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Texas Residential Energy Code Field Study: Final Report

September 2022

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Prepared for
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Executive Summary

A research project in the state of Texas 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 Texas 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 October 2014 and continued through October 2015. During this period, research teams visited 133 homes in 30 counties in and around Houston during various stages of construction, resulting in a substantial data set based on observations made directly in the field. Stakeholders in the state agreed that these 30 counties represented levels of energy codes and enforcement seen across the state. At the project team’s request, the analytical results were calculated in two ways: Climate Zone (CZ) 2A results only and results extrapolated statewide from the CZ2A data. For the statewide results, the CZ2A data were used as observed values in all of the climate zones and analytical results were extrapolated statewide. This extrapolation was repeated in Phase III. See Section 2.4.1 for additional details. The results in the main body of this report are presented for the CZ2A data. Statewide results are presented in Appendix E. Analysis of the Phase I data led to a better understanding of the energy features typically present in Texas homes, and indicated over \$4.8 million in potential annual savings to homeowners that could result from increased code compliance (Table ES.2).

Starting in December 2015 and continuing through March 2018, members of the Texas field study team conducted targeted education and training activities (Phase II). Those activities included classroom and webinar training, factsheets, and checklists. 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 136 homes across the state between April 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 National Association of State Energy Officials (NASEO) with support from the South-central Partnership for Energy Efficiency as a Resource (SPEER) and Cadmus. 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 estimates¹. As part of both the pre- and post-studies, the project team implemented customized

¹ See Section 2.1

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 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.

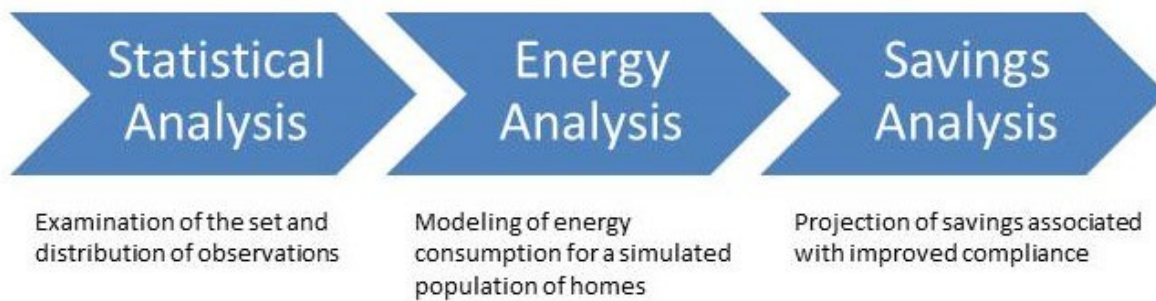


Figure ES.1. Stages of Analysis Applied in the Study

During the Phase I data collection period, the state energy code was the 2009 International Residential Code (IRC) with no amendments. The state energy code was updated to the 2015 IRC prior to Phase III data collection. Therefore, Phase I data collection occurred with homes permitted under the 2009 IRC, while Phase III data collection occurred with homes permitted under the 2015 IRC. All of the results in this report are based on the 2015 International Energy Conservation Code (IECC), which is equivalent to the 2015 IRC, as that is the code that states would need to comply with in the future, and that was the focus of training in the state, and so a direct comparison between Phase I and Phase III savings potential can be made.

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/ft²] 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 2015 IECC). 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 1.9 percent more energy than would be expected relative to homes built to the minimum prescriptive requirements of the 2015 IECC. This percentage improved to 6.4 percent less energy in Phase III, representing a change in EUI of approximately 8.1 percent (1.83 kBtu/ft²) between Phases I and III.

Table ES.1. Average Modeled Energy Use Intensity in Texas CZ2A (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) |
|-------------------------------|---------|---|-----------|---|----------------------------|
| 22.15 | 22.57 | +1.9% | 20.74 | -6.4% | -8.1% |

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

Table ES.2. Estimated Annual Texas CZ2A Cost Savings Potential

| Measure | Total Energy Cost Savings Potential (\$) | | \$ Change | % Change |
|--------------------------|--|--------------------|---------------------|-----------------|
| | Phase I | Phase III | Phase III vs. I | Phase III vs. I |
| Envelope Air Tightness | 654,623 | 170,471 | -484,152 | -73.9% |
| Exterior Wall Insulation | 511,748 | 359,086 | -152,662 | -29.8% |
| Duct Tightness | 1,914,867 | 170,171 | -1,744,696 | -91.1% |
| Lighting | 1,550,412 | 4,050 | -1,546,362 | -99.7% |
| Ceiling Insulation | 216,147 | 540,180 | +324,033 | +149.9% |
| TOTAL | \$4,847,797 | \$1,243,958 | -\$3,603,839 | -74.3% |

Overall, there was a reduction in savings potential between Phase I and Phase III. This is an improvement of 74 percent and over \$3.6 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 \$1.2 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 Texas. 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. See Appendix E for EUI and savings potential results based on a statewide extrapolation of CZ2A results. 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.

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

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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 guidance throughout the project as well as his contributions to the content of this report.

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- Chris Herbert, *SPEER*
- Eric Makela, *Cadmus Group (Cadmus)*
- Jolyn Green, *Cadmus*
- Jerica Stacey, *Cadmus*
- Allen Lee, *Cadmus*

NASEO

The National Association of State Energy Officials is a national non-profit association for the governor-designated energy officials from each of the 56 states and territories. Formed by the states in 1986, NASEO facilitates peer learning among state energy officials, serves as a resource for and about state energy offices, and advocates the interests of the state energy offices to Congress and federal agencies. For more information on NASEO, visit <http://www.naseo.org>.

SPEER

The South-central Partnership for Energy Efficiency as a Resource is a regional energy efficiency organization that aims to accelerate the adoption of advanced building systems and energy efficient products and services in Texas and Oklahoma. For more information, see <https://eepartnership.org>.

Cadmus

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

Acronyms and Abbreviations

| | |
|-------------------|---|
| AC | air conditioning |
| ACH | air changes per hour |
| AFUE | annual fuel utilization efficiency |
| AHU | air handling unit |
| BOAT | Building Officials Association of Texas |
| Btu | British thermal unit |
| cfm | cubic feet per minute |
| CFA | conditioned floor area |
| CO ₂ e | carbon dioxide equivalent |
| CZ | climate zone |
| DOE | U.S. Department of Energy |
| EF | energy factor |
| ESL | Energy Systems Laboratory of Texas A&M University |
| EUI | energy use intensity |
| EUMMOT | Electric Utility Marketing Managers of Texas |
| FOA | funding opportunity announcement |
| GHBA | Greater Houston Builders Association |
| HSPF | heating season performance factor |
| ICC | International Code Council |
| IECC | International Energy Conservation Code |
| IIQ | insulation installation quality |
| IRC | International Residential Code |
| kBtu | thousand British thermal units |
| MMBtu | million British thermal units |
| MT | metric ton |
| NA | not applicable |
| NASEO | National Association of State Energy Officials |
| PNNL | Pacific Northwest National Laboratory |
| ROI | return on investment |
| SECO | Texas State Energy Conservation Office |
| SEER | seasonal energy efficiency ratio |
| SHGC | solar heat gain coefficient |
| SPEER | South-central Partnership for Energy Efficiency as a Resource |
| TAB | Texas Association of Builders |
| TECCC | Texas Energy Code Compliance Collaborative |
| TX | Texas |

