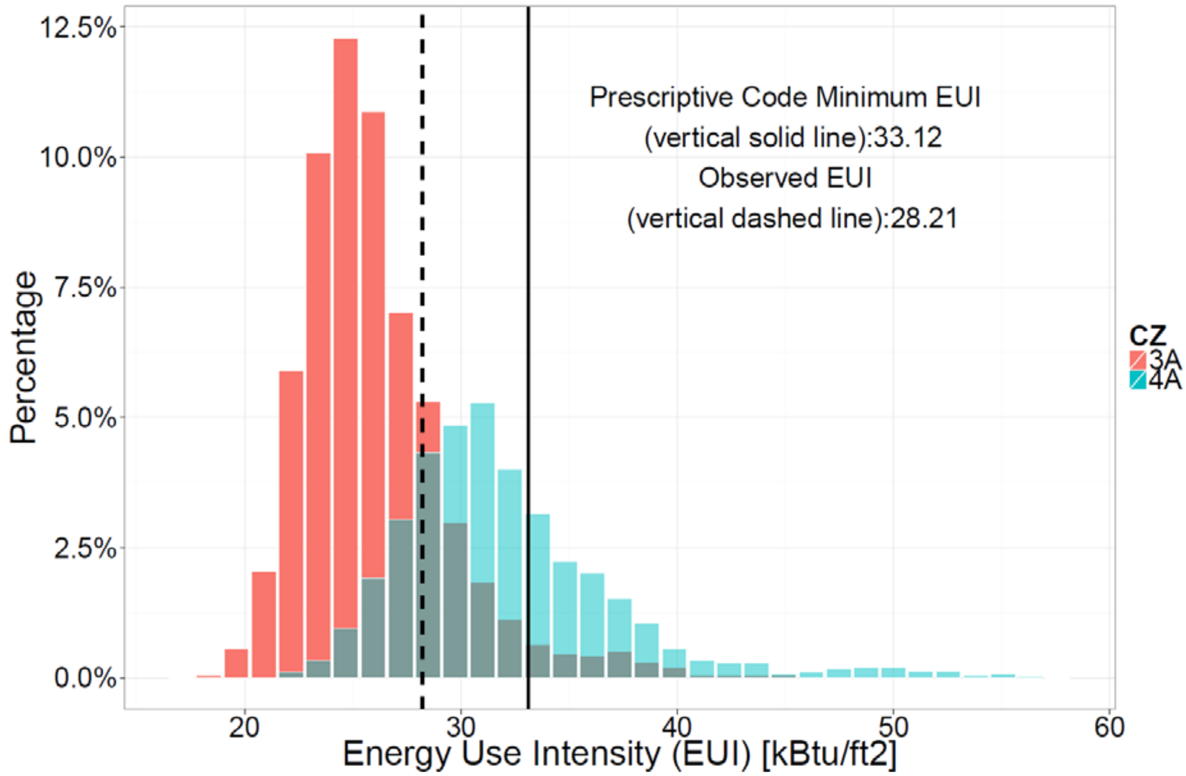

Figure 3.10. Statewide EUI Analysis for the 2014 Arkansas Energy Code

When the observed EUI of 28.21 kBtu/ft2-yr is compared to 31.54 kBtu/ft2-yr for homes meeting the 2009 IECC (Figure 3.11), the EUI for the typical home in the state is about 9% better than code.

