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Georgia Residential Energy Code Field Study: Final Report

September 2022

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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 Georgia identified opportunities to reduce homeowner utility bills in residential single-family new construction by increasing compliance with the state energy code. The study was comprised of three phases; (1) a **baseline study** to document typical practice and identify opportunities for improvement based on empirical data gathered from the field; (2) an **education and training** phase targeting the opportunities identified; and (3) a **post-study** to assess whether a reduction in average statewide energy use could be detected following the education and training phase. Together, this approach is intended to assist states in identifying technology trends and practices based on empirical data gathered in the field, evaluating how their codes are being implemented in practice, and targeting the most impactful and cost-effective opportunities for improvement based on their codes. The purpose of this report is to document findings and final results from the Georgia field study, including a summary of key trends observed in the field, their impact on energy efficiency, and whether the selected education and training activities resulted in a measurable change in statewide energy use. Public and private entities—state government agencies, utilities, and others—can also use this information to justify and catalyze investments in workforce education, training and related energy efficiency programs.

Background

The baseline field study (Phase I) was initiated in April 2015 and continued through November 2015. During this period, research teams visited 216 homes during various stages of construction, resulting in a substantial data set based on observations made directly in the field. Analysis of the Phase I data led to a better understanding of the energy features typically present in Georgia homes, and indicated over $4.5 million in potential annual savings to homeowners in the state that could result from increased code compliance (Table ES.2).

Starting in April 2016 and continuing through October 2017, members of the Georgia field study team conducted targeted education and training activities (Phase II). Those activities included circuit rider assistance[1], in-person trainings, an energy code hotline, and online videos. More information on the specific education and training activities employed in the state is included in Section 2.5. Following the baseline study and the education and training phases, the research team conducted the post-study (Phase III), visiting an additional 139 homes across the state between March 2018 and September 2018. The results of this effort are presented Table ES.1 and discussed further in Section 3.0.

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[2]. As part of both the pre- and post-studies, the project team implemented customized sampling plans representative of new construction within the state, which were originally developed by Pacific Northwest National Laboratory (PNNL) and then vetted with stakeholders.

Following each data collection phase, 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

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[1] A *circuit rider* is an individual with subject matter expertise who mobilizes to serve multiple jurisdictions across a given geographic area (e.g., providing insight, expertise and training on compliance best practices).
[2] See Section 2.1

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 results based on three metrics emphasized by states as of interest relative to tracking code implementation status—potential energy savings, consumer cost savings, and environmental impacts associated with increased code compliance. Together, these findings provide valuable insight on challenges facing energy code implementation and enforcement.

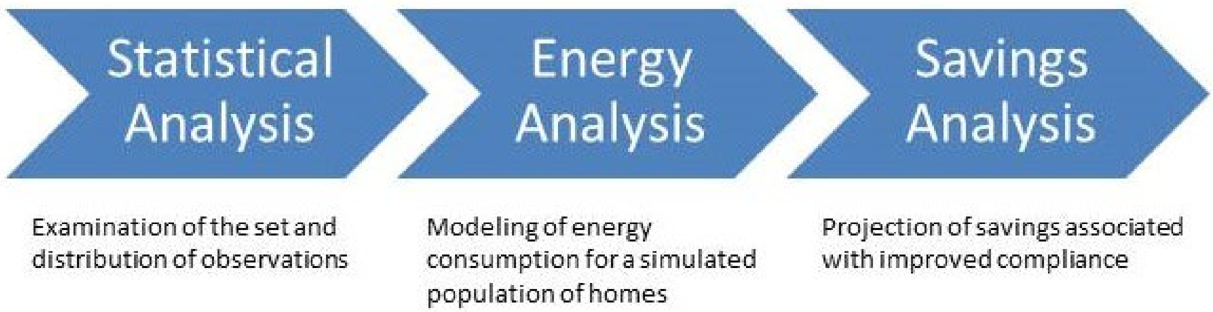

Figure ES.1. Stages of Analysis Applied in the Study

Success for the study is characterized by the following between Phase I and Phase III: 1) a measurable decrease in estimated statewide energy use [a decrease in energy use intensity (EUI) of at least 1.25 kBtu/ft^2] and 2) a reduction in measure-level savings potential. To estimate average statewide energy consumption, field data was analyzed to calculate average statewide energy use as characterized by EUI. Field observations from Phase I and Phase III were analyzed independently and compared to a scenario based on the state energy code's minimum prescriptive requirements. The Phase III results were then compared to the Phase I results to determine whether a measurable change could be detected.

Results

As shown in Table ES.1, the Phase I analysis indicated homes used about 7 percent less energy than would be expected relative to homes built to the minimum prescriptive requirements of the current state code. This percentage improved to 14.2 percent in Phase III, representing a change in EUI of approximately 7.7 percent (2.04 kBtu/ft^2) between Phases I and III.

Table ES.1. Average Modeled Energy Use Intensity in Georgia (kBtu/ft2-yr)

Prescriptive EUI[1]	Phase I	Differential (Phase I vs. Prescriptive)	Phase III	Differential (Phase III vs. Prescriptive)	% Change (Phase III vs. I)
28.52	26.52	-7.0%	24.48	-14.2%	-7.7%

Next, the field data was assessed from the perspective of individual energy efficiency measures, or the key items with the greatest potential for savings in the state, as presented in Table ES.2. These figures represent the potential annual savings associated with each observable measure compared to a counterfactual scenario where all observations meet the prescriptive code requirement. The statistical trends were then extrapolated based on projected new construction across the state. These items, as identified in the Phase I baseline field study, were targeted as a focal point for Phase II education and training activities, and then reassessed following the Phase III study to examine whether a measurable

[1] Calculated based on the minimum prescriptive requirements of the state energy code.

change was detected. Improvement is achieved through a *reduction* in measure-level savings potential between Phases I and III.

Table ES.2. Estimated Annual Statewide Cost Savings Potential

	Total Energy Cost Savings Potential ($)		$ Change	% Change
Measure	**Phase I**	**Phase III**	**Phase III vs. I**	**Phase III vs. I**
Exterior Wall Insulation	1,151,262	936,827	-214,435	-18.6%
Lighting	799,065	104,101	-694,964	-87.0%
Duct Tightness	685,683	215,305	-470,378	-68.6%
Ceiling Insulation	1,880,668	494,910	-1,385,758	-73.7%
TOTAL	$4,516,678	$1,751,143	-$2,765,535	-61.2%

Overall, there was a reduction in savings potential between Phase I and Phase III. This is an improvement of 61 percent and over $2.7 million in annual cost savings achieved by Phase II targeted education and training activities. Despite the positive impact of the project, a savings potential of over $1.7 million still remains that can be further reduced through targeted education and training.

This project provides the state with significant and quantified data that can be used to help direct future energy efficiency activities. DOE encourages states to conduct these types of studies every 3-5 years to validate state code implementation, quantify related benefits achieved, and identify ongoing opportunities to hone workforce education and training programs.

See Section 2.5 for additional information on the specific Phase II education and training activities conducted in Georgia. Detailed comparisons of key item distributions comparing Phase I and Phase III trends are in Section 3.1. For a complete table comparing Phase I and Phase III annual energy and cost savings potential across all three metrics and 5-, 10-, and 30-year savings potential projections see Appendix D. Although the focus of the study was on the key items, field data was collected that included home details (e.g., home size and number of stories) as well as many other code requirements (e.g., equipment efficiencies, labeling and sealing, etc.). Findings from this “other data” are provided in Appendix C.

Acknowledgments

This report was prepared by Pacific Northwest National Laboratory (PNNL) for the U.S. Department of Energy (DOE) Building Energy Codes Program. The authors would like to thank Jeremy Williams at DOE for providing oversight and programmatic guidance throughout the project as well as his contributions to the content of this report.

The following members comprised the Georgia project team (with their affiliations during the project time period):

- Lauren Westmoreland, *Southeast Energy Efficiency Alliance (SEEA)*
- Sareena Nagpal, *SEEA*
- Amy Dzura, *SEEA*
- Arlene Brown, *Advanced Energy*
- Sam Myers, *Advanced Energy*
- Shaun Hassel, *Advanced Energy*
- Jonathan Coulter, *Advanced Energy*
- Bourke Reeve, *Southface*
- Chris North, *Southface*
- Mike Barcik, *Southface*

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/.

Southface

Since 1978, Southface Energy Institute has provided technical assistance to homeowners, builders, remodelers, architects, developers, utilities and others in the building industry. Southface has expertise in building science, energy efficiency and green design for new and existing buildings including single-family homes, multifamily buildings and commercial structures. Southface is a 501(c)(3) nonprofit organization headquartered in Atlanta, Georgia, with affiliated support throughout the southeast region. Southface develops and manages local, regional and national programs to promote sustainable homes, workplaces and communities. See more at http://www.southface.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
AFUE	annual fuel utilization efficiency
AHU	air handling unit
AIA	American Institute of Architects
Btu	British thermal unit
cfm	cubic feet per minute
CZ	climate zone
DCA	Georgia Department of Community Affairs
DET	duct and envelope tightness
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EUI	energy use intensity
FOA	funding opportunity announcement
GA	Georgia
GEFA	Georgia Environmental Finance Authority
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
SEEA	Southeast Energy Efficiency Alliance
SHGC	solar heat gain coefficient

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1.0 Introduction

A three-phase research project in the state of Georgia investigated the energy code-related aspects of newly constructed, single family homes across the state. The study followed a prescribed methodology, with the objectives of generating an empirical data set based on observations made directly in the field, which could then be analyzed to identify compliance trends, their impact on statewide energy consumption, and calculate savings that could be achieved through increased code compliance. The next phase of the project included education and training activities targeting the specific energy efficiency measures and compliance trends identified in the first phase. Finally, an additional data collection phase and analysis were applied to determine if the education and training activities were effective in producing a measurable reduction in statewide energy use. The prescribed approach is intended to assist states in characterizing technology trends and practices, evaluating how their codes are being implemented in practice, and targeting the most impactful and cost-effective opportunities for improvement. In addition, the findings can help states, utilities and other industry stakeholders increase their return on investment (ROI) through compliance-improvement initiatives, and is intended to catalyze additional investments in workforce education, training and related energy efficiency programs.

The baseline field study (Phase I) was initiated in April 2015 and continued through November 2015. During this period, research teams visited 216 homes across the state during various stages of construction, resulting in a substantial data set based on observations made directly in the field. Analysis of the Phase I data led to a better understanding of the energy features typically present in Georgia homes, and indicated over $2,700,000 in potential annual savings to homeowners in the state that could result from increased code compliance.

Starting in April 2016 and continuing through October 2017, members of the Georgia field study team conducted targeted education and training activities (Phase II). Those activities included circuit rider assistance[1], in-person trainings, an energy code hotline, online videos, and stakeholder outreach through the Georgia State Energy Codes Hub. More information on the specific education and training activities employed in the state is included in Section 2.5. Following the baseline study and the education and training phases, the research team conducted the post-study (Phase III), visiting an additional 139 homes across the state between March 2018 and September 2018. The results of this effort are presented in Section 3.0. At the time of the study, the state had the 2011 Georgia Energy Code[2], 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)[3] with the goal of determining whether an investment in education, training, and outreach programs can produce a significant, measurable change in single-family residential building code energy use. Participating states:

[1] A *circuit rider* is an individual with subject matter expertise who mobilizes to serve multiple jurisdictions across a given geographic area (e.g., providing insight, expertise and training on compliance best practices).
[2] Georgia's amendments are available at https://4553qr1wvuj43kndml31ma60-wpengine.netdna-ssl.com/wp-content/uploads/2016/07/georgia-state-supplements-and-amendments-international-energy-conservation-code-2011-1.pdf
[3] Available at https://www.energycodes.gov/residential-energy-code-field-studies

I. Conducted a **baseline field study** to determine installed energy values of code-required items, identify issues, and calculate savings opportunities [Phase I];

II. Implemented **education and training** activities designed to increase code compliance [Phase II]; and

III. Conducted a **second field study** to re-measure the post-training values using the same methodology as the baseline study [Phase III].

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 homeowners realize the benefits of improved codes—something which happens only through high levels of compliance. More information on the original FOA and overall goals of the study is available on the DOE Building Energy Codes Program website.[6]

1.2 Project Team

The Georgia project was led by the Southeast Energy Efficiency Alliance (SEEA), with field study data collected by Southface and 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 organizations
- Trade organizations
- Utilities
- Consumer interest groups

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[4] *National Energy and Cost Savings for New Single- and Multifamily Homes: A Comparison of the 2006, 2009, and 2012 Editions of the IECC.* https://www.energycodes.gov/sites/default/files/2020-06/NationalResidentialCostEffectiveness_2009_2012.pdf

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

[6] Available at https://www.energycodes.gov/energy-code-field-studies

- Other important entities identified by the project team

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

Members of these groups are critical to the success of the project, as they hold important information about building design, construction and compliance trends within a given state or region, and which affect the research. For example, local building departments (i.e., building officials) typically maintain a database of homes under construction and are therefore key to the sampling process, control access to homes needed for site visits, administer and participate in education and training programs, or, as is typically the case with state government agencies, have oversight responsibilities for code adoption, implementation, and professional licensing. Utilities were also identified as a crucial stakeholder at the outset of the program. Many utilities have expressed an increasing interest in energy code investments and are looking at energy code compliance as a means to provide assistance. The field study was aimed specifically at providing a strong, empirically-based case for such utility investment—identifying key technology trends and quantifying the value of increased compliance, as is often required by state regulatory agencies (e.g., utility commissions) as a prerequisite to assigning value and attribution for programs contributing to state energy efficiency goals.

2.0 Methodology

2.1 Overview

The Georgia field study was based on a methodology developed and established by DOE to assist states in identifying technology trends, impacts and opportunities associated with increased energy code compliance. This methodology involves gathering field data on priority energy efficiency measures, as installed and observed in actual homes. In the subsequent analysis, trends and issues are identified, which are intended to inform workforce education and training initiatives and other compliance-improvement programs. The methodology empowers states through an empirically-based assessment of trends, challenges and opportunities, and through an approach which can be adapted and replicated to track changes over time.

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
- **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 and assembly U-factor)[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.

[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.

Success for the study is characterized by the following between Phase I and Phase III: 1) a measurable decrease in estimated statewide energy use [a change in energy use intensity (EUI) of at least 1.25 kBtu/ft^2] and 2) a reduction in measure-level savings potential.

The following sections describe how the methodology was implemented as part of the Georgia study, including sampling, data collection, and resulting data analysis. More information on the DOE data collection and analysis methodology is published separately from this report (DOE 2018) and is available on the DOE Building Energy Codes Program website.[1]

2.2 State Study

The prescribed methodology was customized 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 statewide sampling plans 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[2]. The sampling plan specified the number of key item observations required in each selected county (totaling 63 of each key item across the entire state).

Statistical sampling methods were developed by PNNL and 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 geographic boundaries. These considerations were taken into account and incorporated into the final statewide sample plans shown in Appendix B.

2.2.2 Data Collection

Following confirmation of the sample plans, the project team obtained lists of homes recently permitted for each of the sampled jurisdictions. These lists were then sorted using a random drawing process and applicable builders were contacted to gain site access. That information was then passed onto the data collection team who arranged a specific time for a site visit. As prescribed by the methodology, each home was visited only once to avoid any bias associated with multiple site visits. Only installed items directly observed by the field teams during site visits were recorded. If access was denied for a particular home on the list, field personnel moved onto the next home on the list.