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1.0 Introduction

A three-phase research project in the state of Texas 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 October 2014 and continued through October 2015. During this period, research teams visited 133 homes in 30 counties in and around Houston during various stages of construction, resulting in a substantial data set based on observations made directly in the field. Stakeholders in the state agreed that these 30 counties represented levels of energy codes and enforcement seen across the state. At the project team's request, the analytical results were calculated in two ways: Climate Zone (CZ) 2A results only and results extrapolated statewide from the CZ2A data. For the statewide results, the CZ2A data were used as observed values in all of the climate zones and analytical results were extrapolated statewide. This extrapolation was repeated in Phase III. See Section 2.4.1 for additional details.

The results in the main body of this report are presented for the CZ2A data. Statewide results are presented in Appendix E. Analysis of the Phase I data led to a better understanding of the energy features typically present in Texas homes, and indicated nearly \$5 million in potential annual savings to homeowners in the state that could result from increased code compliance.

Starting in December 2015 and continuing through March 2018, members of the Texas field study team conducted targeted education and training activities (Phase II). Those activities included classroom and webinar training, factsheets, and checklists. 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 136 homes across the state between April 2018 and September 2018. The results of this effort are presented in Section 3.0.

At the time of Phase I of the study, Texas had the 2009 International Residential Code (IRC) with no amendments. Following Phase I data collection, the state proceeded in adopting an updated energy code, known as the 2015 Texas Energy Code.¹ Therefore, Phase I data collection occurred with homes permitted under the 2009 IRC, while Phase III data collection occurred with homes permitted under the 2015 IRC. All of the results in this report, including savings potential, are based on the 2015 International Energy Conservation Code (IECC), which is equivalent to the 2015 IRC, as that was the code that homes would need to comply with in the future, and so a direct comparison between Phase I and

¹ The 2015 Texas Energy Code is based on the 2015 International Residential Code with state amendments to modify the Energy Rating Index values and is available at <http://seco.cpa.state.tx.us/tbec/singlefam.php>.

Phase III can be made. 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)² 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:

- 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.^{3,4} 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.⁵

1.2 Project Team

The Texas project was led by the National Association of State Energy Officials (NASEO), with support from the South-central Partnership for Energy Efficiency as a Resource (SPEER), and field data collected by Cadmus. 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

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

³ *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

⁴ Available at <https://www.energycodes.gov/status/residential>

⁵ Available at <https://www.energycodes.gov/residential-energy-code-field-studies>

- Homebuilders
- Subcontractors
- Material supply distributors
- Government agencies
- Energy efficiency organizations
- Trade organizations
- Utilities
- Consumer interest groups
- 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 Texas 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 ft² 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/ft²] and 2) a reduction in measure-level savings potential.

The following sections describe how the methodology was implemented as part of the Texas 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.³

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

Given both the large geographic size and population of Texas, the project team decided to limit data collection to an area comprising 30 counties in south central and southeast Texas anchored on Houston (all climate zone 2). It includes dense metropolitan areas, small- to mid-size cities and towns and unincorporated areas of counties and has a population of approximately 7 million, about 25% of the state population.

An initial sample plan for the area was first developed by PNNL, and then vetted by stakeholders within the state. For purposes of the study, stakeholders agreed that this area could be used to represent the entire state as it includes a broad range of the energy codes in use and levels of enforcement seen across the state. The samples were apportioned to individual jurisdictions in proportion to their average level of construction over the past three years compared to the overall construction activity in the 30 counties⁴. This approach is known as a proportional random sample. The plan specified the number of key item observations required in each selected jurisdiction (totaling 63 of each key item for the 30-county area). The sample taken in the 30-county area was also adjusted so that the ratio of urban to rural areas was similar to the overall state ratio. See Section 2.4.1, Applicability of Results, for additional discussion of how the data collected in CZ2A was applied to the entire state.

Special considerations were discussed by stakeholders at the project kickoff meeting, such as state-specific construction practices and systematic differences across county or climate zone boundaries. These considerations were taken into account and incorporated into the final statewide sample 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

³ Available at <https://www.energycodes.gov/residential-energy-code-field-studies>.

⁴ Available at <http://censtats.census.gov/> (select the “Building Permits” data)

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 IECC⁵ in Phase I and the 2015 IECC⁶ in Phase III. The final data collection form is available in spreadsheet format on the DOE Building Energy Codes Program website.⁷ 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 RESNET⁸ 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.⁹

⁵ Several questions were removed as they were not applicable to Texas: basements and crawlspaces, slab insulation, and snow and ice melting systems.

⁶ The Phase III data was collected with an un-edited version of the 2015 IECC data collection form and thus had questions related to the features discussed in the previous footnote.

⁷ Available at <https://www.energycodes.gov/residential-energy-code-field-studies> based on the forms typically used by the REScheck compliance software.

⁸ See https://www.resnet.us/wp-content/RESNET-Mortgage-Industry-National-HERS-Standards_3-8-17.pdf.

⁹ Available at <https://www.energycodes.gov/residential-energy-code-field-studies>.

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 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.

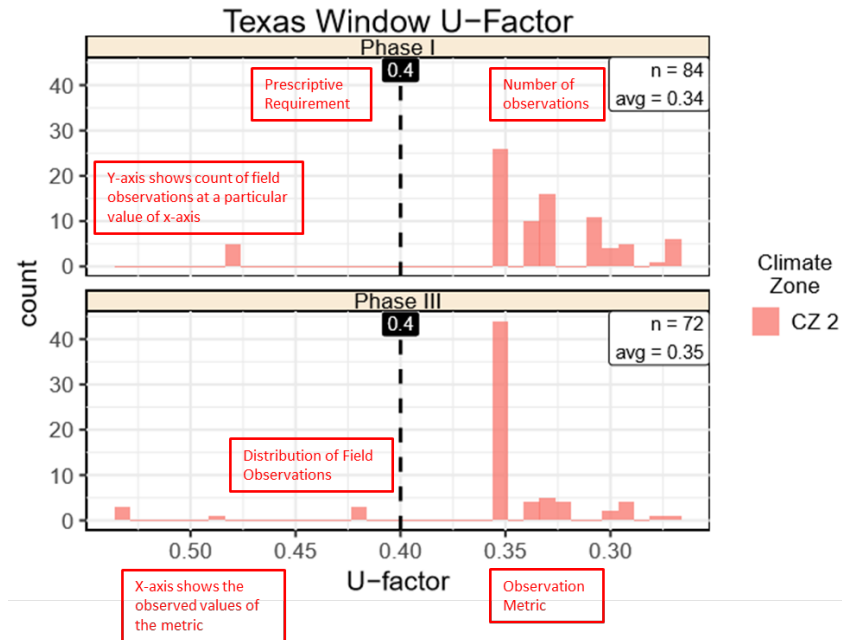


Figure 2.1. Sample Graph

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 CZ2 is 0.4)—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.¹⁰ 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.