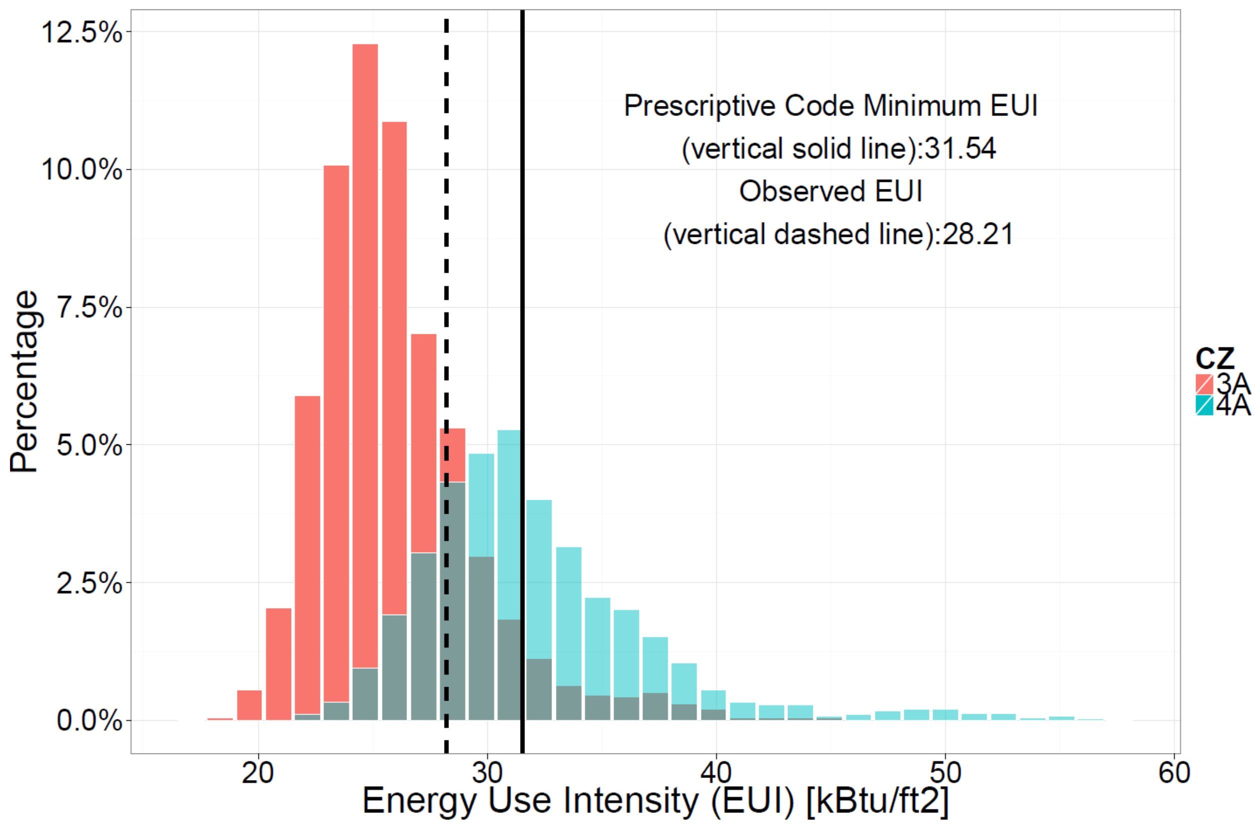

Figure 3.11. Statewide EUI Analysis for the 2009 IECC

3.3 Savings Potential

Several key items exhibit the potential for improvement. Those with the greatest potential[3], shown below followed by the percent of observations that met or exceeded the associated code requirement, were analyzed further to calculate the associated savings potential, including energy, cost and carbon savings.

- Exterior Wall Insulation (98%),
- Envelope Air Leakage (81%),
- Window SHGC (78%), and
- Duct Leakage (70%).

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 greatest total energy 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.

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[3] Defined here as those 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.

Table 3.11. Statewide Annual Measure-Level Savings for Arkansas

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	3A	126	7	1,133	3,296	3,733	62,883	409
	4A	150	10	1,506	1,961	2,954	47,642	307
	State Total	**135**	**8**	**1,272**	**5,257**	**6,687**	**110,524**	**716**
Envelope Air Leakage	3A	76	10	1,214	3,296	4,001	55,640	340
	4A	102	15	1,828	1,961	3,586	48,383	292
	State Total	**86**	**11**	**1,443**	**5,257**	**7,587**	**104,022**	**632**
Exterior Wall Insulation	3A	76	6	846	3,296	2,788	43,362	275
	4A	80	8	1,105	1,961	2,167	31,431	195
	State Total	**78**	**7**	**943**	**5,257**	**4,955**	**74,792**	**470**
Window SHGC	3A	103	-3	71	3,296	233	22,882	185
	4A	73	-4	-151	1,961	-295	5,675	57
	State Total	**92**	**-3**	**-12**	**5,257**	**-63**	**28,557**	**242**
TOTAL		**931**	**23**	**3,646**	**5,257**	**19,166**	**317,895**	**2,060**