2.2.2.1 Data Collection Form

The field teams relied on a data collection form customized to the mandatory and prescriptive requirements of the state energy code (the 2009 IECC with Georgia-specific amendments[3]). The final

[1] Available at https://www.energycodes.gov/residential-energy-code-field-studies.
[2] Available at http://censtats.census.gov/ (select the "Building Permits" data)
[3] The Georgia code is available at https://4553qr1wvuj43kndml31ma60-wpengine.netdna-ssl.com/wp-content/uploads/2016/07/georgia-state-supplements-and-amendments-international-energy-conservation-code-2011-1.pdf

data collection form is available in spreadsheet format on the DOE Building Energy Codes Program website.[1] 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 tightness test on every home where such tests could be conducted, using RESNET[2] protocols.

Additional data was collected beyond the key items which was used during various stages 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 such as 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. In general, as much data was gathered as possible during a given site visit. However, data on the key items were prioritized given that a specified number was required for fulfillment of the sampling plan.

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 previous studies, simply stated whether an item did or did not comply (i.e., typically assessed as 'Yes', 'No', 'Not Applicable' or 'Not Observable'). 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 designated energy code or similar baseline.

2.2.2.2 Data Management and Availability

Once each 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 for each Phase is available in spreadsheet format on the DOE Building Energy Codes Program website.[3]

2.3 Data Analysis

All data analysis in the study was performed by PNNL, and was applied through three basic stages (for both Phase I and Phase III):

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

[1] Available at https://www.energycodes.gov/residential-energy-code-field-studies based on the forms typically used by the RES*check* compliance software.
[2] See https://www.resnet.us/wp-content/RESNET-Mortgage-Industry-National-HERS-Standards_3-8-17.pdf.
[3] Available at https://www.energycodes.gov/residential-energy-code-field-studies.

what would be expected if sampled homes just met minimum code requirements. The third stage then calculated potential savings based on several metrics of interest to states and utilities—energy savings, consumer cost savings, and avoided carbon emissions associated with increased code compliance. This combination of methods and metrics provides valuable insight on challenges facing energy code implementation in the field, 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. 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.

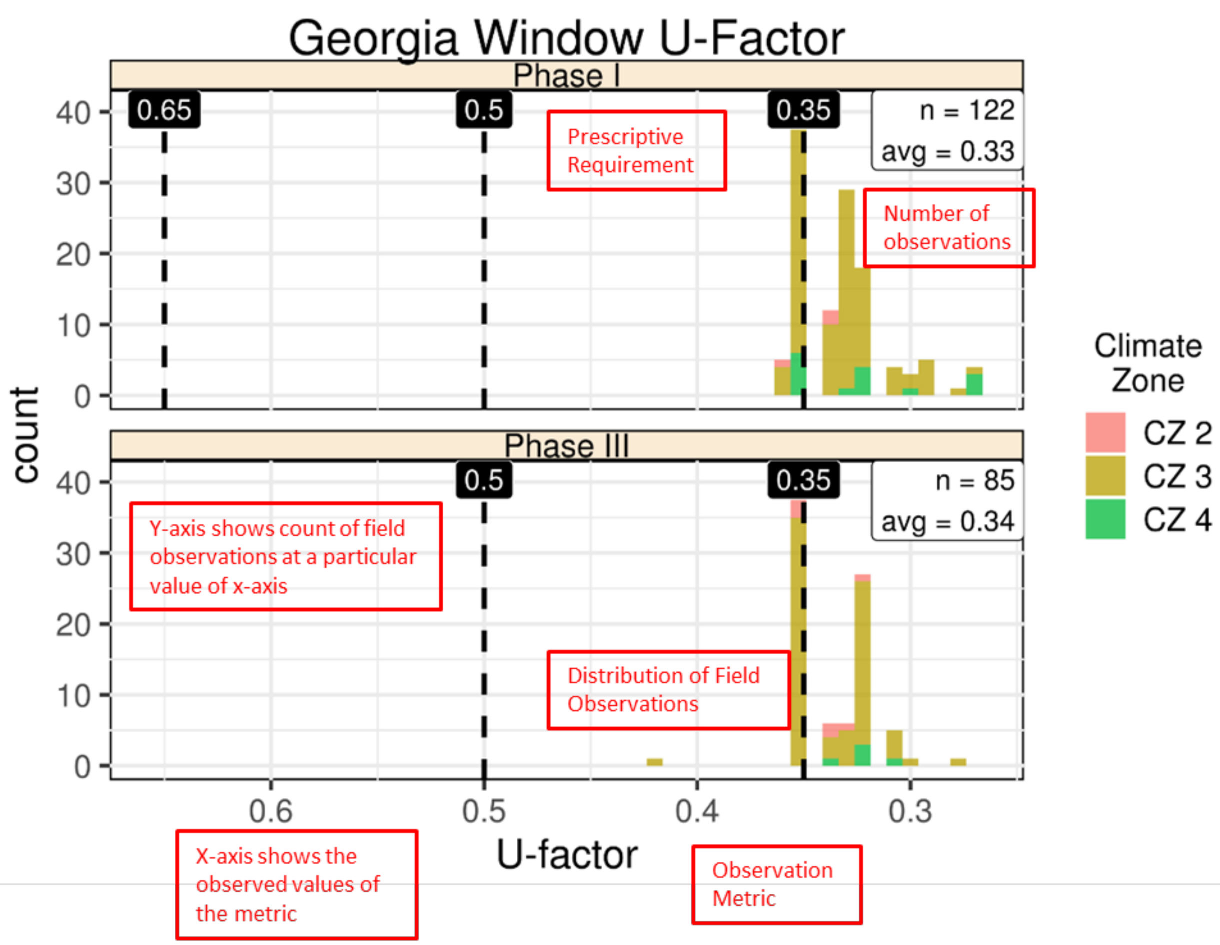

Figure 2.1. Sample Graph

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 (e.g., the prescriptive requirement in CZ4 is 0.35)—values to the right-hand side of this line represent observations which are *better than code*. Values to the left-hand side represent areas for improvement.

2.3.2 Energy Analysis

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

Energy simulation was then conducted using the EnergyPlus™ software.[1] 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. In the energy analysis, the presence of both above code and below code items is included and therefore reflected in the statewide EUI.

Further specifics of the energy analysis are available in a supplemental methodology report (DOE 2018).[2]

2.3.3 Savings Analysis

To begin the third stage, 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[3]. 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

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

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

[3] "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. However, if a measure met the 15% threshold in Phase I but not in Phase III, it was still included in the measure-level savings for Phase III regardless of the worse-than-code percentage so as not to potentially overstate savings by ignoring the reduced, but not necessarily zero, measure-level savings in Phase III.

exactly met the corresponding code requirement).[1] The worse-than-code observations for the key item under consideration are used to create a second set of models (*as built*) that can be compared to the baseline (*full compliance*) models. 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. Potential energy savings were further weighted using construction starts to obtain the average statewide energy savings potential. State-specific construction volumes and fuel prices were used to calculate the maximum energy savings potential for the state in terms of *energy* (MMBtu), *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.

Another aspect of savings potential that is not included is the presence of better-than-code items. While it is indeed possible that one better-than-code component may offset the energy lost due to another worse-than-code component, the collected data does not allow for the assessment of paired observations for a given home. Additionally, the analysis identifies the maximum theoretical savings potential for each measure; therefore, credit for better-than-code measures is not accounted for in the savings analysis.

An issue that can impact both the EUI and savings potential analysis is the presence of abnormal values. One of the lessons learned during previous field studies is that there are occasional data outliers, observations that seem much higher or lower than expected, such as higher than anticipated total duct tightness rates or ceiling insulation values of R-0. Such data outliers may be the result of errors (by the builder or by the field team) or they may simply be extreme but valid data points. It can be difficult to differentiate between these two cases given the limited information available to and provided by field data collectors.

Under ideal circumstances, project teams would identify outliers at the time of data collection during field visits, and employ procedures to flag and evaluate atypical conditions, data points or observations. During the course of the data QA/QC process, remaining outliers were discussed with the project teams and, where applicable and appropriate, data were modified prior to analysis. Given that this was a research study, and in many cases valid extremes do exist in the field, it was decided to retain all other data outliers in the analysis. This allows a given team or state to understand the presence of, and related impacts, of valid outliers in their data set. The impact of this decision is that there may be some "extreme" data points that appear in the key item plots and impact the measure level savings and EUI results, which have been deliberately retained in the data set. In addition, the field methodology and related tools (e.g., data collection forms) were updated to help guide future data collection teams in

[1] 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.

proactively identifying potential outliers and to the greatest extent possible verifying (or mitigating) their impacts in the field.

2.4 Limitations

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

2.4.1 Applicability of Results

An inherent limitation of the study design is that the results (key item distributions, EUI, and measure-level savings) are statistically significant only at the state level. Other results, such as analysis based on climate zone level, reporting of non-key items (e.g., gas furnace efficiency), or further stratifications of the public data set are included and available but should not be considered statistically representative.

2.4.2 Definition and 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 in its entirety, since 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 affecting energy performance (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. This approach gives a robust representation of measure compliance across the state.

2.4.3 Sampling Substitutions

As is often the case with field-based research, substitutions to the state sampling plans 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 plans and any state-specific substitutions is 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 tightness 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.

2.5 Phase II Targeted Education and Training

The intent of the overall study was to identify the highest-impact, biggest "bang-for-the-buck" energy efficiency measures (key items), and then assess whether average statewide energy use could be reduced by focusing on those measures. Phase II involved education and training targeting those measures. For example, if wall insulation, lighting, and envelope air tightness all exhibited significant savings potential following Phase I analysis, those measures became the focal point for Phase II. By focusing on key measures, the methodology helps ensure maximum ROI for education and training activities and other compliance improvement programs. Many states have some form of ongoing training and identifying and focusing on the key items helps those programs maximize their investment.

Given their state-specific knowledge, the project team and stakeholders selected the education and training activities to be used that were anticipated to have the largest impact in the state. Activities were conducted throughout the entire state.

For any given state, a variety of activities was used, ranging from more traditional activities such as classroom-based training, to more advanced approaches, such as web-based and onsite education, as well as circuit rider programs. All activities were designed to coordinate with, and complement, any related or ongoing training efforts in the state (such as those conducted by local utilities, state governments, or national programs such as EPA EnergyStar). The level of funding and effort for Phase II activities varied by state.

For Georgia, specific Phase II activities included:

- Circuit rider: The circuit rider was the focus of the Phase II intervention activities and provided support to individual stakeholders (e.g., code officials and builders) that was supplemented with the in-person trainings, online training program, and energy codes hotline. The circuit rider traveled across the state and contacted code officials in individual jurisdictions to determine their interest in hosting classroom trainings or presentations on the Phase I findings of the study. If the jurisdiction agreed, a training or presentation was scheduled and local officials and builders were invited. Southface Energy Institute filled the role of circuit rider and provided the classroom training (MEEA 2018). Seventeen jurisdictions were contacted and more than 1,000 hours of technical assistance and support was provided on a wide variety of topics, ranging from insulation installation to duct sealing.
- In-person training: Classes ranged from 1 to 5 hours and focused on the major challenges identified in Phase I. All classes emphasized the reasoning and building science principles behind the code

required. Classes were held between April 2016 and October 2017 with at least one class in each climate zone. Total attendance was 606 people.

- Online training: Georgia offered an online learning management system to provide online training opportunities. Three specific, 1-hour long training modules were developed on the issues with the most savings potential: Duct Sealing for Construction Professionals, Energy Efficient Lighting for Construction Professionals and High Efficiency Insulation for Construction Professionals. Continuing education units were available to participants who chose to take a short exam at the end of the course. In addition to the training module videos, various "Tech Tip" sheets and informational guides were also available on the learning management system.[1]
- Online energy code hotline: A hotline and email inquiry resource line went live in September 2017 and received 120 hotline requests via phone and email.
- Energy Codes Hub: A list of updated and relevant energy code resources was made available. The Hub also contains energy code hotline information and directs users there to get their concerns addressed in detail.[2]
- Other: Questionnaires regarding the issues identified in Phase I were developed and distributed to all training attendees. In addition, the surveys included questions regarding code official workload, energy code knowledge and resources currently used for energy code compliance. Results were provided to the circuit rider to help design solutions to the issues identified. Eleven program update presentations were also made to more than 300 participants between April 2016 and October 2017. Scheduling outreach activities around existing conferences and events was seen as particularly helpful since a large contingent of stakeholders was already present (MEEA 2018).

2.6 Phase III Field Study and Analysis

In Phase III, the data collection undertaken in Phase I was repeated, starting with a new sample plan. Once the field data was collected, PNNL analyzed the data in the same way as in Phase I (described in Section 2.3) with the following exceptions that were held constant between Phase I and Phase III:

1. Annual number of permits estimated for the state
2. Split of permits between climate zones in multi-climate zone states
3. Distribution of heating system types in the state
4. Distribution of foundation types in the state
5. Number of observations of key items per climate zone in multi-climate zone states used in the Monte Carlo simulations
6. For states in which the baseline energy code changed and for which PNNL compared the observations to two codes, PNNL only compared the observations to the newest code in Phase III.

All of these changes were made to minimize variability between the Phase I and Phase III analyses that could be attributed to the study methodology and that might obscure the impact of actual changes in the key items.

[1] The coursework is available at https://southface.learnupon.com.
[2] https://dca.ga.gov/local-government-assistance/construction-codes-industrialized-buildings/construction-codes/energy.

3.0 State Results

3.1 Field Observations

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. (See Section 2.3.1 for a sample graph and explanation of how they should be interpreted.) Note that these key items are also the basis of the results presented in the subsequent *energy* and *savings* stages of analysis.

The following key items were found applicable within the state:

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. Foundations – conditioned basements and floors (assembly U-factor), and slabs (R-value)
7. Duct tightness (cfm per 100 ft^2 of conditioned floor area at 25 Pascals)

The three main foundation types observed were conditioned basements, floors, and slabs.