¹⁰ See <https://energyplus.net/>

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).¹¹

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 requirement¹². For these items, additional models were created to assess the savings potential, comparing what was observed in the field to a scenario of full compliance (i.e., where all worse-than-code observations for a particular item exactly met the corresponding code requirement).¹³ 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

¹¹ Available at <https://www.energycodes.gov/residential-energy-code-field-studies>

¹² “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.

¹³ 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.

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 leakage 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 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 are statistically significant only in the geographical region that was sampled; the 30-county area comprising the sample. The results were also extrapolated to the entire state at the project team’s request (see Appendix E for the extrapolated results). In absence of additional data, data collected in CZ2A were analyzed in CZ3A, CZ3B, and CZ4B assuming that construction would remain similar (i.e., observed values from CZ2A were used as observed values in the other climate zones as well). Specifically, the random sampling process was applied to the set of observations in each CZ separately, followed by simulation runs. The state EUI results were derived by aggregating the results of the multiple climate zones-moisture regimes weighted with the CZ construction fractions provided by the project team (i.e., CZ2A:55%, CZ3A: 33%, CZ3B: 11% and CZ4B: 1%).

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 rider¹⁴ 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 Texas, specific Phase II activities included:

- Outreach materials: Handouts, social media messaging and factsheets for each measure to drive target audiences to training and webinars.
- Training: There were 70 field study trainings and webinars with over 1,850 attendees, including inspectors, builders, contractors, plan reviewers, city leaders, and designers. International Code Council CEUs were made available for each event. Field sessions ranged from classroom settings to early morning workshops with insulation contractors at warehouses. The project team recommends providing a point of contact participants can ask questions of or request more training.
- Other: Additional resources that were developed to support the project include: fact sheets and inspection checklists. Fact sheet¹⁵ topics include lighting requirements, HVAC system duct sealing and testing, envelope sealing and air tightness, insulation R-value and installation quality, and HVAC sizing. A residential inspection high impact checklist and a residential plan review high impact checklist were also created.

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. The following quantities that were derived from Phase I data and analysis were held constant between Phase I and Phase III:

¹⁴ 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).

¹⁵ The fact sheets and checklists are available at <https://eepartnership.org/program-areas/energy-codes-2/energy-codes/2015-energy-code-adoption-toolkit/code-adoption-tools/training-and-resources/>.

- Annual number of permits estimated for the state and the split of permits between climate zones in multi-climate zone states
- Distribution of heating system types in the state
- Distribution of foundation types in the state
- Number of observations of key items per climate zone in multi-climate zone states used in the Monte Carlo simulations
- 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. Texas has multiple climate zones, but samples were only taken from CZ2A. The data taken from CZ2A was treated as a representative data set of the state and was used to generate models for the other three climate zones/moisture regimes. (See Section 2.4.1, Applicability of Results for more information on how the CZ2 observations were used in the statewide analysis.)

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 ft² of conditioned floor area at 25 Pascals).

The predominant foundation type observed was slab-on-grade. Since Texas has no insulation requirement for slabs in CZ2 under the 2015 Texas Energy Code, and because the project team specifically requested removal of the foundation insulation questions from the data collection form, foundation insulation is not included in this section.

All of the results in this section are based on comparison to the 2015 IECC.

3.1.1.1 Envelope Tightness

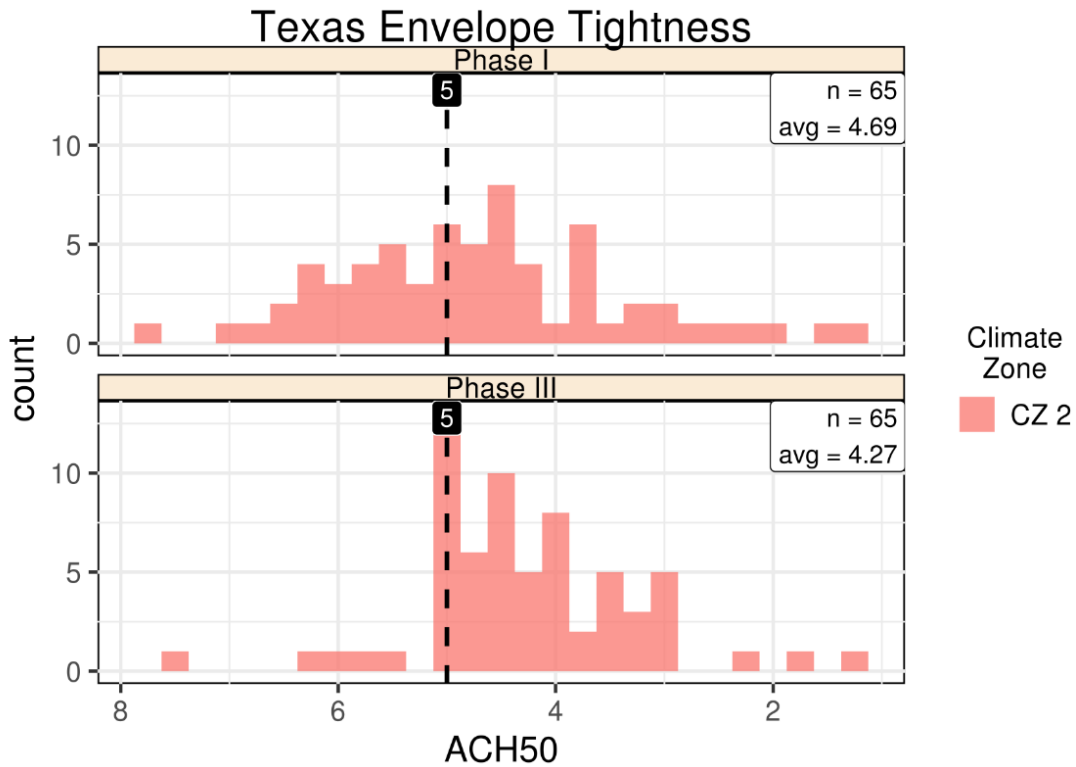


Figure 3.1. Comparison of Phase I and Phase III Envelope Tightness for Texas CZ2A

Table 3.1. Texas CZ2A Envelope Tightness in Phase I and Phase III

| Envelope Tightness (ACH50) | Phase I | Phase III |
|----------------------------|----------------|----------------|
| Requirement | 5.0 | 5.0 |
| Observations | | |
| Number | 65 | 65 |
| Range | 7.9 to 1.2 | 7.6 to 1.3 |
| Average | 4.7 | 4.3 |
| Compliance Rate | 39 of 65 (60%) | 60 of 65 (92%) |

• Interpretations

- In Phase I, reductions in envelope air tightness represented an area for improvement in the state and was a focus of Phase II education and training activities.
- There was significant improvement (from 60% compliance to 92% compliance) after the Phase II activities.