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

Measure	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
	5yr	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Duct Leakage	100,305	367,785	3,109,455	1,507,860	5,528,820	46,743,660	10,740	39,380	332,940
Envelope Air Leakage	113,805	417,285	3,527,955	1,560,330	5,721,210	48,370,230	9,480	34,760	293,880
Exterior Wall Insulation	74,325	272,525	2,304,075	1,121,880	4,113,560	34,778,280	7,050	25,850	218,550
Window SHGC	-945	-3,465	-29,295	428,355	1,570,635	13,279,005	3,630	13,310	112,530
TOTAL	**287,490**	**1,054,130**	**8,912,190**	**4,768,425**	**17,484,225**	**147,821,175**	**30,900**	**113,300**	**957,900**

4.0 Conclusions

The Arkansas field study provides an enhanced understanding of statewide code implementation, and suggests that additional savings are available through increased compliance with the state energy code. From a statewide perspective, the average home in Arkansas uses about 8.5% 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 19,166 MMBtu, which equates to $317,895 in cost savings, and emission reductions of 2,060 MT CO2e. Over a 30-year period, these impacts grow to 8.9 million MMBtu, $147 million, and over 957,000 CO2e in avoided emissions.

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

Table 4.1. Annual Statewide Savings Potential in Arkansas

	Annual Savings		
Key Measure	**Energy** (MMBtu)	**Cost** ($)	**Carbon** (MT CO2e)
Duct Leakage	6,687	110,524	716
Envelope Air Leakage	7,587	104,022	632
Exterior Wall Insulation	4,955	74,792	470
Window SHGC	-63	28,557	242
Total	**19,166 MMBtu**	**$317,895**	**2,060 MT CO2e**

5.0 References

Census Bureau. 2016. Censtats Building Permits Database. http://censtats.census.gov/

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

DOE Building Energy Codes Program's residential field study website is available at https://www.energycodes.gov/compliance/residential-energy-code-field-study (accessed August 1, 2016).

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EnergyPlus. https://energyplus.net/.

The Arkansas residential field study website is available at http://seealliance.org/initiatives/built-environment/energy-codes/residential-energy-code-compliance-se/ (accessed March 1, 2017).

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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 Arkansas	Trade association representing builders in the state of Arkansas to strengthen the industry through legislative, educational, technical and public relations programs.
Entergy Arkansas	An investor-owned utility in Arkansas serving over 700,000 customers in 63 counties.
CenterPoint Energy	An investor-owned utility serving over 3 million customers in several states, including Arkansas.
SWEPCO	An investor-owned utility in Arkansas that is part of the American Electric Power system that serves over 5 million customers in 11 states.
Arkansas Public Service Commission	A state entity charged with ensuring that public utilities provide safe, adequate and reliable utility service at just and reasonable rates. Responsible for approval of all utility energy efficiency programs.
Arkansas Energy Office	The state entity in charge of all energy codes. They run the code adoption process and provide technical assistance and resources.
COAR	Represents all code officials in the state of Arkansas.
Arkansas HVACR Association	Trade association representing HVAC contractors in the state of Arkansas. The mission of the Arkansas HVACR Association is to promote professionalism and help our members become more profitable by providing benefits, information, education and legislative representation.
Pulaski Technical College	Pulaski Technical College had a Weatherization Training Center that provided educational resources to the industry.

Appendix B

State Sampling Plan

Appendix B

State Sampling Plan

B.1 State Sampling Plan

Table B.1. State Sampling Plan

Location	Sample	Actual
Bentonville, Benton	8	8
Fayetteville, Washington	10	10
Little Rock, Pulaski	7	7
Jonesboro, Craighead	3	3
Rogers, Benton	2	2
Fort Smith, Sebastian	2	2
Benton, Saline	3	3
Conway, Faulkner	2	2
Bryant, Saline	2	2
Centerton, Benton	2	2
North Little Rock, Pulaski	1	1
Cabot, Lonoke	2	2
Maumelle, Pulaski	2	2
Cave Springs, Benton	3	3
Lowell, Benton	1	1
Russellville, Pope	3	3
Searcy, White	1	1
Jacksonville, Pulaski	1	1
Shannon Hills, Saline	1	Substituted Hot Springs
Vilonia, Faulkner	1	1
Texarkana AR, Miller	1	1
Goshen, Washington	2	2
Greenwood, Sebastian	2	2
Siloam Springs, Benton	1	1
Total	**63**	**63**

B.2 Substitutions

In the Arkansas study, the following substitutions were made: the project team had to substitute one sample for Shannon Hills, a suburb along the edge of Little Rock, AR. The substituted location was Hot Springs, an adjacent jurisdiction to Shannon Hills with similar demographic criteria to Shannon Hills.

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