3.1.1.1 Envelope Tightness

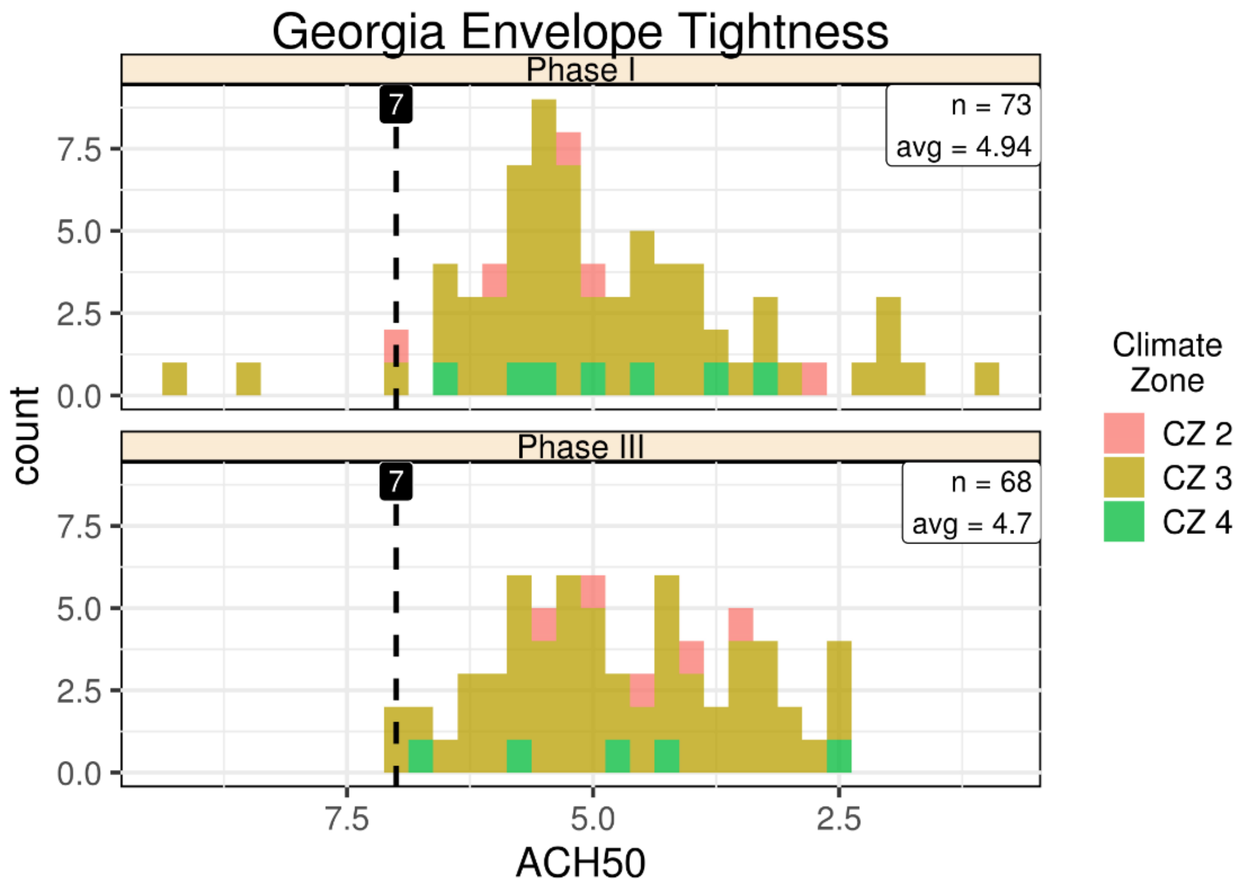

Figure 3.1. Comparison of Phase I and Phase III Envelope Tightness for Georgia

Table 3.1. Georgia Envelope Tightness in Phase I and Phase III

Envelope Tightness (ACH50)	Phase I CZ2	Phase I CZ3	Phase I CZ4	Phase I Statewide	Phase III CZ2	Phase III CZ3	Phase III CZ4	Phase III Statewide
Requirement	7	7	7	7	7	7	7	7
Observations								
Number	5	61	7	73	5	58	5	68
Range	6.9 to 2.8	9.28 to 1.1	6.53 to 3.30	9.28 to 1.1	3.6 to 5.5	2.38 to 6.97	2.5 to 6.84	2.38 to 6.97
Average	5.2	4.9	4.9	4.9	4.6	4.7	4.8	4.7
Compliance Rate	5 of 5 (100%)	58 of 61 (95%)	7 of 7 (100%)	70 of 73 (96%)	5 of 5 (100%)	58 of 58 (100%)	5 of 5 (100%)	68 of 68 (100%)

- **Interpretations:**
  - Statewide, in Phase I, 96% (70 of 73) of the observations met or exceeded the code requirement, and this rose to 100% (68 of 68) in Phase III. Envelope air tightness requirements appear to be met successfully within the state.
  - In Phase I, the project team noted that Georgia adopted a strengthening amendment to the 2009 IECC, which changes the envelope test from voluntary to mandatory. Beginning January 1, 2012,

all new single-family houses were required to show compliance with the 7 ACH50 requirement through testing. The team also noted that envelope tightness has been an area of training focus, including the development of a state-specific program called the Duct and Envelope Tightness (DET) Verifier Program which trained additional individuals to conduct testing.

3.1.1.2 Window SHGC

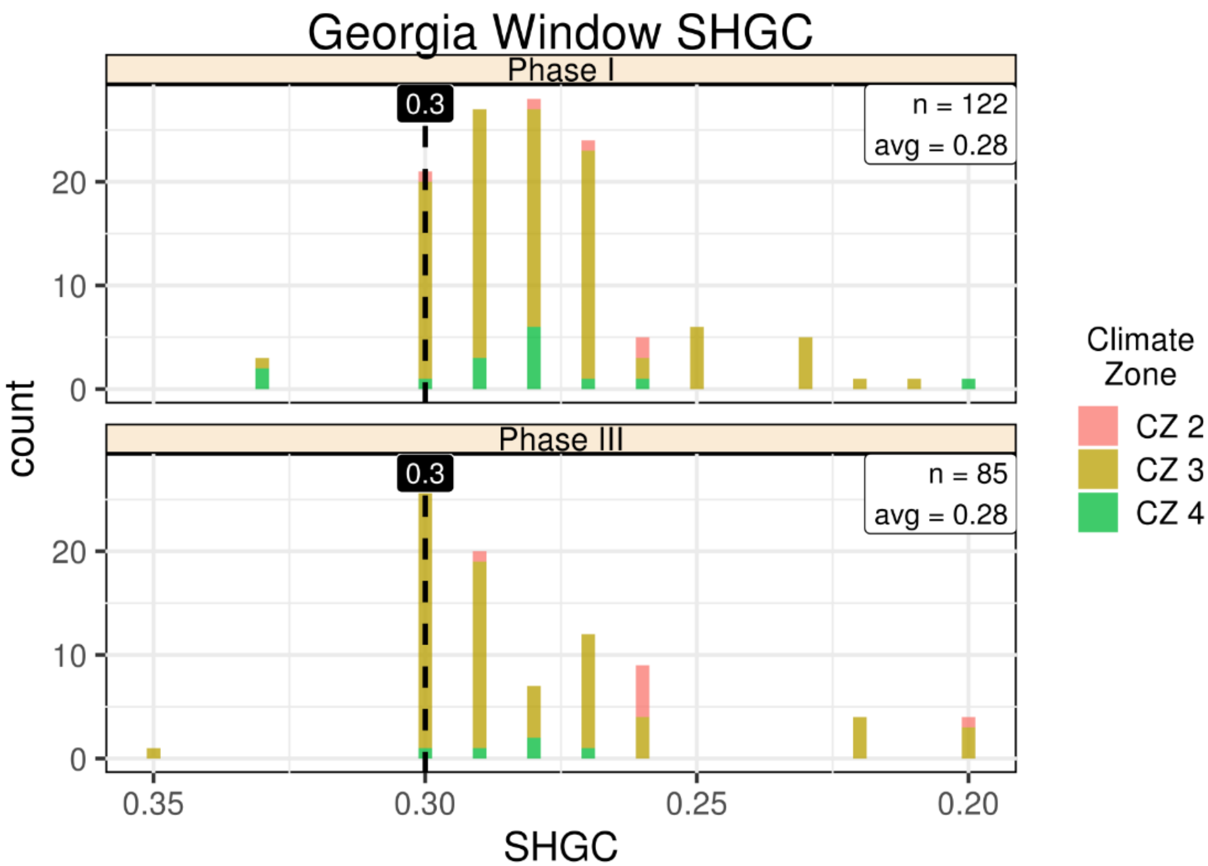

Figure 3.2. Comparison of Phase I and Phase III Window SHGC for Georgia

Table 3.2. Georgia Window SHGC in Phase I and Phase III

Window SHGC	Phase I CZ2	CZ3	CZ4	Statewide	Phase III CZ2	CZ3	CZ4	Statewide
Requirement	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Observations								
Number	5	102	15	122	7	73	5	85
Range	0.30 to 0.26	0.33 to 0.21	0.33 to 0.20	0.33 to 0.20	0.20 to 0.29	0.20 to 0.35	0.27 to 0.30	0.20 to 0.35
Average	0.27	0.28	0.28	0.28	0.26	0.28	0.28	0.28
Compliance Rate	5 of 5 (100%)	101 of 102 (99%)	13 of 15 (87%)	119 of 122 (98%)	7 of 7 (100%)	72 of 73 (99%)	5 of 5 (100%)	84 of 85 (99%)

- **Interpretations:**
  - SHGC values consistently exceeded the prescriptive requirement for all climate zones.
  - The majority of the observations (greater than 90%) were in the 0.25 to 0.30 SHGC range.

3.1.1.3 Window U-Factor

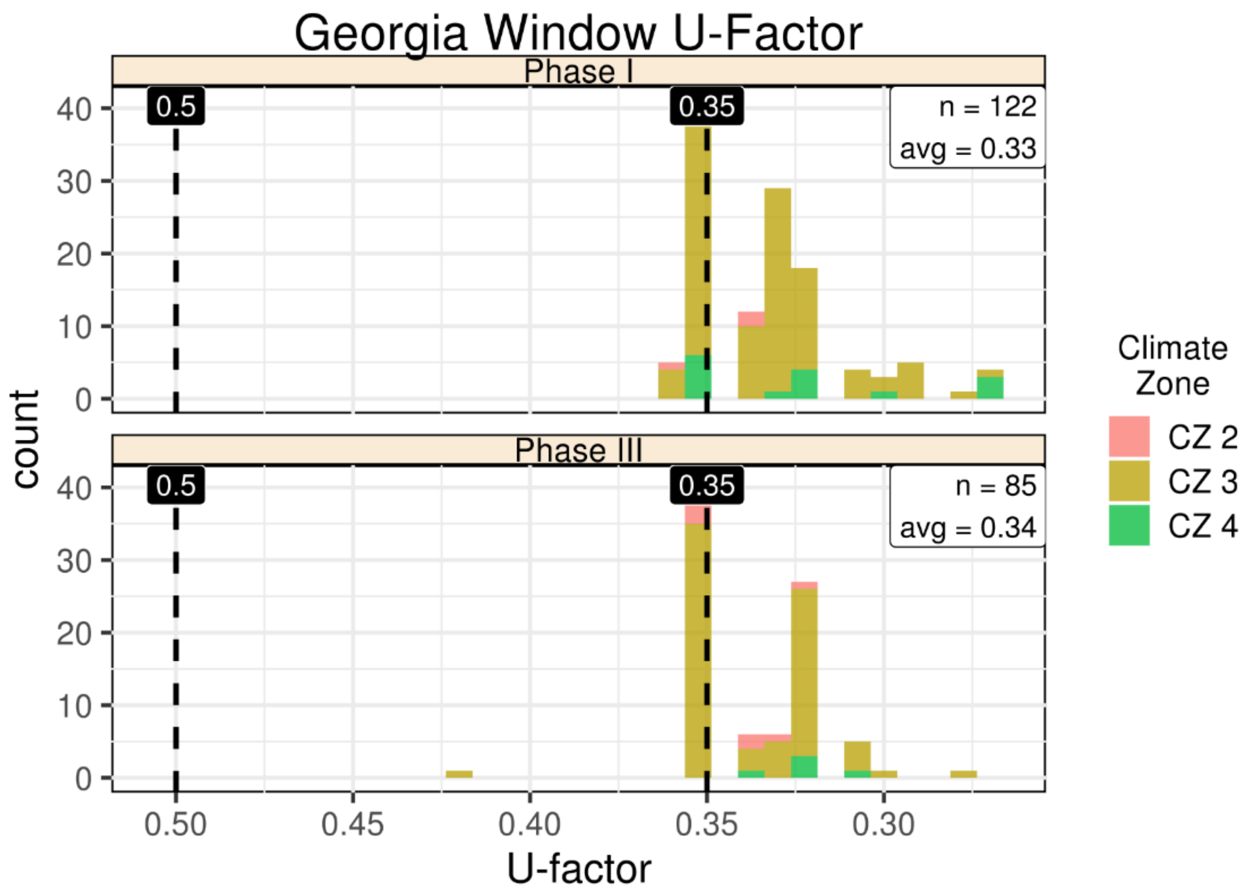

Figure 3.3. Comparison of Phase I and Phase III Window U-Factors for Georgia

Table 3.3. Georgia Window U-Factors in Phase I and Phase III

Window U-Factor	Phase I CZ2	CZ3	CZ4	Statewide	Phase III CZ2	CZ3	CZ4	Statewide
Requirement	0.5	0.5	0.35	Varies as shown	0.5	0.5	0.35	Varies as shown
Observations								
Number	5	102	15	122	7	73	5	85
Range	0.36 to 0.34	0.36 to 0.27	0.35 to 0.27	0.36 to 0.27	0.32 to 0.35	0.28 to 0.42	0.31 to 0.34	0.28 to 0.42
Average	0.35	0.33	0.32	0.33	0.34	0.34	0.32	0.34
Compliance Rate	5 of 5 (100%)	102 of 102 (100%)	15 of 15 (100%)	22 of 122 (100%)	7 of 7 (100%)	73 of 73 (100%)	5 of 5 (100%)	85 of 85 (100%)

- **Interpretations:**
  - There was 100% compliance for fenestration products in both phases.
  - Window U-factor requirements have been implemented with a high rate of success across the state.

3.1.1.4 Wall Insulation

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

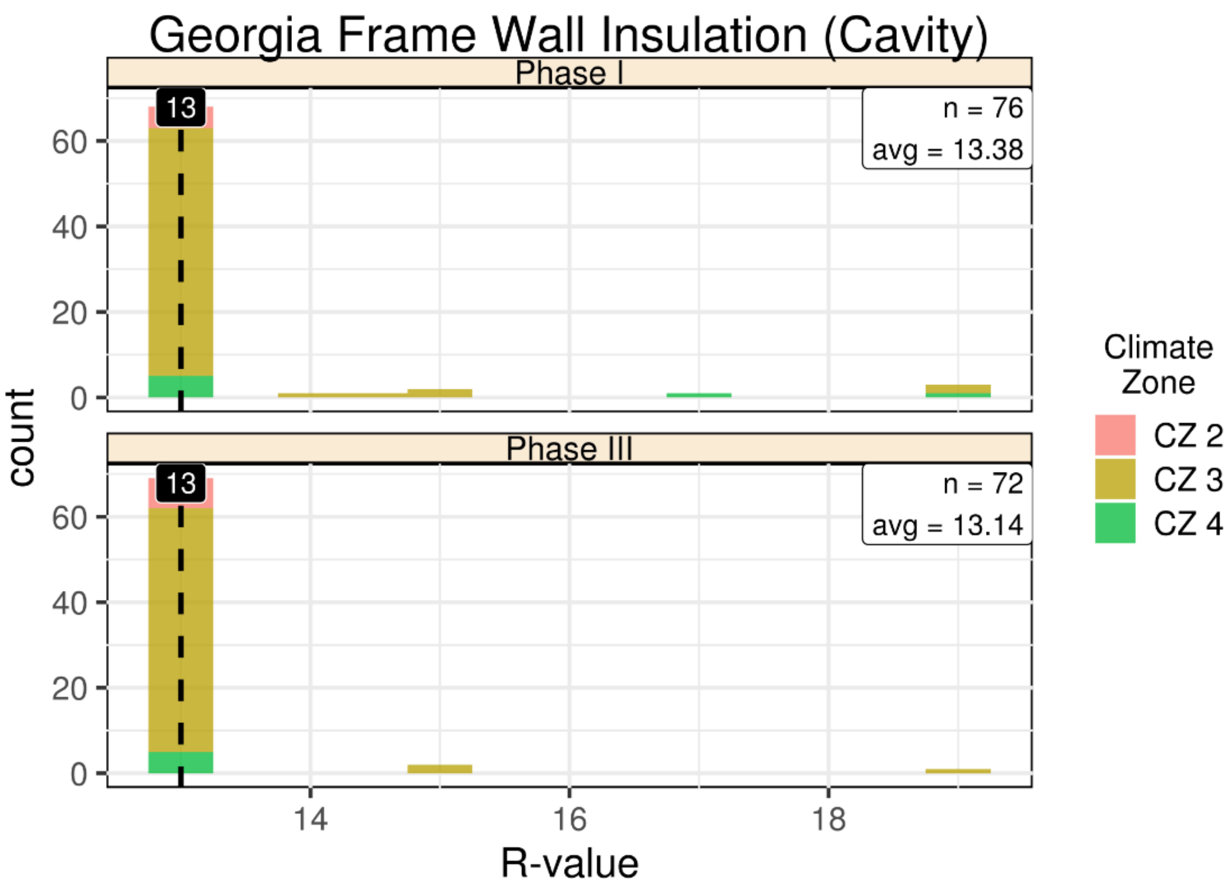

Figure 3.4. Comparison of Phase I and Phase III Wall Cavity R-Values for Georgia

Table 3.4. Georgia Wall Cavity R-Values in Phase I and Phase III

Wall R	CZ2	Phase I CZ3	CZ4	Statewide	CZ2	Phase IIICZ3	CZ4	Statewide
Requirement	13	13	13	13	13	13	13	13
Observations								
Number	5	64	7	76	7	60	5	72
Range	R-13 to R-13	R-13 to R-13	R-13 to R-19	R-13 to R-19	R-13 to R-13	R-13 to R-19	R-13 to R-13	R-13 to
Average	R-13	R-13.3	R-14.4	R-13.4	R-13	R-13.2	R-13	13.1
Compliance Rate	13 of 13 (100%)	64 of 64 (100%)	7 of 7 (100%)	76 of 76 (100%)	7 of 7 (100%)	60 of 60 (100%)	5 of 5 (100%)	72 of 72 (100%)

At the start of the overall project, IIQ was noted as a particular concern among project teams and stakeholders, as it plays an important role in the energy performance of envelope assemblies. IIQ was therefore collected by the field teams whenever possible and applied as a *modifier* in the analyses for applicable key items (i.e., wall insulation, ceiling insulation, and foundation insulation). Teams followed the RESNET[1] assessment protocol for cavity insulation which has three grades; Grade I being the best quality installation and Grade III being the worst.