3.1.1.2 Window SHGC

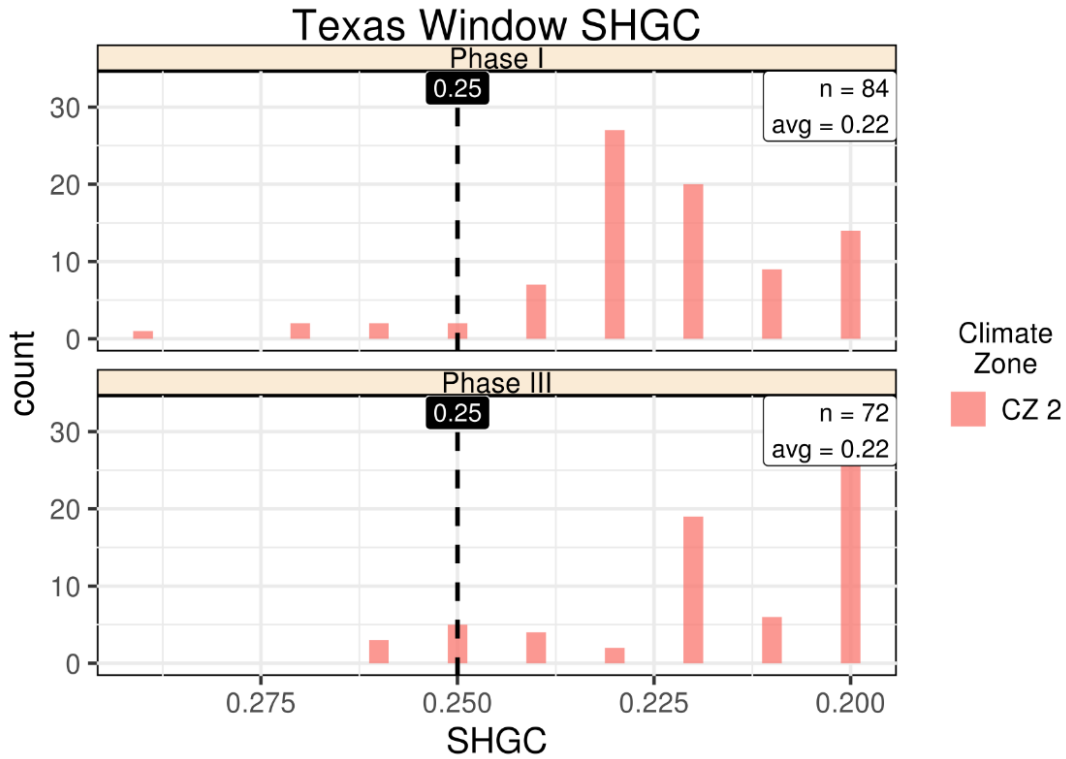


Figure 3.2. Comparison of Phase I and Phase III Window SHGC for Texas CZ2A

Table 3.2. Texas CZ2A Window SHGC in Phase I and Phase III

| Window SHGC | Phase I | Phase III |
|-----------------|----------------|----------------|
| Requirement | 0.25 | 0.25 |
| Observations | | |
| Number | 84 | 72 |
| Range | 0.29 to 0.20 | 0.26 to 0.2 |
| Average | 0.22 | 0.22 |
| Compliance Rate | 79 of 84 (94%) | 69 of 72 (96%) |

- **Interpretations:**

- Compliance was comparable in both Phase I (94%) and Phase III (96%), with a modest improvement in Phase III.

3.1.1.3 Window U-Factor

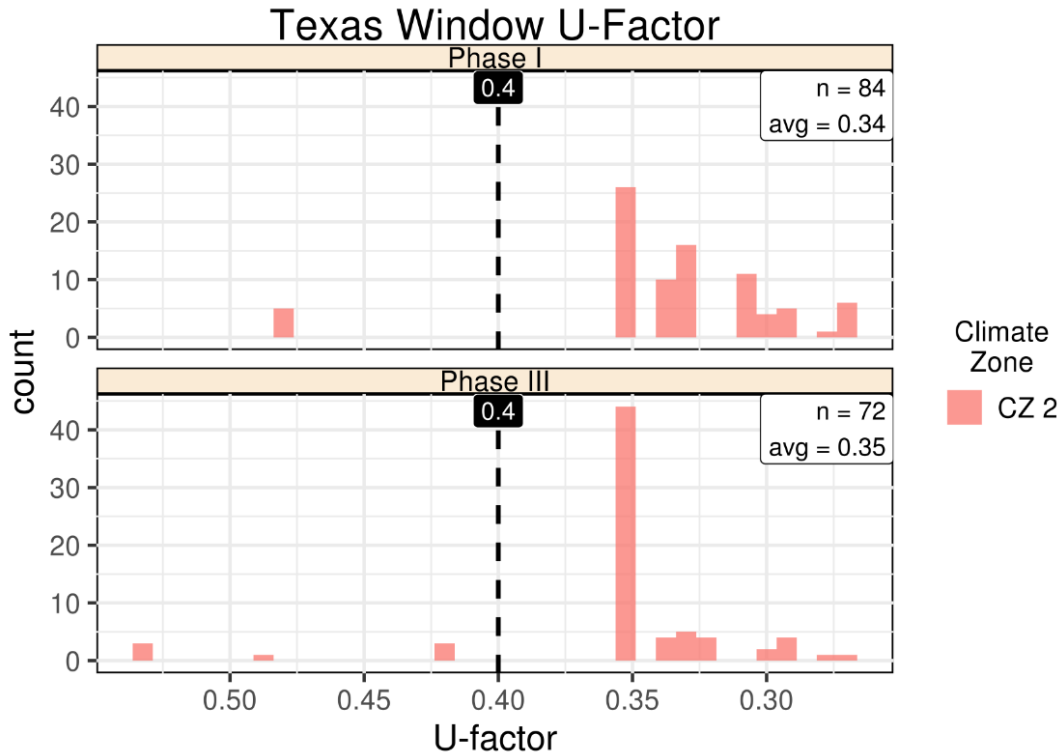


Figure 3.3. Comparison of Phase I and Phase III Window U-Factors for Texas CZ2A

Table 3.3. Texas CZ2A Window U-Factors in Phase I and Phase III

| Window U | Phase I | Phase III |
|---------------------|----------------|----------------|
| Requirement | 0.40 | 0.40 |
| Observations | | |
| Number | 84 | 72 |
| Range | 0.48 to 0.27 | 0.53 to 0.27 |
| Average | 0.34 | 0.35 |
| Compliance Rate | 79 of 84 (94%) | 65 of 72 (90%) |

• **Interpretations:**

- There is a high rate of compliance for fenestration products across both Phase I (94%) and Phase III (90%), with a slight decrease in Phase III.
- This represents one of the most significant findings of the field study, with nearly all of the observations at or above the code requirement.

3.1.1.4 Wall Insulation

The energy performance of a wall insulation system is determined both by the R-value of the insulation installed and the quality of the installation. Given the large number of possible combinations of

compliance options and installation qualities, the results are presented as U-factors which allow all relevant aspects to be considered in one metric.

At the start of the overall project, insulation installation quality (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 RESNET¹ assessment protocol for cavity insulation which has three grades; Grade I being the best quality installation and Grade III being the worst.

Table 3.4 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 was comparable in both Phase I and Phase III, with Grade I installations accounting for about 60%. The number of Grade III installations did decrease from 8% in Phase I to 3% in Phase III.

Table 3.4. Comparison of Phase I and Phase III Above Grade Wall IIQ for Texas CZ2A

| 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 | 38 / 42 | 19 / 27 | 5 / 2 | 62 / 71 |
| Above Grade Percentages | 61% / 59% | 31% / 38% | 8% / 3% | 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 3.4. 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.

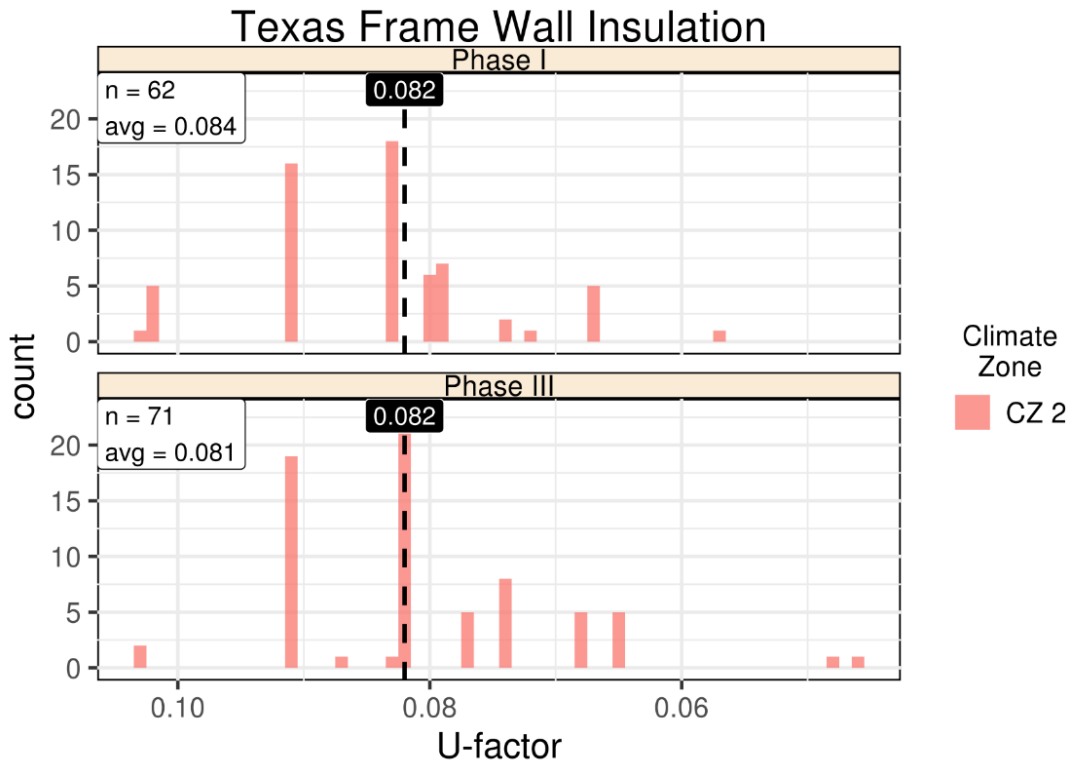


Figure 3.4. Comparison of Phase I and Phase III Wall U-Factors for Texas CZ2A

Table 3.5. Texas CZ2A Wall U-Factors in Phase I and Phase III

| Wall U | Phase I | Phase III |
|---------------------|----------------|----------------|
| Requirement | 0.082 | 0.082 |
| Observations | | |
| Number | 62 | 71 |
| Range | 0.103 to 0.058 | 0.103 to 0.046 |
| Average | 0.084 | 0.081 |
| Compliance Rate | 40 of 62 (65%) | 48 of 71 (68%) |

• **Interpretations:**

- The compliance rate for wall U-factor is consistent across phases.

3.1.1.5 Ceiling Insulation

Figure 3.5 represents the observed R-values for Texas ceilings.

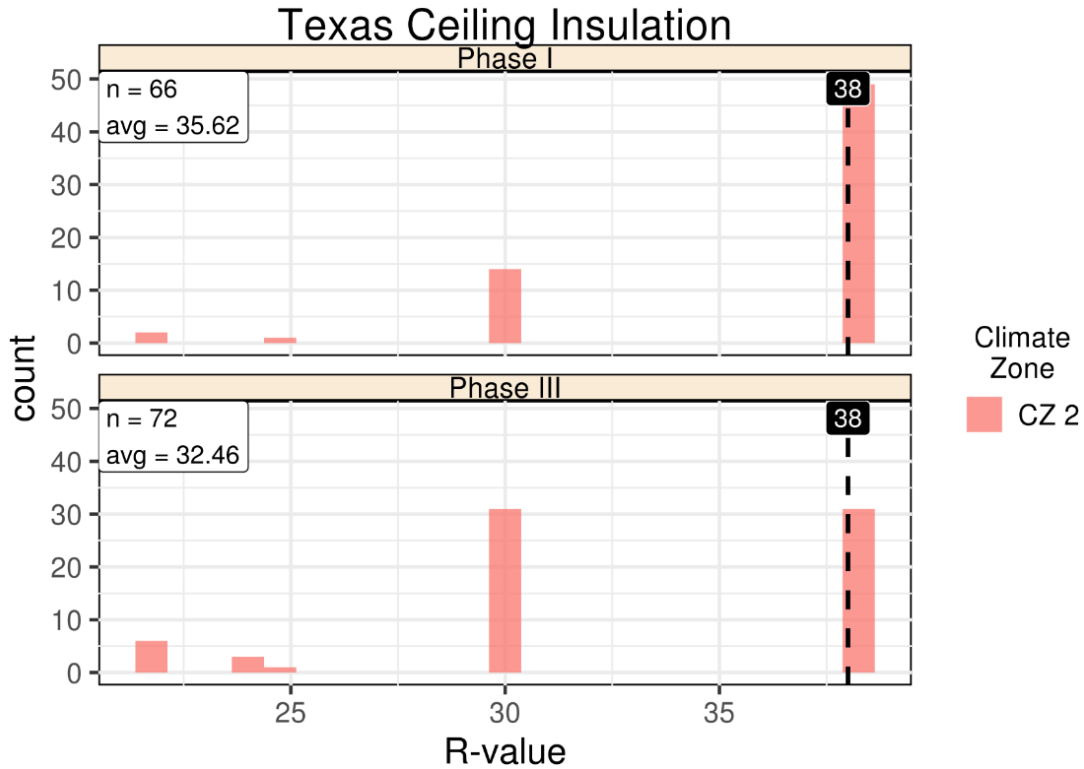


Figure 3.5. Comparison of Phase I and Phase III Ceiling R-Values for Texas CZ2A

Table 3.6. Texas CZ2A Ceiling R-Values in Phase I and Phase III

| Ceiling R | Phase I | Phase III |
|---------------------|----------------|----------------|
| Requirement | R-38 | R-38 |
| Observations | | |
| Number | 66 | 72 |
| Range | R-22 to R-38 | R-22 to R-38 |
| Average | R-35.6 | R-32.5 |
| Compliance Rate | 49 of 66 (74%) | 31 of 72 (43%) |

Table 3.7 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 from Phase I to Phase III, with most Phase III observations being Grade I.