Table 3.5 shows the number and percentage of IIQ observations by grade for above grade wall insulation for Phase I and Phase III. The table illustrates that above grade wall IIQ improved slightly from Phase I to Phase III, with fewer Grade III observations.

Table 3.5. Comparison of Phase I and Phase III Above Grade Wall IIQ for Georgia

Assembly	Ph I / Ph III Grade I	Ph I / Ph III Grade II	Ph I / Ph III Grade III	Ph I / Ph III Total Observations
Above Grade Wall Observations	11 / 14	28 / 36	37 / 22	**76 / 72**
Above Grade Percentages	14% / 19%	37% / 50%	49% / 31%	**100% / 100%**

Given the importance of IIQ, in addition to reviewing the observations for cavity insulation, U-factors were calculated and reviewed including the effects of IIQ as shown in Figure 3.5. In the graph, observations are binned for clearer presentation based on the most commonly observed combinations.

[1] See the January 2013 version at https://www.resnet.us/wp-content/uploads/RESNET-Mortgage-Industry-National-HERS-Standards_3-8-17.pdf; the current version at the time the study began.

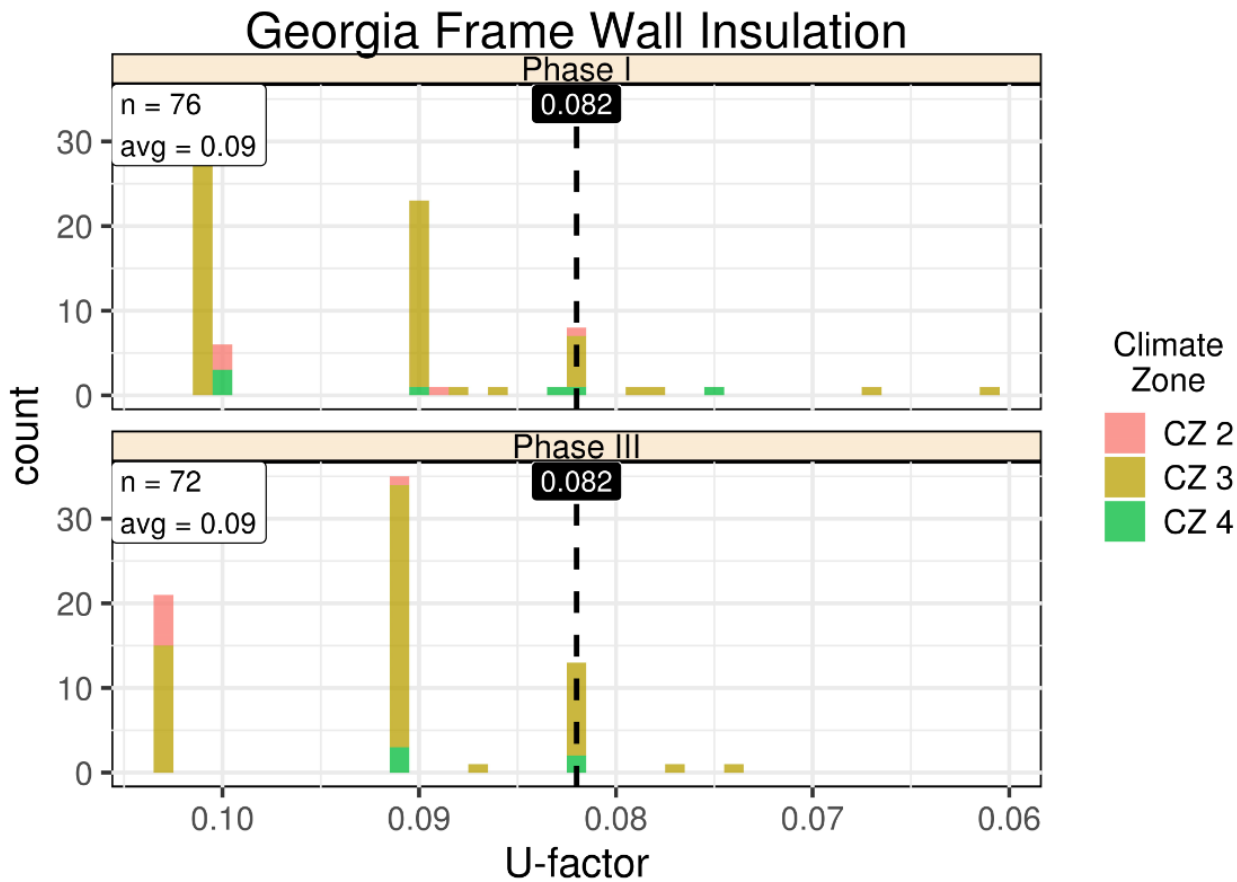

Figure 3.5. Comparison of Phase I and Phase III Wall U-Factors for Georgia

Table 3.6. Georgia Wall U-Factors in Phase I and Phase III

Wall U	Phase I CZ2	Phase I CZ3	Phase I CZ4	Phase I Statewide	Phase III CZ2	Phase III CZ3	Phase III CZ4	Phase III Statewide
Requirement	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Observations								
Number	5	64	7	76	7	60	5	72
Range	0.102 to 0.083	0.102 to 0.062	0.102 to 0.077	0.102 to 0.062	0.103 to 0.091	0.103 to 0.077	0.091 to 0.082	0.103 to 0.077
Average	0.096	0.094	0.092	0.094	0.101	0.092	0.087	0.092
Compliance Rate	1 of 5 (20%)	10 of 64 (16%)	2 of 7 (29%)	13 of 76 (17%)	0 of 7 (0%)	13 of 60 (22%)	2 of 3 (67%)	15 of 72 (21%)

- **Interpretations:**
  - Cavity insulation is achieved at a high rate in both Phase I and Phase III—all the observations met or exceeded the prescriptive code requirement for wall cavity insulation (based on labeled R-value).
  - From an assembly perspective, however, a majority of observations had below Grade I IIQ—86% in Phase I and 81% in Phase III—were rated as Grades II or III. The U-factors exhibit room for improvement even after Phase II – an opportunity for further savings.

3.1.1.5 Ceiling Insulation

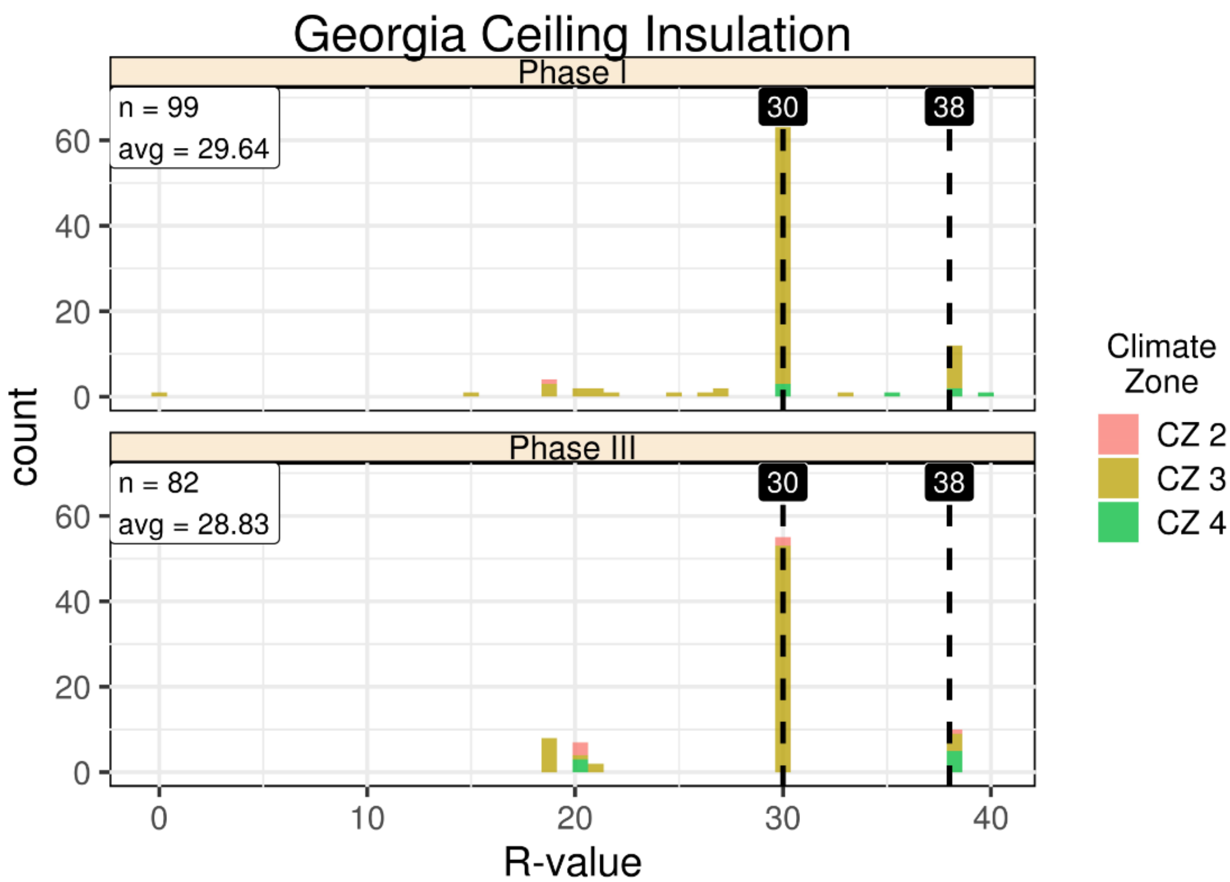

Figure 3.6. Comparison of Phase I and Phase III Ceiling R-Values for Georgia

Table 3.7. Georgia Ceiling R-Values in Phase I and Phase III

		Phase I				**Phase III**		
Ceiling R	**CZ2**	**CZ3**	**CZ4**	**Statewide**	**CZ2**	**CZ3**	**CZ4**	**Statewide**
Requirement	30	30	38	30/38	30	30	38	30/38
Observations								
Number	5	87	7	99	6	68	8	82
Range	19 to 30	0 to 38	30 to 40	0 to 40	20 to 38	19 to 38	20 to 38	19 to 38
Average	27.8	29.4	34.4	29.6	26.3	28.8	31.3	28.8
Compliance Rate	4 of 5 (80%)	73 of 87 (84%)	6 of 7 (86%)	83 of 99 (83%)	3 of 6 (50%)	57 of 68 (84%)	5 of 8 (63%)	65 of 82 (79%)

- **Interpretations:**
  - There is a wide range of insulation values across the CZs, with the majority of observations at R-30 or R-38 in both phases.
  - There is also variation around R-30 and R-38 in the data. For example, in Phase I, there are two observations of R-27, one of R-33, and one of R-35, and a value of R-40. There is less variation in Phase III, but there is a cluster of observations around R-19/R-20.

In Phase I, the project team observed that the variation around R-30 and R-38 is due to the project team's method for collecting information. Instead of recording what was on the insulation card in the attic (installed by the insulation contractor), the project team measured insulation height in 3-4 locations around the attic and calculated the R-value based on insulation type and height. The actual installed value occasionally varied from what was listed on the insulation card.

Additionally, the project team noted that the cause of some instances below R-30 may point to the use of a UA trade-off path. The project team in Phase I recorded insulation locations for 11 of the 15 houses that had less than R-30. In those cases, 7 of the observations indicated insulation installed on the roof rafters, the typical location for spray foam insulation. Similar arguments can be made for the Phase III data.

Table 3.8 shows the number and percentage of IIQ observations by grade for roof cavity insulation for Phase I and Phase III. The table illustrates that roof cavity IIQ improved greatly from Phase I to Phase III.

Table 3.8. Comparison of Phase I and Phase III Roof IIQ for Georgia

Assembly	**Ph I / Ph III Grade I**	**Ph I / Ph III Grade II**	**Ph I / Ph III Grade III**	**Ph I / Ph III Total Observations**
Roof Cavity Observations	19 / 61	45 / 16	33 / 0	**96 / 77**
Roof Cavity Percentages	20% / 79%	47% / 21%	34% / 0%	**100% / 100%**

Given the importance of IIQ, in addition to reviewing the observations for cavity insulation, U-factors were calculated and reviewed including the effects of IIQ as shown in Figure 3.7.

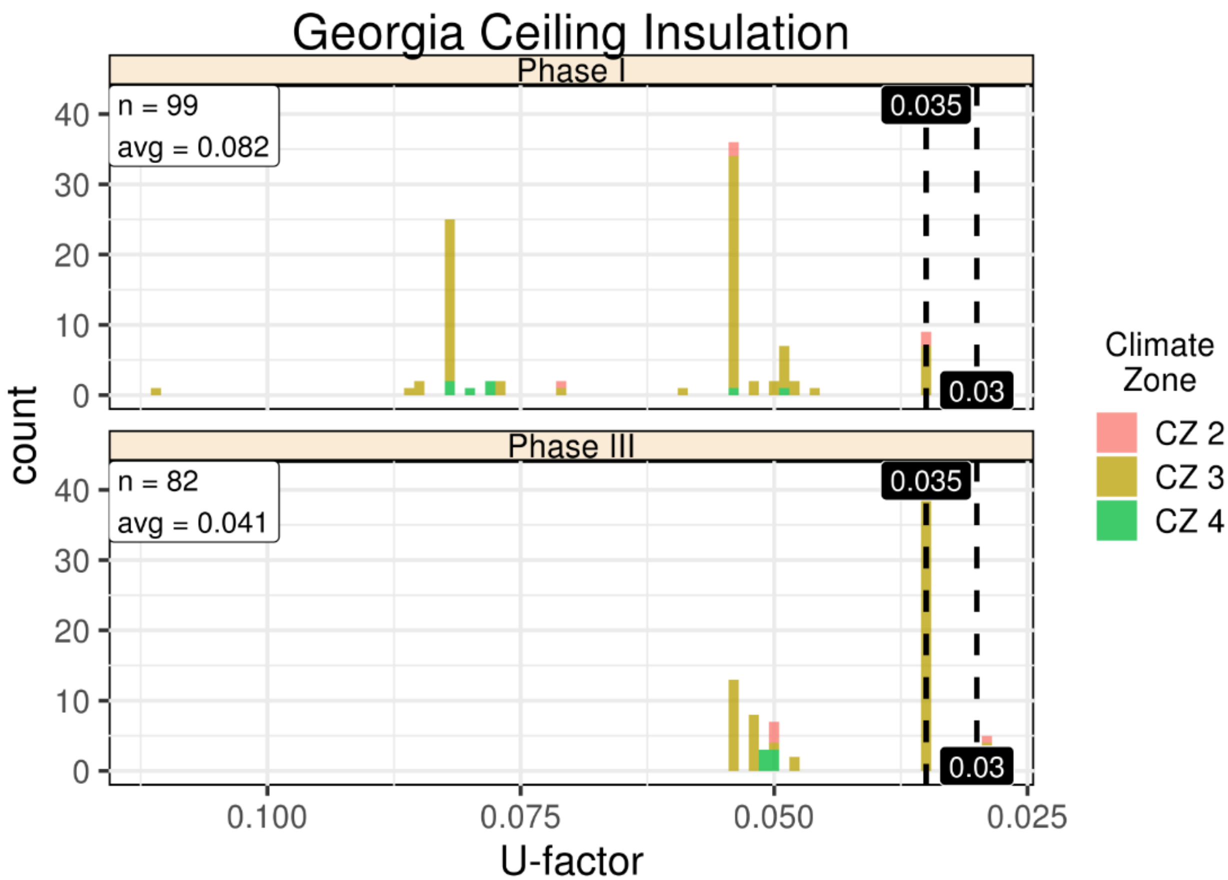

Figure 3.7. Comparison of Phase I and Phase III Ceiling U-factors for Georgia

Table 3.9. Georgia Ceiling U-factors in Phase I and Phase III

Ceiling U	CZ2	Phase I CZ3	CZ4	Statewide	CZ2	Phase III CZ3	CZ4	Statewide
Requirement	0.035	0.035	0.03	Varies	0.035	0.035	0.03	Varies
Observations								
Number	5	87	7	99	6	68	8	82
Range	0.071 to 0.054	2.072[1] to 0.029	0.082 to 0.049	2.072 to 0.029	0.050 to 0.029	0.054 to 0.029	0.051 to 0.030	0.054 to 0.029
Average	0.050	0.084	0.071	0.082	0.042	0.041	0.045	0.041
Compliance Rate	2 of 5 (40%)	9 of 87 (10%)	0 of 7 (0%)	11 of 99 (11%)	3 of 6 (50%)	44 of 68 (65%)	2 of 8 (25%)	49 of 82 (60%)

- **Interpretations:**
  - Phase I has a broader range of U-factors than Phase III. There was a significant improvement in the overall compliance rate between Phase I and Phase III, but there is a continued savings opportunity for ceilings, including further improvement in IIQ.