Table 3.7. Comparison of Phase I and Phase III Roof IIQ for Texas CZ2A

| 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 | 36 / 71 | 11 / 1 | 2 / 0 | 49 / 72 |
| Roof Cavity Percentages | 74% / 99% | 22% / 1% | 4% / 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 3.6.

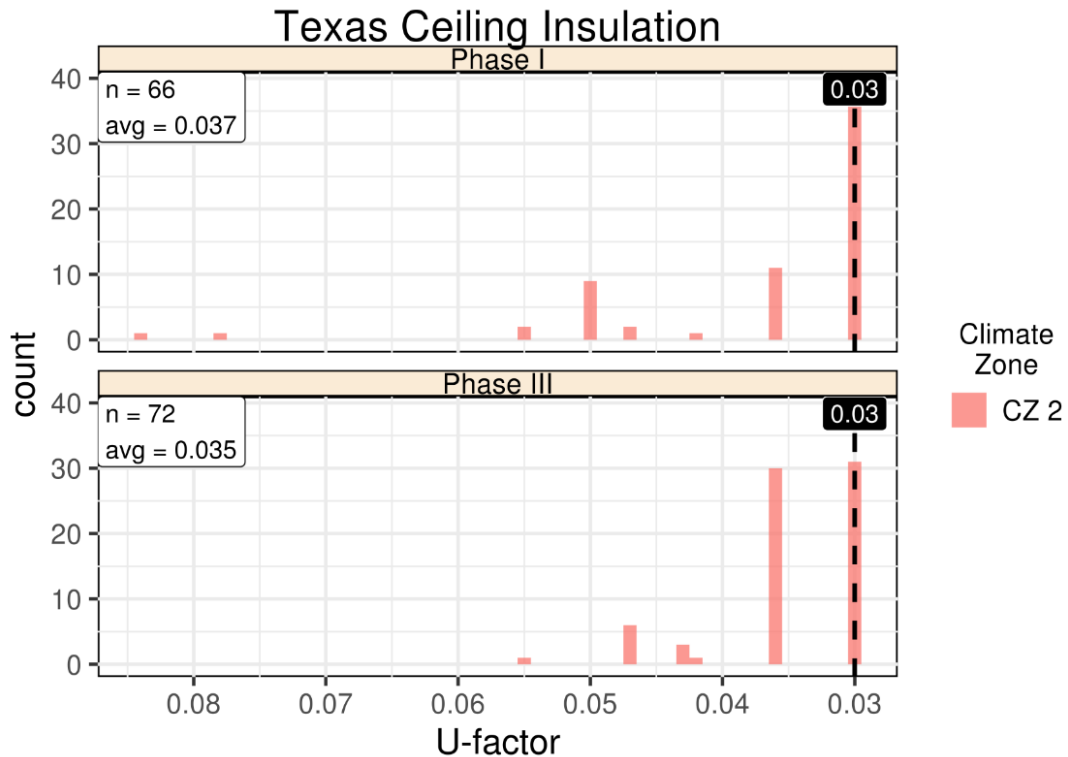


Figure 3.6. Comparison of Phase I and Phase III Ceiling U-Factors for Texas CZ2A

Table 3.8. Texas CZ2A Ceiling U-Factors in Phase I and Phase III

| Ceiling U | Phase I | Phase III |
|---------------------|----------------|----------------|
| Requirement | 0.03 | 0.03 |
| Observations | | |
| Number | 66 | 72 |
| Range | 0.084 to 0.030 | 0.055 to 0.030 |
| Average | 0.037 | 0.035 |
| Compliance Rate | 39 of 66 (59%) | 31 of 72 (43%) |

• **Interpretations:**

- The compliance rate for ceiling U-factor decreased from 59% in Phase I to 43% in Phase III. The driver of this decrease appears to be an increase in the number of R-30 ceiling insulation observations, which may be cathedral ceilings and therefore would comply under the 2015 IECC.

3.1.1.6 Lighting

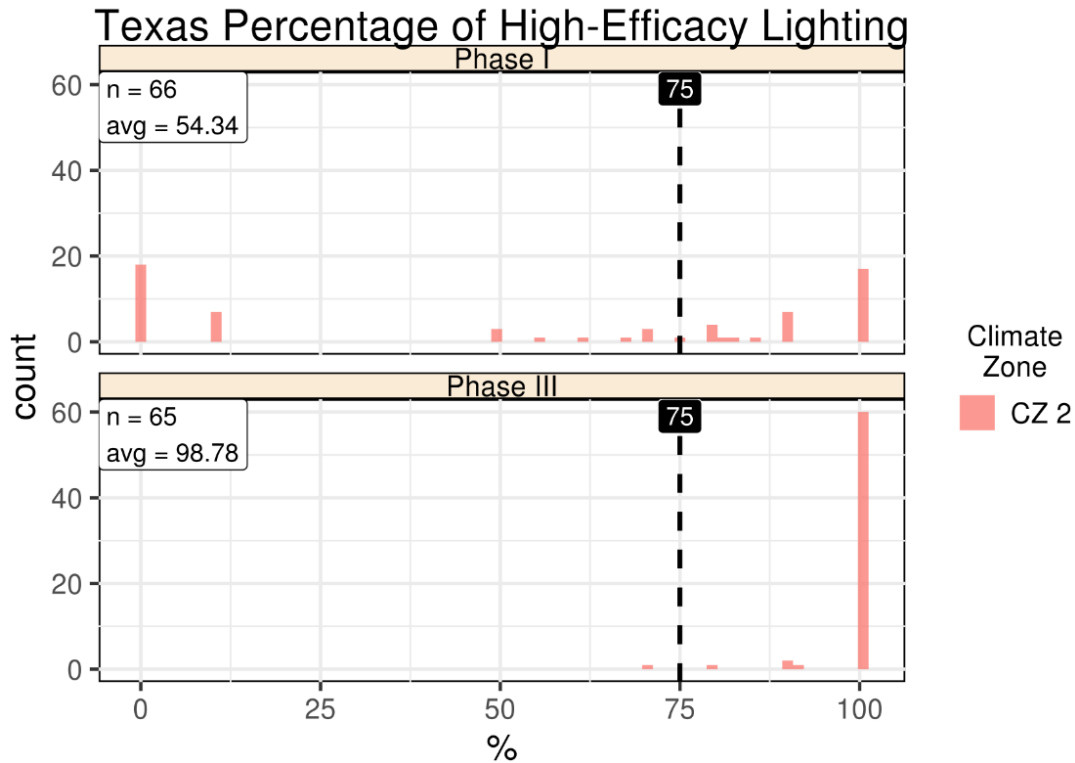


Figure 3.7. Comparison of Phase I and Phase III High-Efficacy Lighting Percentages for Texas CZ2A

Table 3.9. Texas CZ2A High-Efficacy Lighting in Phase I and Phase III

| Lighting | Phase I | Phase III |
|---------------------|----------------|----------------|
| Requirement | 75 | 75 |
| Observations | | |
| Number | 66 | 65 |
| Range | 0 to 100 | 70 to 100 |
| Average | 54.3 | 98.8 |
| Compliance Rate | 32 of 66 (48%) | 64 of 65 (98%) |

• **Interpretations:**

- A little less than half of the field observations were observed to meet the requirement in Phase I; a much lower number than expected. This represented an area of significant savings potential and was a focus of Phase II education and training activities.
- There was a significant improvement in Phase III with nearly all of the observations meeting or exceeding the requirement.

3.1.1.7 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 tightness 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.

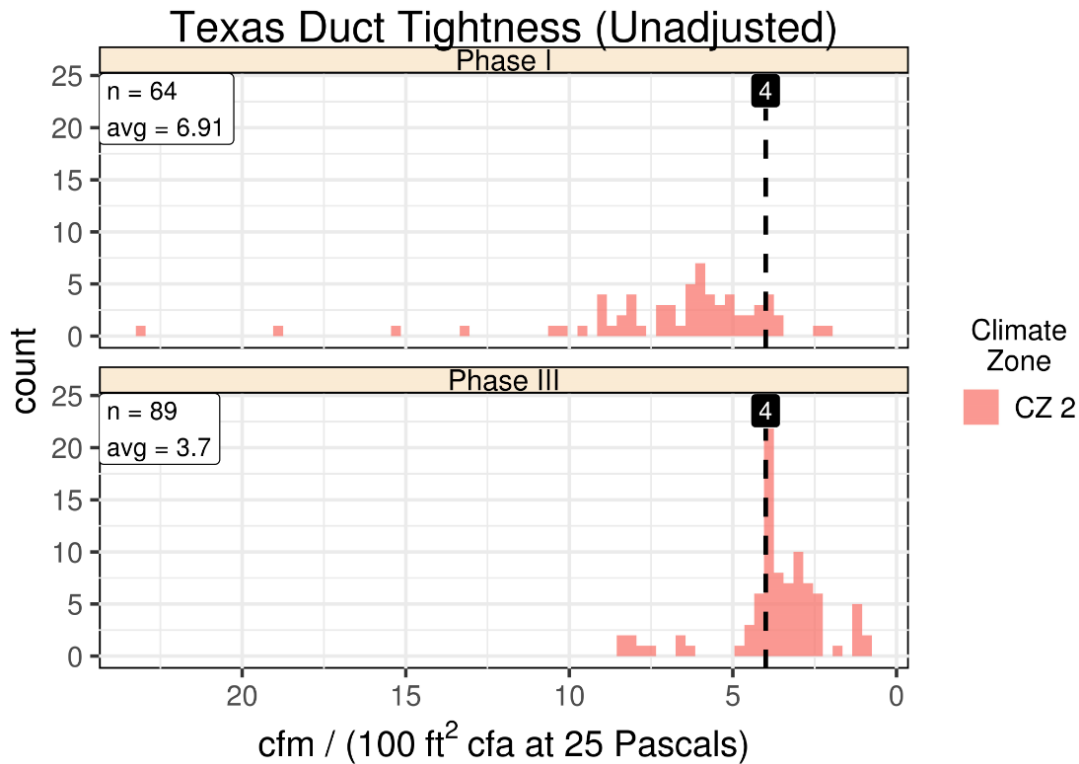


Figure 3.8. Comparison of Phase I and Phase III Duct Tightness Values for Texas CZ2A

Table 3.10. Texas CZ2A Duct Tightness Values in Phase I and Phase III (unadjusted)

| Duct Tightness | Phase I | Phase III |
|---------------------|----------------------------------|----------------------------------|
| Requirement | 4.0 CFM25/100ft ² CFA | 4.0 CFM25/100ft ² CFA |
| Observations | | |
| Number | 64 | 89 |
| Range | 23.0 to 2.0 | 8.4 to 1.0 |
| Average | 6.9 | 3.7 |
| Compliance Rate | 8 of 65 (12%) | 70 of 89 (79%) |

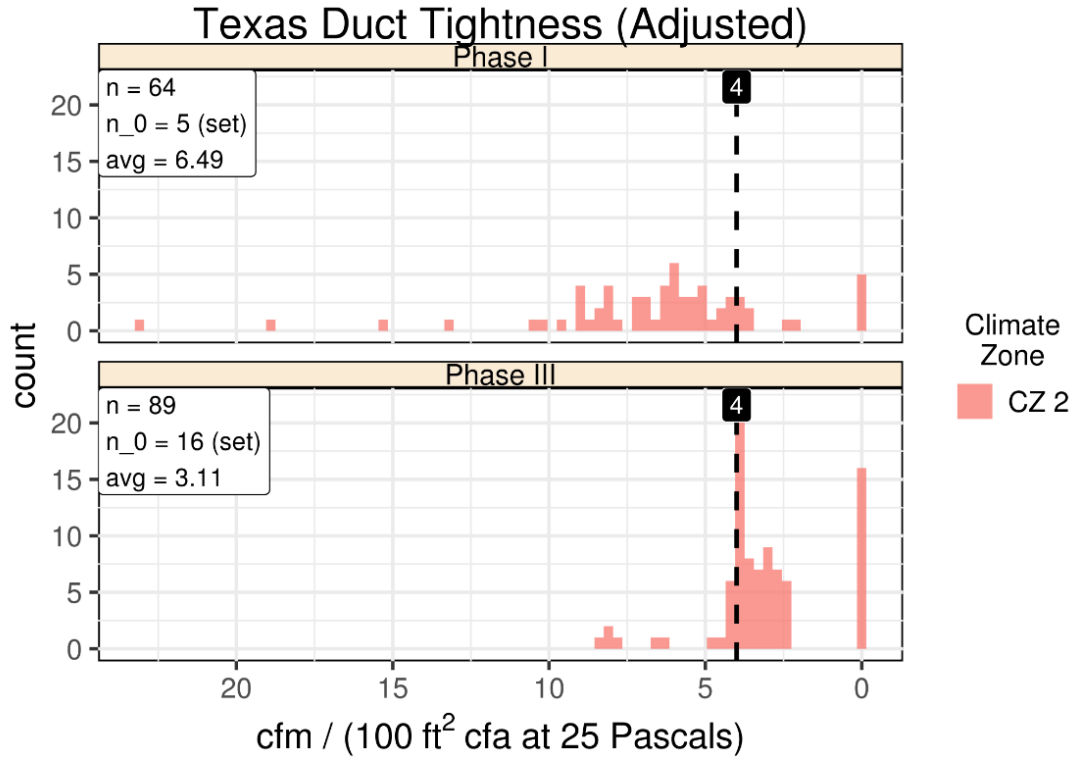


Figure 3.9. Comparison of Phase I and Phase III Adjusted Duct Tightness Values for Texas CZ2A