[1] The high U-factor observation is not shown on the graph due to scaling issues.

3.1.1.6 Lighting

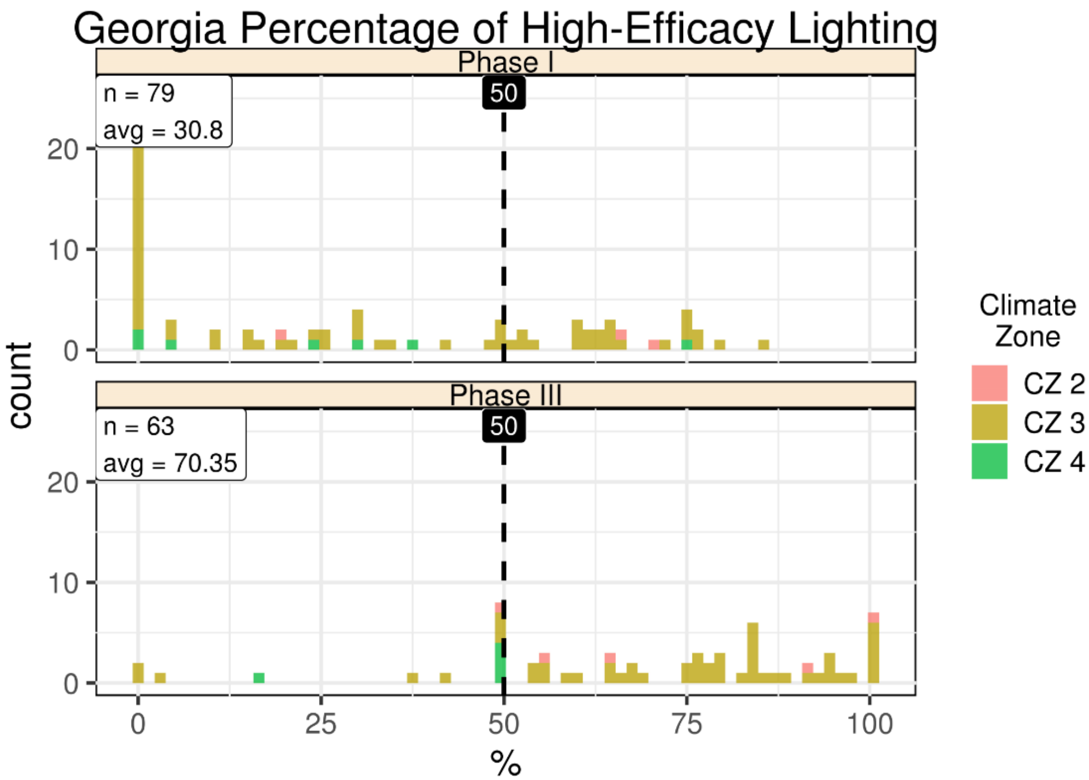

Figure 3.8. Comparison of Phase I and Phase III High-efficacy Lighting Percentages for Georgia

Table 3.10. Georgia High-efficacy Lighting in Phase I and Phase III

Lighting	CZ2	Phase I CZ3	CZ4	Statewide	CZ2	Phase III CZ3	CZ4	Statewide
Requirement	50	50	50	50	50	50	50	50
Observations								
Number	5	67	7	79	5	53	5	63
Range	0 to 70	0 to 86	0 to 75	0 to 86	50 to 100	0 to 100	16 to 50	0 to 100
Average	31.2	31.4	24.4	30.8	72.4	72.7	43.2	70.3
Compliance Rate	2 of 5 (40%)	26 of 67 (39%)	1 of 7 (14%)	29 of 79 (38%)	1 of 5 (20%)	48 of 50 (96%)	4 of 5 (80%)	53 of 63 (84%)

- **Interpretations:**
  - In Phase I, in CZ2 and CZ3, less than half of the observations met the current code requirement, and that dropped significantly in CZ4. This represented an area of significant savings potential and was a focus of Phase II education and training activities.
  - Although there was a wide range of observations in both phases, the percentage of high-efficacy lighting meeting the requirements improved significantly in Phase III.

3.1.1.7 Foundation Assemblies

There were three predominant foundation types observed in Georgia: conditioned basements, floors (over unheated basements or vented crawlspaces), and slabs.[1] Two graphs are shown for basement walls and floors, insulation (R-value) and binned assembly (U-factor). The R-value graphs show the insulation R-values observed. The binned U-factor graphs indicate the U-factor of the assembly, including both cavity and continuous insulation layers, framing, and considering IIQ, as observed in the field. The U-factors are binned to reduce the number of bars in the chart as individual U-factor observations may be only slightly different. For slabs, only an R-value graph is shown.

While initially combined into a single key item (i.e., foundation assemblies[2]), the variety of observed foundation types is disaggregated in this section, as described above. This approach helps to portray the combinations of cavity and continuous insulation employed across each foundation type, which was anticipated to be of value for energy code training programs. From a savings perspective, results are calculated for both the aggregated perspective individual foundation types (presented later in Section 3.3), however; only the aggregated observations should be considered statistically representative at the statewide level.

Floors

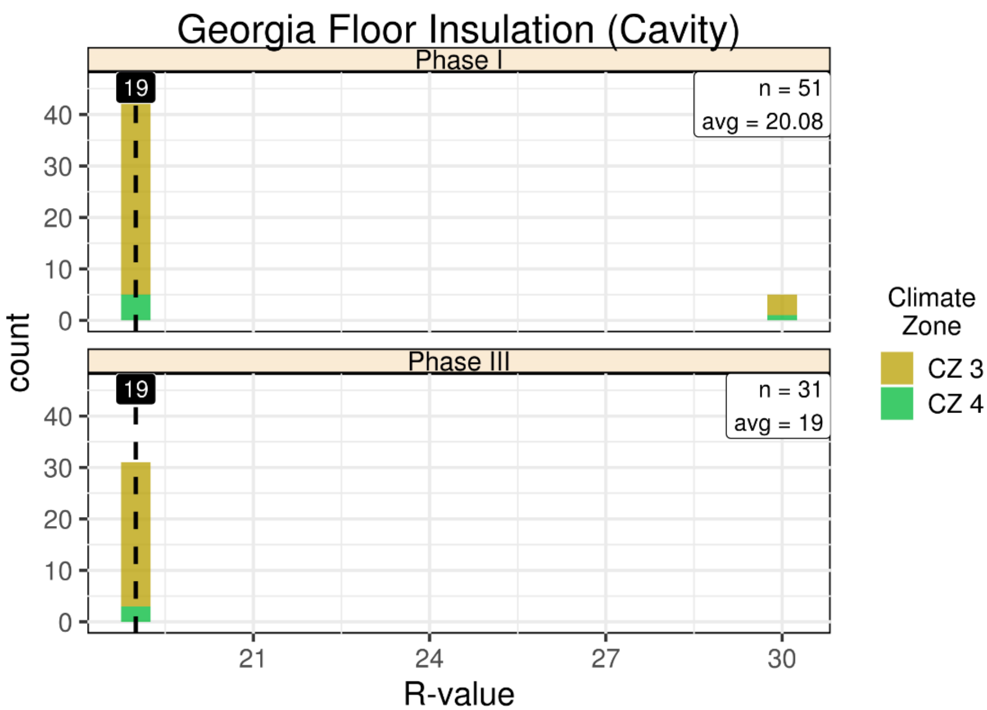

Figure 3.9. Comparison of Phase I and Phase III Floor R-Values for Georgia

[1] There were also single observations of unvented crawlspace walls in both Phase I and Phase III in Georgia. Due to the small number of observations, no further discussion of unvented crawlspaces is provided.
[2] Floor insulation, basement wall insulation, and slab insulation were combined into a single key item of foundation insulation.

Table 3.11. Georgia Floor R-Values in Phase I and Phase III

Floor R	CZ2	Phase I CZ3	CZ4	Statewide	CZ2	Phase III CZ3	CZ4	Statewide
Requirement	19	19	19	19	19	19	19	19
Observations								
Number	0	45	6	51	0	28	3	31
Range	NA	19 to 30	19 to 30	19 to 30	NA	19	19	19
Average	NA	20.0	20.8	20.1	NA	19	19	19
Compliance Rate	NA	45 of 45 (100%)	6 of 6 (100%)	51 of 51 (100%)	NA	28 of 28 (100%)	3 of 3 (100%)	31 of 31 (100%)

Table 3.12 shows the number and percentage of IIQ observations by grade for floor insulation for Phase I and Phase III. The table illustrates that floor IIQ improved from Phase I to Phase III. Given the importance of IIQ, in addition to reviewing the observations for cavity insulation, U-factors were calculated and reviewed including the effects of IIQ as shown in Figure 3.10.

Table 3.12. Floor IIQ Comparison between Phase I and Phase III for Georgia

Assembly	Ph I / Ph III Grade I	Ph I / Ph III Grade II	Ph I / Ph III Grade III	Ph I / Ph III Total Observations
Floor Observations	0 / 2	11 / 20	38 / 9	**49 / 31**
Floor Percentages	0% / 6%	22% / 65%	78% / 29%	**100% / 100%**

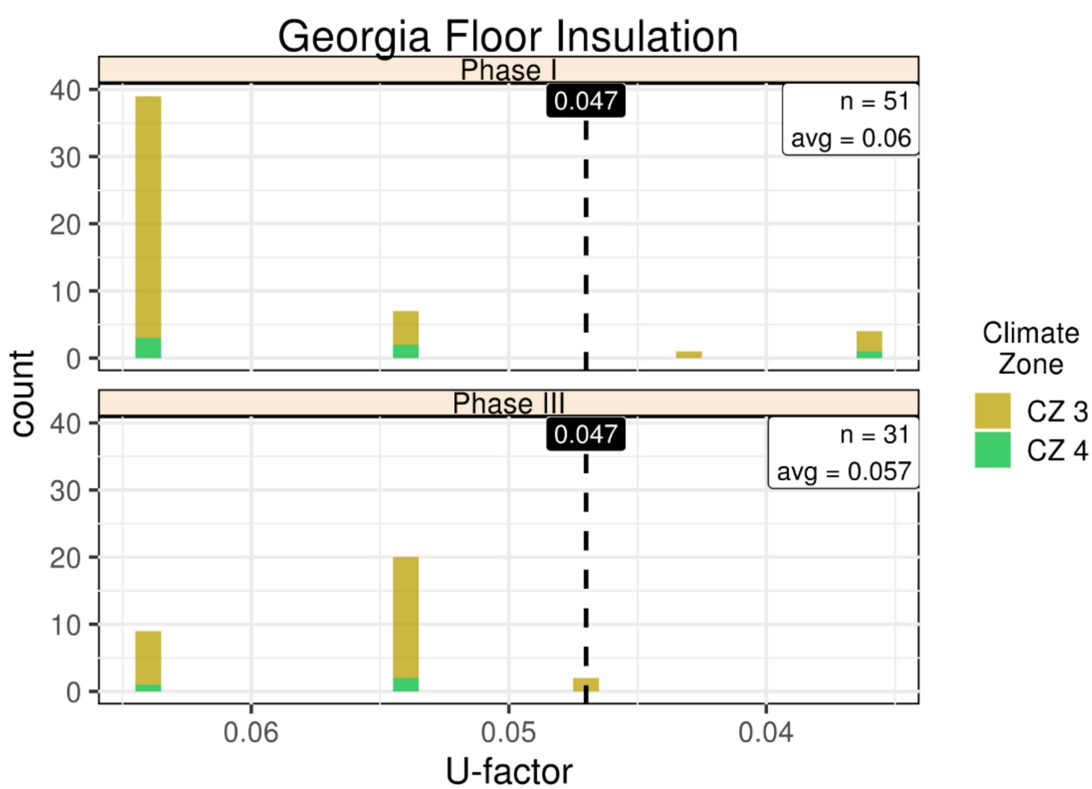

Figure 3.10. Comparison of Phase I and Phase III Floor U-Factors for Georgia

Table 3.13. Georgia Floor U-Factors in Phase I and Phase III

Floor U	Phase I CZ2	Phase I CZ3	Phase I CZ4	Phase I Statewide	Phase III CZ2	Phase III CZ3	Phase III CZ4	Phase III Statewide
Requirement	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
Observations								
Number	0	45	6	7	0	28	3	31
Range	NA	0.064 to 0.036	0.064 to 0.036	0.064 to 0.036	NA	0.064 to 0.047	0.064 to 0.054	0.064 to 0.047
Average	NA	0.061	0.056	0.060	NA	0.057	0.057	0.057
Compliance Rate	NA	4 of 45 (9%)	1 of 6 (17%)	5 of 51 (10%)	NA	2 of 28 (7%)	0 of 3 (0%)	2 of 31 (6%)

- **Interpretations:**
  - Cavity insulation in both Phase I and Phase III was achieved at 100%. However, the majority of installations are Grade II or Grade III. This results in only 10% meeting or exceeding the U-factor requirement in Phase I and 6% in Phase III. IIQ remains a savings opportunity in the state.

Slabs

In Phase I, there were 90 slab observations, all with no insulation. In Phase III, there were three slab observations, again all with no insulation. Because there are no slab insulation requirements in Georgia, no slab plots or tables are shown in this report.

Basement Walls

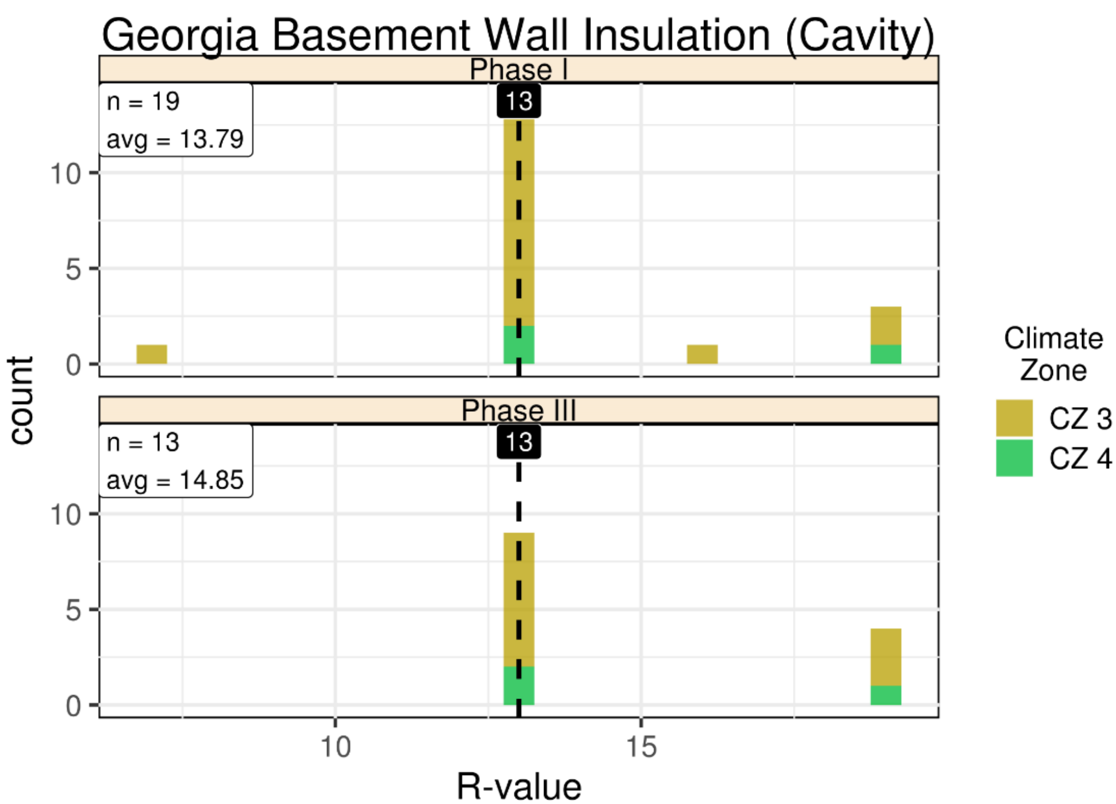

Figure 3.11. Comparison of Phase I and Phase III Basement Wall Cavity R-Values for Georgia

Table 3.14. Georgia Basement Wall Cavity R-Values in Phase I and Phase III

Basement Cavity R	Phase I CZ2	CZ3	CZ4	Statewide	Phase III CZ2	CZ3	CZ4	Statewide
Requirement	13	13	13	13	13	13	13	13
Observations								
Number	0	16	3	19	0	10	3	13
Range	NA	7 to 19	13 to 19	0 to 40	NA	13 to 19	13 to 19	13 to 19
Average	NA	13.6	15	13.8	NA	14.8	15.0	14.9
Compliance Rate	NA	15 of 16 (94%)	3 of 3 (100%)	18 of 19 (95%)	NA	10 of 10 (100%)	3 of 3 (100%)	13 of 13 (100%)

Table 3.15 shows the number and percentage of IIQ observations by grade for basement wall insulation for Phase I and Phase III. Given the importance of IIQ, in addition to reviewing the observations for cavity insulation, U-factors were calculated and reviewed including the effects of IIQ as shown in Figure 3.12.

Table 3.15. Basement Wall IIQ Comparison between Phase I and Phase III for Georgia

Assembly	Ph I / Ph III Grade I	Ph I / Ph III Grade II	Ph I / Ph III Grade III	Ph I / Ph III Total Observations
Basement Wall Observations	4 / 3	10 / 6	5 / 1	**19 / 10**
Basement Wall Percentages	21% / 30%	53% / 60%	26% / 10%	**100% / 100%**

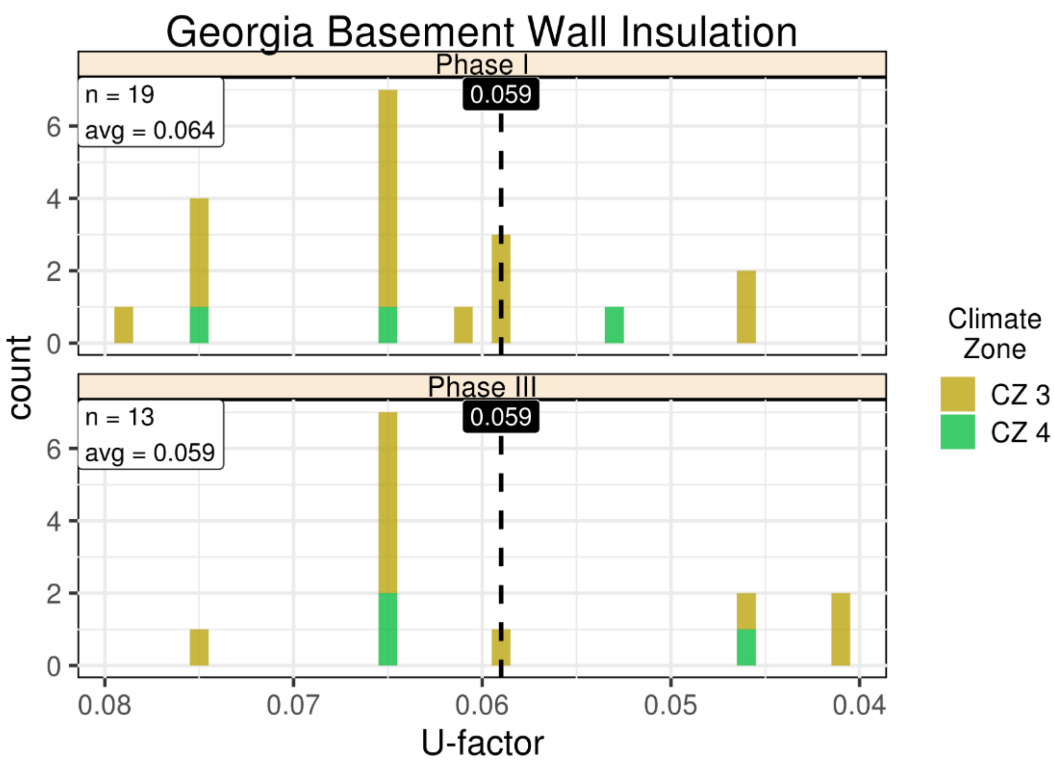

Figure 3.12. Comparison of Phase I and Phase III Basement Wall U-Factors for Georgia

Table 3.16. Georgia Basement Wall U-Factors in Phase I and Phase III

Basement U	Phase I CZ2	Phase I CZ3	Phase I CZ4	Phase I Statewide	Phase III CZ2	Phase III CZ3	Phase III CZ4	Phase III Statewide
Requirement	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Observations								
Number	0	16	3	19	0	10	3	13
Range	NA	0.079 to 0.046	0.075 to 0.053	0.079 to 0.046	NA	0.065 to 0.041	0.065 to 0.046	0.065 to 0.041
Average	NA	0.064	0.064	0.064	NA	0.059	0.059	0.059
Compliance Rate	NA	5 of 16 (31%)	1 of 3 (33%)	6 of 19 (32%)	NA	4 of 10 (40%)	1 of 3 (33%)	5 of 13 (38%)

- **Interpretations:**
  - R-value observations indicate the levels of insulation meet the requirements. However, IIQ is mostly Grades II and III, which results in most (68% in Phase I and 62% in Phase III) of the basement wall U-factor observations not meeting the requirement.
  - While there was a slight improvement in basement wall U-factors between Phase I (32%) and Phase III (38%), basement wall IIQ remains a savings opportunity in the state.

3.1.1.8 Duct Tightness

For ducts, this report presents both unadjusted (raw) duct tightness and adjusted duct tightness. Unadjusted duct tightness is simply the values of duct leakage observed in the field. Adjusted duct tightness looks at the location of the ducts and adjusts the leakage values for any ducts which are entirely in conditioned space by setting the leakage of those ducts to zero (0). The adjustment reflects the fact that duct tightness tests are not required if the ducts are entirely in conditioned space.

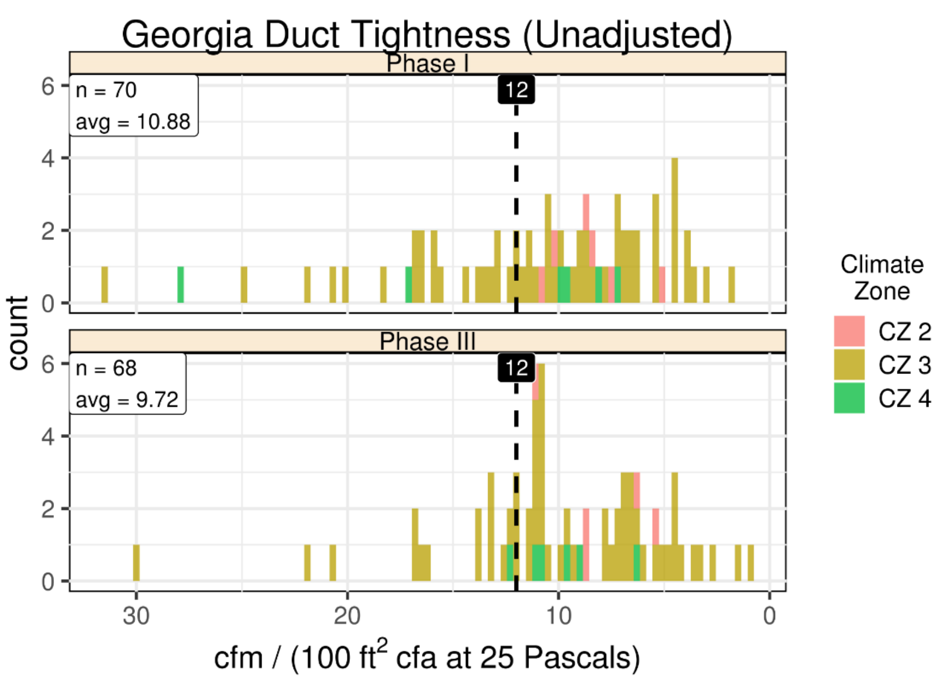

Figure 3.13. Comparison of Phase I and Phase III Duct Tightness Values for Georgia

Table 3.17. Georgia Duct Tightness Values in Phase I and Phase III (unadjusted)

Duct Tightness	Phase I CZ2	CZ3	CZ4	Statewide	Phase III CZ2	CZ3	CZ4	Statewide
Requirement	12	12	12	12	12	12	12	12
Observations								
Number	6	58	6	70	5	57	6	68
Range	5.0 to 10.7	3.0 to 31.5	7.3 to 28.0	3.0 to 31.5	5.5 to 11.1	0.9 to 29.9	6.2 to 12.3	0.9 to 29.9
Average	8.4	10.9	13.3	10.9	8.0	9.9	9.0	9.7
Compliance Rate	6 of 6 (100%)	38 of 58 (66%)	4 of 6 (67%)	48 of 70 (69%)	5 of 5 (100%)	42 of 57 (74%)	5 of 6 (83%)	52 of 68 (76%)

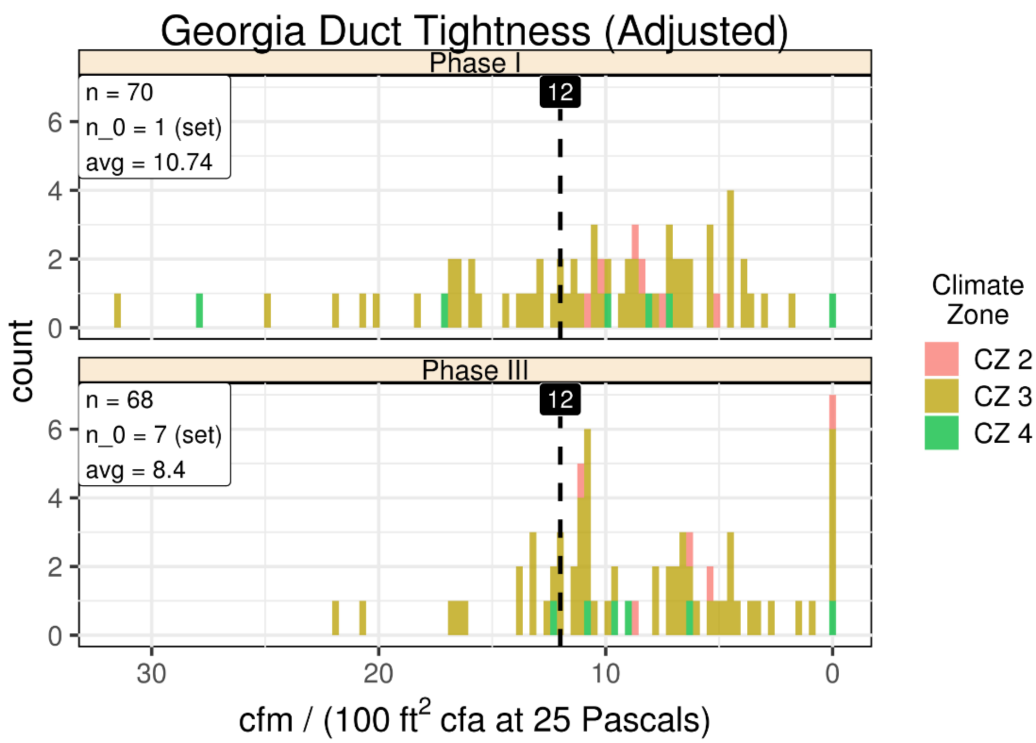

Figure 3.14. Comparison of Phase I and Phase III Duct Tightness Values for Georgia (Adjusted)

Table 3.18. Georgia Duct Tightness Values in Phase I and Phase III (Adjusted)

Duct Tightness	Phase I CZ2	CZ3	CZ4	Statewide	Phase III CZ2	CZ3	CZ4	Statewide
Requirement	12	12	12	12	12	12	12	12
Observations								
Number	6	58	6	70	5	57	6	68
Range	5.0 to 10.7	3.0 to 31.5	0 to 28.0	3.0 to 31.5	0 to 11.1	0.9 to 21.9	0 to 12.3	0 to 21.9
Average	8.4	10.9	11.7	10.7	6.3	8.6	8.0	8.4
Compliance Rate	6 of 6 (100%)	38 of 58 (66%)	4 of 6 (67%)	48 of 70 (69%)	5 of 5 (100%)	44 of 57 (77%)	5 of 6 (83%)	54 of 68 (79%)

- **Interpretations:**
  - For unadjusted duct tightness, the distribution of Phase I observations exhibited higher leakage than expected compared to the current code requirement. There was also a large range of results. Duct tightness was a focus of Phase II education and training activities, and results improved in Phase III. It is also notable that the number of outliers in the distribution was greatly reduced.
  - The average unadjusted duct leakage amounts in Phase I were 11.1 in unconditioned space and 9.7 for ducts 100% in conditioned space. In Phase III, averages were 10.2 in unconditioned space and 12.9 for ducts 100% in conditioned space.
  - For adjusted duct tightness, the distributions in both Phase I and Phase III have averages below the current code requirement, with Phase III results showing improvement.

The project team noted in Phase I that there were cases where the ducts did not meet total leakage, but, most likely, would have passed a leakage-to-outdoors test. The project team focused on the duct sealing requirements in Phase II to ensure that the construction industry recognizes that ducts must be sealed, regardless of the testing method.

3.1.2 Additional Data Items

The project team collected data on all code requirements within the state as well as other items 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, in addition to the key items alone.

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 Georgia field study is contained in Appendix C. The full data set is also available on the DOE Building Energy Codes Program website.[1]

The percentages provided in the section below represent percentages of total observations or the percentage of observations that complied.

3.1.2.1 Average Home

Table 3.19. Average Home

Home Statistics	Phase I	Phase III
Average square footage (ft^2)	2777	2917
Number of Stories	2.15	1.86

3.1.2.2 Compliance

In Phase I, the majority of observations (n=210) were permitted under the 2009 IECC GA (99.5%) or 2015 IECC (0.5%). In Phase III, there were only 4 observations, with 1 (25%) listed as 2009 IECC GA and 3 (75%) listed as 2011 Code.

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

3.1.2.3 Envelope

Table 3.20. Envelope

Requirement	Phase I	Phase III
Profile		
Walls	All wood-framed with mix of 4” (94%) and 6” (6%) (n=68)	All wood-framed with 4” (n=8)
Foundations	n=157	n=139
Basement	32%[1]	31%[2]
Slab-on-grade	62%	60%
Floors	6%	9%
Insulation labeled	100% (n=5)	33% (n=3)
Attic hatches and doors complied	81% (n=36)	100% (n=22)
Attic access openings sealed	63% (n=8)	NA*
Envelope areas behind tubs and showers	100% (n=6)	100% (n=2)
Openings around doors and windows	73% (n=11)	100% (n=2)
Knee walls sealed	38% (n=13)	100% (n=2)

*Not reported in Phase III

3.1.2.4 Duct & Piping Systems

Table 3.21. Duct and Piping Systems

Requirement	Phase I	Phase III
Profile		
Supply ducts located within conditioned space (percentage of duct system)	30% (n=28)	32% (n=100)
Return ducts located within conditioned space (percentage of duct system)	26% (n=27)	33% (n=99)
Supply ducts entirely within conditioned space (percentage of homes and number)	4% (1 home)	14% (14 homes)
Return ducts entirely within conditioned space (percentage of homes and number)	4% (1 home)	15% (15 homes)
Duct Insulation	R- 7.7 (n=23)	NA (n=0)
Pipe Insulation	R-2 (n=3)	NA*
Air handlers sealed	60% (n=5)	NA*
Filter boxes sealed	20% (n=5)	NA*

*Not reported in Phase III

[1] 38% of the basement observations in Phase I were conditioned
[2] 13% of the basement observations in Phase III were conditioned

3.1.2.5 HVAC Equipment

Table 3.22. HVAC Equipment

Requirement	Phase I	Phase III
Profile		
Heating equipment type	Mix of gas furnaces and heat pumps (n=35), 25 gas furnace and 10 electric heat pumps	Mix of gas furnaces and heat pumps (n=98), 48 gas furnace and 50 electric heat pumps
Heating equipment efficiency	80+ AFUE furnace, 8.3 HSPF heat pump (n=98 total)	Not collected
Cooling equipment type	Mix of central AC and heat pump (n=29, 12 heat pump, 17 central AC)	Not collected
Cooling equipment efficiency	13.8 SEER	Not collected
Water heating equipment type	Mostly gas storage and electric storage (n=29, 17 gas storage and 12 electric storage)	Mostly gas storage and electric storage (n=27, 11 gas storage and 16 electric storage)
Water heating equipment capacity	57 gallons (n=29)	57 gallons (n=27)
Water heating equipment efficiency	EF 0.75 (n=29)	EF 0.84 (n=27)

3.2 Energy Intensity

The statewide energy analysis results in Figure 3.15 how an estimated decrease in EUI between Phase I and III of 1.82 kBtu/ft^2, which surpasses the 1.25 kBtu/ft^2 threshold for statistically significant savings. The observed data set (as gathered in the field) was compared against the same set of homes meeting prescriptive code requirements. Average energy consumption decreased by over 7% between Phase I and Phase III. Table 3.23 compares the Phase I and Phase III results.

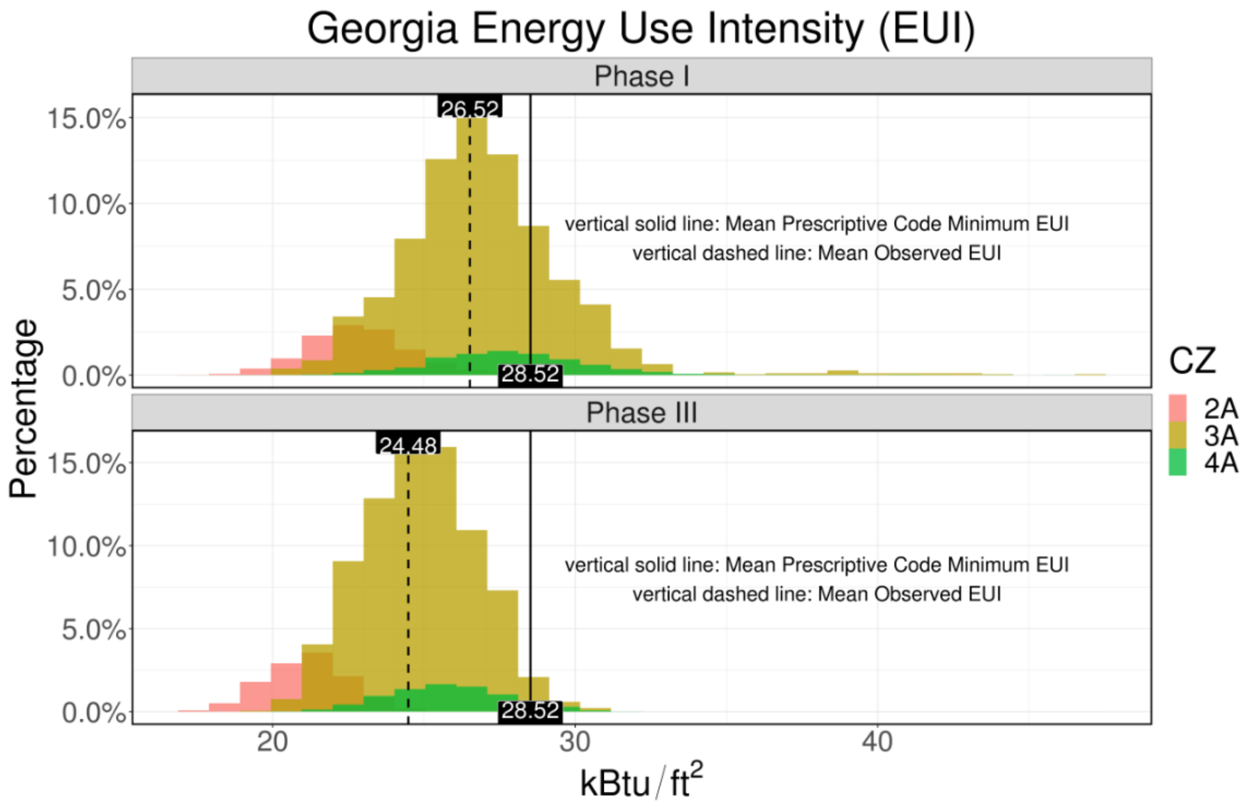

Figure 3.15. Comparison of Phase I and Phase III Statewide EUI for Georgia

Table 3.23. Georgia Statewide EUI in Phase I and Phase III

Prescriptive EUI[1]	Phase I	Differential (Phase I vs. Prescriptive)	Phase III	Differential (Phase III vs. Prescriptive)	% Change (Phase III vs. I)
28.52	26.52	-7.0%	24.48	-14.2%	-7.7%

3.3 Savings Potential

Several key items in Phase I were previously identified as targets for improvements via education, training and compliance-improvement initiatives. Those with the greatest potential[2], shown below followed by the percent that met code, were further analyzed to estimate the associated savings potential for energy, cost and environmental impacts.

[1] Calculated based on the minimum prescriptive requirements of the state energy code.
[2] Defined here as those with less than 85% of observations meeting the prescriptive code requirement

Table 3.24. Comparison of Phase I and Phase III Compliance Rates by Measure in Georgia

Measure	Phase I Compliance Rate	Phase III Compliance Rate	Phase III to Phase I Difference in Compliance Rate
Exterior Wall Insulation	17%	21%	+4%
Lighting	38%	84%	+46%
Duct Tightness[1]	69%	79%	+10%
Ceiling Insulation	10%	60%	+50%

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

The results for the energy, cost, and environmental savings potential are shown in Table 3.25. The results indicate that the Phase II education and training activities were successful in reducing the overall savings potential for all measures. Improvement is measured by a reduction in measure-level savings potential between Phase I and Phase III.

Table 3.25. Comparison of Phase I and Phase III Estimated Annual Statewide Savings Potential

	Potential Total Energy Savings (MMBtu)		Potential Total Energy Cost Savings ($)		Potential Total State Emissions Reduction (MT CO2e)	
Measure	**Phase I**	**Phase III**	**Phase I**	**Phase III**	**Phase I**	**Phase III**
Exterior Wall Insulation	47,069	41,633	1,151,262	936,827	26,602	19,084
Lighting	15,774	1,976	799,065	104,101	31,168	4,131
Duct Tightness	25,387	8,713	685,683	215,305	17,885	5,035
Ceiling Insulation	73,070	20,702	1,880,668	494,910	46,281	11,062
TOTAL	**161,300 MMBtu**	**73,024 MMBtu**	**$4,516,678**	**$1,751,143**	**121,936 MT CO2e**	**39,312 MT CO2e**

Overall measure-level energy cost savings potential showed a 61% reduction between Phase I and Phase III. To reflect the longer-term cost savings potential of improved compliance, annual savings were accumulated over 5, 10, and 30 years of new construction (Table 3.26). See Appendix D for additional details on electricity savings and natural gas savings per home associated with each measure; savings by individual foundation components; and the total savings and emissions reductions accumulated over 5, 10, and 30 years of construction.

[1] This compliance rate is for adjusted duct tightness observations.

Table 3.26. Comparison of Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential Phase III vs. Phase I

Measure	Potential Total Energy Cost Savings ($) 5 yr		Potential Total Energy Cost Savings ($) 10 yr		Potential Total Energy Cost Savings ($) 30 yr	
	Phase I	**Phase III**	**Phase I**	**Phase III**	**Phase I**	**Phase III**
Exterior Wall Insulation	17,268,930	14,052,403	63,319,410	51,525,479	535,336,830	433,624,505
Lighting	11,985,975	1,561,509	43,948,575	5,725,534	371,565,225	48,406,784
Duct Tightness	10,285,245	3,229,577	37,712,565	11,841,784	318,842,595	100,116,899
Ceiling Insulation	28,210,017	7,423,654	103,436,729	27,220,066	874,510,530	230,133,285
TOTAL	**67,750,167**	**26,267,144**	**248,417,279**	**96,312,862**	**2,100,255,180**	**814,281,473**

4.0 Conclusions

The Georgia field study successfully achieved a measurable decrease in estimated statewide energy consumption and a reduction in measure-level savings potential through targeted education and training. A reduction in savings potential equates to improvement.

Based on the study's findings, the prototypical, newly constructed home in Georgia consumes 14.2 percent less energy than a home exactly meeting the state energy code. As shown in Table 4.1, the average home showed an estimated improvement in energy performance of over 7 percent between Phase I and III.

Table 4.1. Average Modeled Energy Use Intensity in Georgia (kBtu/ft2-yr)

Prescriptive EUI[1]	Phase I	Differential (Phase I vs. Prescriptive)	Phase III	Differential (Phase III vs. Prescriptive)	% Change (Phase III vs. I)
28.52	26.52	-7.0%	24.48	-14.2%	-7.7%

This results in nearly $2.8 million in annual achieved savings, an improvement of nearly 61% following the Phase II targeted education and training activities (Table 4.2).[2] The contributing factor to the reduction in measure-level savings potential was improvements in all key items: exterior wall insulation, lighting, duct tightness, and ceiling insulation, with lighting having a particularly positive change.

Table 4.2. Estimated Annual Statewide Energy Cost Savings Potential

Measure	% Change Phase III vs. I
Exterior Wall Insulation	-18.6%
Lighting	-87.0%
Duct Tightness	-68.6%
Ceiling Insulation	-73.7%
TOTAL	**-61.2%**

This project provides the state with significant and quantified data that can be used to help direct future energy efficiency activities. DOE encourages states to conduct these types of studies every 3-5 years to validate state code implementation, quantify benefits achieved, and identify ongoing opportunities to hone workforce education and training programs.

[1] Calculated based on the minimum prescriptive requirements of the state energy code.
[2] See Table 3.25 for potential total energy cost savings in each phase.

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 Georgia (HBAG)	The Home Builders Association of Georgia (HBAG) is part of a three-tiered federation of organizations who share a common mission: to serve the housing industry and provide expanding opportunities for all consumers to have safe, decent and affordable housing. Individual members join local associations, which in turn are affiliated with the Home Builders Association of Georgia and the National Association of Home Builders.
Georgia Power Company	The only investor-owned utility in Georgia and has the most customers of utilities in the state.
Georgia Public Service Commission	Agency responsible for approval of all utility energy efficiency programs.
Georgia Environmental Finance Agency	The Georgia State Energy Office resides at GEFA and is directly involved in the energy code adoption process.
Georgia Department of Community Affairs	The state entity in charge of all building codes.
Building Official Association of Georgia (BOAG)	The organization that represents all code officials in the state of Georgia.
Conditioned Air Association of Georgia (CAAG)	The Conditioned Air Association of Georgia (CAAG) is a state-wide, non-profit trade association which represents heating, ventilation, air conditioning and refrigeration contractors (HVACR) who work on residential, commercial and industrial construction projects.
Georgia Building Performance Association	Georgia Building Performance Association (GABPA) was formed in June of 2015 to offer Georgia's home and building performance companies and professionals support and representation in the marketplace.
American Institute of Architects, Georgia Chapter (AIA-GA)	A professional organization for architects that offers education, government advocacy, community redevelopment, and public outreach to support the architecture profession.

Appendix B

State Sampling Plan

Appendix B

State Sampling Plan

B.1 State Sampling Plan

Table B.1. Phase I State Sampling Plan

Location	Sample	Actual
Forsyth County Unincorporated Area, Forsyth	8	8
Gwinnett County Unincorporated Area, Gwinnett	5	4 – Gwinnett County 1 – Dekalb County
Columbia County Unincorporated Area, Columbia	2	2
Cobb County Unincorporated Area, Cobb	4	4
Cherokee County Unincorporated Area, Cherokee	2	2
Atlanta, Fulton	2	2
Lowndes County Combined, Lowndes	1	1
Henry County Unincorporated Area, Henry	2	1 – Henry County 1 – Douglasville
Milton, Fulton	2	2
Oconee County Unincorporated Area, Oconee	2	2
Warner Robins, Houston	2	2
Paulding County Unincorporated Area, Paulding	1	1
Coweta County Unincorporated Area, Coweta	1	1
Woodstock, Cherokee	1	1
Sandy Springs, Fulton	2	2
Smyrna, Cobb	2	2
Houston County Unincorporated Area, Houston	1	1
Effingham County Unincorporated Area, Effingham	1	1
Hinesville, Liberty	1	1
Fannin County, Fannin	1	1
Fayette County Unincorporated Area, Fayette	1	1
Perry, Houston	1	1
Harris County Unincorporated Area, Harris	1	1
Canton, Cherokee	1	1
Spalding County Unincorporated Area, Spalding	1	1
Marietta, Cobb	2	2
Greene County, Greene	1	1– Oconee County
Catoosa County Unincorporated Area, Catoosa	1	1
Richmond Hill, Bryan	1	1
Braselton town, Jackson	1	1

Location	Sample	Actual
Thomas County Unincorporated Area, Thomas	1	1
Jackson County Unincorporated Area, Jackson	1	1
Dawson County Unincorporated Area, Dawson	2	2
Rockdale County Unincorporated Area, Rockdale	1	1
Carrollton, Carroll	1	1 – Unincorporated Carroll County
Habersham County Unincorporated Area, Habersham	1	1
Baldwin County Unincorporated Area, Baldwin	1	1
Peach County Unincorporated Area, Peach	1	1
Total	**63**	**63**

Table B.2. Phase III State Sampling Plan

Location	Sample	Actual
Loudoun County, Loudoun County	9	9
Prince William County Unincorporated Area, Prince William County	3	3
Chesterfield County, Chesterfield County	5	5
Stafford County, Stafford County	4	4
Chesapeake, Independent City	7	7
Fairfax County Unincorporated Area, Fairfax County	1	1
Henrico County, Henrico County	2	2
Virginia Beach, Independent City	2	2
Hanover County, Hanover County	2	2
James City County, James City County	2	2
Norfolk, Independent City	1	1
Rockingham County, Rockingham County	2	2
Suffolk, Independent City	1	1
Albemarle County, Albemarle County	2	2
Arlington County, Arlington County	2	2
Fauquier County Unincorporated Area, Fauquier County	1	1
Culpeper County, Culpeper County	3	3
Louisa County, Louisa County	2	2
Augusta County, Augusta County	1	1
Alexandria, Independent City	1	1
Gloucester County, Gloucester County	1	1
Goochland County, Goochland County	1	1
Warren County, Warren County	2	2
Campbell County, Campbell County	1	1
Shenandoah County, Shenandoah County	1	1
Orange County, Orange County	1	1

Location	Sample	Actual
Mecklenburg County Unincorporated Area, Mecklenburg County	1	1
Hopewell, Independent City	1	1
Washington County Unincorporated Area, Washington County	1	1
Total	**63**	**63**

B.2 Substitutions

In the Phase I Georgia study, the project team had to substitute 4 samples in total from one jurisdiction to another. The substitute counties were selected to best match the social demographics of the original county. Each substitution was considered individually, with additional details for each provided below:

- **Original: City of Carrollton. Substitution: City of Carrollton and Unincorporated Carroll County.** In the original sample plan, the project team was to collect one sample set from the City of Carrollton in Carroll County. However, upon receiving the permit list from the Carrollton Building Department, the project team discovered that the number of new single-family permits (3) was far below the previous years, and well below a level that was considered adequate for the study. Unincorporated Carroll County was identified as an acceptable alternative and did have sufficient permits. Although these jurisdictions have different building departments, it was assumed that the construction community serves both jurisdictions and samples from both would provide an accurate portrait of the location. Therefore, the project team combined the City of Carrollton and unincorporated Carroll County to complete the one required sample set.
- **Original: Greene County. Substitution: Oconee County.** Greene County required one sample set based on the original sampling plan. Permits were obtained and site visits were conducted, but the project team was unable to complete the sample due to limited access to houses. Oconee County was selected as a substitution due to its adjacent location, similar construction type (e.g., many lakefront homes in gated communities), and similar median sale prices compared to Greene County.
- **Original: Henry County. Substitution: City of Douglasville.** The original sampling plan required two samples from Henry County. One complete sample set was achieved; however, the project team exhausted all available permits before fulfilling the second sample set. Douglasville was determined to be an appropriate sample due to its similar proximity to the metro Atlanta region and similar median house price.
- **Original: Gwinnett County Unincorporated. Substitution: Dekalb County Unincorporated.** The original sampling plan required five samples from Gwinnett County. Four complete sample sets were achieved; however, the project team exhausted all available permits before fulfilling the last sample set. Dekalb County was determined to be an appropriate sample due to its similar proximity to the metro Atlanta region and similar median house price.

In Phase III, no substitutions were needed.

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 Georgia 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

Table C.1. Home Size

Home Statistics	Phase I	Phase III
Average Square Footage (ft^2)	2777	2917
Number of Stories	2.15	1.86
Number of Homes Visited	216	139

Table C.2. Conditioned Floor Area (ft^2)

Conditioned Floor Area (ft^2)	< 1000	1000 to 1999	2000 to 2999	3000 to 3999	4000+
Percentage (Phase I)	0%	9%	52%	33%	6%
Percentage (Phase III)	1%	12%	46%	32%	10%

Table C.3. Number of Stories

No. of Stories	1/1.5	2	3	4+
Percentage (Phase I)	8%	68%	23%	0%
Percentage (Phase III)	19%	78%	3%	0%

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

C.1.1.2 Wall Profile

Table C.4. Wall Characteristics

Wall Characteristic	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Framing Type			68	3
Frame Walls	100%	100%		
Mass Walls	0%	0%		
Framing Material			75	6
Wood	100%	100%		
Steel	0%	0%		
Framing Depth			63	8
4 inch	94%	100%		
6 inch	6%	0%		

C.1.1.3 Foundation Profile

Table C.5. Foundation Characteristics

Foundation Characteristic	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Foundation Type			157	139
Basement	32%	31%		
Slab on Grade	62%	60%		
Crawlspace	6%	9%		
Basement Type			52	44
Conditioned	38%	20%		
Unconditioned	62%	80%		

C.1.2 Compliance

The following summarizes information related to compliance, including the energy code associated with individual homes, whether the home was participating in an above-code program, and which particular programs were reported. The percentages provided in the sections below represent percentages of total observations or the percentage of observations that complied.

C.1.2.1 Energy Code Used

Table C.6. Energy Code and Above Code Programs

Code or Above Code Program Used	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Energy Code Used			210	4
2009 GA Code	99.5%	25%		
2015 IECC	0.5%			
2011 GA Code		75%		
Was home participating in an above code program?			Not Reported	Not Reported
Which above code program?			Not Reported	Not Reported

C.1.3 Envelope

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

Table C.7. Thermal Envelope Characteristics

Thermal Envelope Characteristic	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Was insulation labeled?			5	3
Yes	100%	33%		
No	0%	67%		
Did the attic hatch/door exhibit the correct insulation value?			36	22
Yes	81%	100%		
No	19%	0%		
Air Sealing in accordance with checklist[1]				
Thermal Envelope sealed?	42%	100%	12	2
Fenestration Sealed?	69%	100%	13	2
Openings around doors and windows sealed?	73%	100%	11	2
Utility penetrations sealed?	71%	Not Reported	17	0
Knee walls sealed?	38%	100%	13	2
Garage walls sealed?	30%	Not Reported	10	0
Tubs and showers sealed?	100%	100%	6	2
Attic access openings sealed?	63%	Not Reported	8	0
Rim joists sealed?	67%	100%	6	1
Other sources of infiltration sealed?	33%	100%	6	2

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

C.1.4 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:

Table C.8. Duct & Piping System Characteristics

Duct & Piping System Characteristic	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Duct location in conditioned space (average percentage)				
Supply	30%	32%	28	100
Return	26%	33%	27	99
Ducts entirely in conditioned space (number and percentage)				
Supply	1 duct system (4%)	14 duct systems (14%)	28	100
Return	1 duct system (4%)	15 duct systems (15%)	27	99
Ducts in unconditioned space insulation (R-value)				
Supply	8	Not Reported	3	0
Return	8	Not Reported	4	0
Ducts in attic insulation (R-value)				
Supply	8	Not Reported	8	0
Return	7.3	Not Reported	8	0
Pipe insulation (R-value)			3	0
Average	R-2	Not Reported		
Range	R-0 to R-2	Not Reported		
Air handlers sealed	60%	Not Reported	5	0
Filter boxes sealed	20%	Not Reported	5	0

C.1.5 HVAC Equipment

The following represents an average profile of observed HVAC equipment, followed by a list of additional questions related to such systems:

C.1.5.1 Heating

Table C.9. Heating Equipment Characteristics

Item	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Fuel Source			35	69
Gas	71%	46%		
Electricity	29%	54%		
System Type			35	70
Furnace	71%	49%		
Heat Pump	29%	51%		
Average System Capacity			14	NA*
Furnace	76,900 Btu/hr	NA*		
Heat Pump	76,500 Btu/hr	NA*		
Average System Efficiency			20	NA*
Furnace	0.82 AFUE	NA*		
Heat Pump	8.3 HSPF	NA*		

*Heating system capacity and system efficiency not collected in Phase III.

C.1.5.2 Cooling

Table C.10. Cooling Equipment Characteristics

Item	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
System Type			29	NA*
Central AC	69%	NA*		
Heat Pump	31%	NA*		
Average System Capacity			17	NA*
Central AC	40,600 Btu/hr	NA*		
Heat Pump	76,500 Btu/hr	NA*		
Average System Efficiency	13.8 SEER	NA*	20	NA*

*Cooling system type, system capacity and system efficiency not collected in Phase III.

C.1.5.3 Water Heating

Table C.11. Water Heating Equipment Characteristics

Item	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
Fuel Source			29	23
Gas	59%	39%		
Electricity	41%	61%		
System Type			30	27
Storage	93%	85%		
Tankless	7%	15%		
Average System Capacity	57 gal	52 gal	23	23
Average System Efficiency				
Electric Storage	EF 0.90	EF 0.94	12	12
Gas Storage	EF 0.59	EF 0.62	15	5
Gas Tankless	EF 0.82	EF 0.83	2	3

Table C.12. Water Heating System Storage Capacity Distribution

Capacity	< 50 gal	50-59 gal	60-69 gal	70-79 gal	80-89 gal	90+ gal
Phase I Percentage	0%	78%	0%	0%	22%	0%
Phase III Percentage	0%	96%	0%	0%	4%	0%

C.1.5.4 Ventilation

Table C.13. Ventilation Characteristics

Item	Phase I Observations	Phase III Observations	Number of Phase I Observations	Number of Phase III Observations
System Type			1	6
AHU-Integrated	100%	100%		

Appendix D

Energy Savings

Appendix D

Energy Savings

D.1 Measure-Level Savings

This appendix contains detailed measure-level annual savings potential results for both Phase I (Table D.1) and Phase III (Table D.2) for Georgia. Also included are multi-year (5-year, 10-year, and 30-year) aggregations of the annual results in Table D.3, Table D.4, and Table D.5. The multi-year savings reflect the same reductions and increases as the annual savings and are simply the annual savings multiplied by 15, 55, and 465 for 5-year, 10-year, and 30-year savings, respectively. For analytical details refer to Section 2.3.3 (Savings Analysis) or the methodology report (DOE 2018).

Table D.1. Phase I Statewide Annual Measure-Level Savings Potential for Georgia

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)
Exterior Wall Insulation	2A	172	8	1,378	3,410	4,700	123,872	3,129
	3A	182	11	1,746	21,920	38,283	930,211	21,318
	4A	186	12	1,880	2,173	4,086	97,183	2,161
	State Total	**181**	**11**	**1,711**	**27,503**	**47,069**	**1,151,262**	**26,602**
Lighting	2A	222	-1	631	3,410	2,153	104,221	4,011
	3A	213	-2	565	21,920	12,393	632,177	24,725
	4A	213	-2	565	2,173	1,228	62,666	2,451
	State Total	**214**	**-2**	**574**	**27,503**	**15,774**	**799,065**	**31,168**
Duct Tightness	2A	113	3	730	3,410	2,490	72,832	2,050
	3A	122	5	944	21,920	20,699	553,200	14,254
	4A	135	5	1,011	2,173	2,198	59,653	1,563
	State Total	**122**	**5**	**923**	**27,503**	**25,387**	**685,683**	**17,885**
Ceiling Insulation	2A	302	12	2,250	3,410	7,673	209,222	5,495
	3A	308	16	2,620	21,920	57,431	1,471,326	36,007
	4A	412	23	3,666	2,173	7,967	200,120	4,780
	State Total	**315**	**16**	**2,657**	**27,503**	**73,070**	**1,880,668**	**46,281**
TOTAL		**832**	**30**	**5,865**	**27,503**	**161,300**	**4,516,678**	**121,936**

Table D.2. Phase III Statewide Annual Measure-Level Savings Potential for Georgia

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)
Exterior Wall Insulation	2A	129	8	1,213	3,410	4,137	101,366	2,344
	3A	130	11	1,545	21,920	33,874	756,522	15,218
	4A	131	12	1,667	2,173	3,621	78,939	1,522
	State Total	**129**	**11**	**1,514**	**27,503**	**41,633**	**936,827**	**19,084**
Lighting	2A	29	0	80	3,410	272	13,561	527
	3A	28	0	71	21,920	1,550	82,379	3,279
	4A	28	0	71	2,173	153	8,161	325
	State Total	**28**	**0**	**72**	**27,503**	**1,976**	**104,101**	**4,131**
Duct Tightness	2A	34	1	252	3,410	861	23,506	618
	3A	34	2	324	21,920	7,101	173,148	3,978
	4A	38	2	346	2,173	751	18,651	439
	State Total	**34**	**2**	**317**	**27,503**	**8,713**	**215,305**	**5,035**
Ceiling Insulation	2A	73	4	632	3,410	2,157	54,835	1,330
	3A	72	5	732	21,920	16,041	381,763	8,478
	4A	108	8	1,153	2,173	2,505	58,312	1,254
	State Total	**75**	**5**	**753**	**27,503**	**20,702**	**494,910**	**11,062**
TOTAL		**267**	**17**	**2,655**	**27,503**	**73,024**	**1,751,143**	**39,312**

Table D.3. Phase I Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential for Georgia

	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
Measure	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Exterior Wall Insulation	706,035	2,588,795	21,887,085	17,268,930	63,319,410	535,336,830	399,303	1,463,121	12,370,021
Lighting	236,610	867,570	7,334,910	11,985,975	43,948,575	371,565,225	467,516	1,714,226	14,493,001
Duct Tightness	380,805	1,396,285	11,804,955	10,285,245	37,712,565	318,842,595	268,275	983,674	8,316,513
Ceiling Insulation	1,096,055	4,018,868	33,977,700	28,210,017	103,436,729	874,510,530	694,213	2,545,448	21,520,609
TOTAL	**2,419,505**	**8,871,518**	**75,004,650**	**67,750,167**	**248,417,279**	**2,100,255,180**	**1,829,037**	**6,706,469**	**56,700,144**

Table D.4. Phase III Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential for Georgia

	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
Measure	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Exterior Wall Insulation	624,494	2,289,811	19,359,311	14,052,403	51,525,479	435,624,505	286,266	1,049,644	8,874,261
Lighting	29,637	108,669	918,744	1,561,509	5,725,534	48,406,784	61,964	227,200	1,920,869
Duct Tightness	130,696	479,219	4,051,575	3,229,577	11,841,784	100,116,899	75,520	276,906	2,341,116
Ceiling Insulation	310,531	1,138,614	9,626,462	7,423,654	27,220,066	230,133,285	165,928	608,401	5,143,756
TOTAL	**1,095,358**	**4,016,312**	**33,956,092**	**26,267,144**	**96,312,862**	**814,281,473**	**589,678**	**2,162,151**	**18,280,003**

Table D.5. Difference between Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential Phase III vs. Phase I

	Total Energy Savings (MMBtu)			Total Energy Cost Savings ($)			Total State Emissions Reduction (MT CO2e)		
Measure	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**	**5yr**	**10yr**	**30yr**
Exterior Wall Insulation	81,541	298,984	2,527,774	3,216,527	11,793,931	99,712,325	113,037	413,477	3,495,760
Lighting	206,973	758,901	6,416,166	10,424,466	38,223,041	323,158,441	405,552	1,487,026	12,572,132
Duct Tightness	250,109	917,066	7,753,380	7,055,668	25,870,781	218,725,696	192,755	706,768	5,975,397
Ceiling Insulation	785,524	2,880,254	24,351,238	20,786,363	76,216,663	644,377,245	528,285	1,937,047	16,376,853
TOTAL	**1,324,147**	**4,855,206**	**41,048,558**	**41,483,023**	**152,104,417**	**1,285,973,707**	**1,239,359**	**4,544,318**	**38,420,141**

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