Table 3.11. Texas CZ2A Duct Tightness Values in Phase I and Phase III (adjusted)

| Duct Tightness Adj | Phase I | Phase III |
|---------------------|----------------------------------|----------------------------------|
| Requirement | 4.0 CFM25/100ft ² CFA | 4.0 CFM25/100ft ² CFA |
| Observations | | |
| Number | 64 | 89 |
| Range | 23.0 to 0.0 | 8.3 to 0.0 |
| Average | 6.5 | 3.1 |
| Compliance Rate | 12 of 64 (19%) | 75 of 89 (84%) |

• **Interpretations:**

- For unadjusted duct tightness, the distribution of Phase I observations exhibited higher leakage than expected compared to the 2015 IECC. There was also a wide range of results. Duct tightness was a focus of Phase II education and training activities, and results improved in Phase III, with the average being less than the code requirement. It is also notable that the number of outliers in the distribution was greatly reduced.
- For adjusted duct tightness, the situation is similar; the distribution in Phase I had an average above code and a large number of outliers. The Phase III distribution has an average below the current code requirement and a higher number of ducts entirely in conditioned space.

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 Texas field study is contained in Appendix C. The full data set is also available on the DOE Building Energy Codes Program website.²

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 3.12. Average Home

| Home Statistics | Phase I | Phase III |
|---|---------|-----------|
| Number of Observations | 133 | 136 |
| Average Square Footage (ft ²) | 2708 | 2680 |
| Number of Stories | 1.82 | 1.77 |

3.1.2.2 Compliance

In Phase I, the majority of homes were permitted under the 2009 IRC (89%) or 2012 IECC (11%). In Phase III, all homes were permitted under the 2015 IECC. Approximately one-quarter of the homes (26%) participated in an above-code program³ in Phase I while none were noted in Phase III.

3.1.2.3 Envelope

Table 3.13. Envelope

| Requirement | Phase I | Phase III |
|-----------------------------|---|---|
| Profile | | |
| Walls | All wood-framed with mix of 4” (97%) and 6” (3%), (n=133) | All wood-framed with mix of 4” (97%) and 6” (3%), (n=136) |
| Foundations | All slab-on-grade (n=133) | All slab-on-grade (n=136) |
| Insulation labeled | 97% (n=77) | 99% (n=70) |
| Lighting fixtures sealed | 98% (n=98) | 100% (n=55) |
| Utility penetrations sealed | 93% (n=101) | 100% (n=71) |
| Dropped ceilings sealed | 26% (n=70) | 93% (n=54) |

² Available at <https://www.energycodes.gov/compliance/energy-code-field-studies>.

³ No specific above-code programs were noted

| Requirement | Phase I | Phase III |
|----------------------------------|------------|------------|
| Knee walls sealed | 67% (n=73) | 96% (n=75) |
| Behind tubs and showers sealed | 70% (n=83) | 91% (n=68) |
| Attic hatches and doors complied | 42% (n=50) | 93% (n=83) |

3.1.2.4 Duct & Piping Systems

Table 3.14. Duct and Piping Systems

| Requirement | Phase I | Phase III |
|---|---------------|----------------|
| Profile | | |
| Supply ducts located within conditioned space (percentage of duct system) | 34% (n=134) | 41% (n=165) |
| Return ducts located within conditioned space (percentage of duct system) | 34% (n=134) | 40% (n=165) |
| Supply ducts entirely within conditioned space (percentage of homes and number) | 5% (7 homes) | 16% (27 homes) |
| Return ducts entirely within conditioned space (percentage of homes and number) | 7% (9 homes) | 16% (27 homes) |
| Duct Insulation ⁴ | R-6.1 (n=273) | R-6.1 (n=282) |
| Pipe Insulation | R-2.7 (n=126) | R-3 (n=97) |
| Building cavities not used as supply ducts | 100% (n=113) | 99% (n=136) |
| Air ducts sealed | 83% (n=111) | 98% (n=136) |
| Air handlers sealed | 90% (n=129) | 97% (n=134) |
| Filter boxes sealed | 90% (n=129) | 98% (n=134) |

Successes

As a percentage of compliant observations, nearly all areas improved in Phase III.

3.1.2.5 HVAC Equipment

Table 3.15. HVAC Equipment

| Requirement | Phase I | Phase III |
|------------------------------|---|--|
| Profile | | |
| Heating equipment type | Mostly gas furnaces (89%), 7% electric furnace, and 5% heat pump (n=122) | Gas furnaces (94%), 4% electric furnace, 2% heat pump (n=165) |
| Heating equipment efficiency | 83 AFUE gas furnace, 81 AFUE electric furnaces, 8.8 SEER heat pump (n=88) | 82 AFUE (n=140) (number reported for gas furnaces only - heat pumps and electric furnaces reported at 100) |

⁴ The number of observations for duct insulation include roughly 273 individual observations in Phase I and 282 in Phase III for both supply and return ducts in attics and in unconditioned space.

| Requirement | Phase I | Phase III |
|------------------------------------|--|---|
| Cooling equipment type | Majority (94%) central AC, 5% heat pump, 1% room AC (n=116) | All central AC (n=115) |
| Cooling equipment efficiency | 15.1 SEER | 14.7 SEER |
| Water heating equipment type | Mostly gas storage (85%), 9% electric storage, and 6% gas tankless (n=114) | Gas storage 67%, gas tankless 20%, electric storage 13%, (n=85) |
| Water heating equipment capacity | 54 gallons (n=102) | 49 gallons (n=64) |
| Water heating equipment efficiency | EF 0.65 (n=65) | EF 0.67 (n=16) |

3.2 Energy Use Intensity

The energy analysis results in Figure 3.10 based on Texas CZ2A show an estimated decrease in EUI between Phase I and III of 1.83 kBtu/ft², which surpasses the 1.25 kBtu/ft² threshold for statistically significant savings. The observed data set (as gathered in the field) was compared against the same set of homes meeting the 2015 IECC prescriptive code requirements. Average energy consumption decreased by approximately 8.1% between Phase I and Phase III. Table 3.16 compares the Phase I and Phase III results.

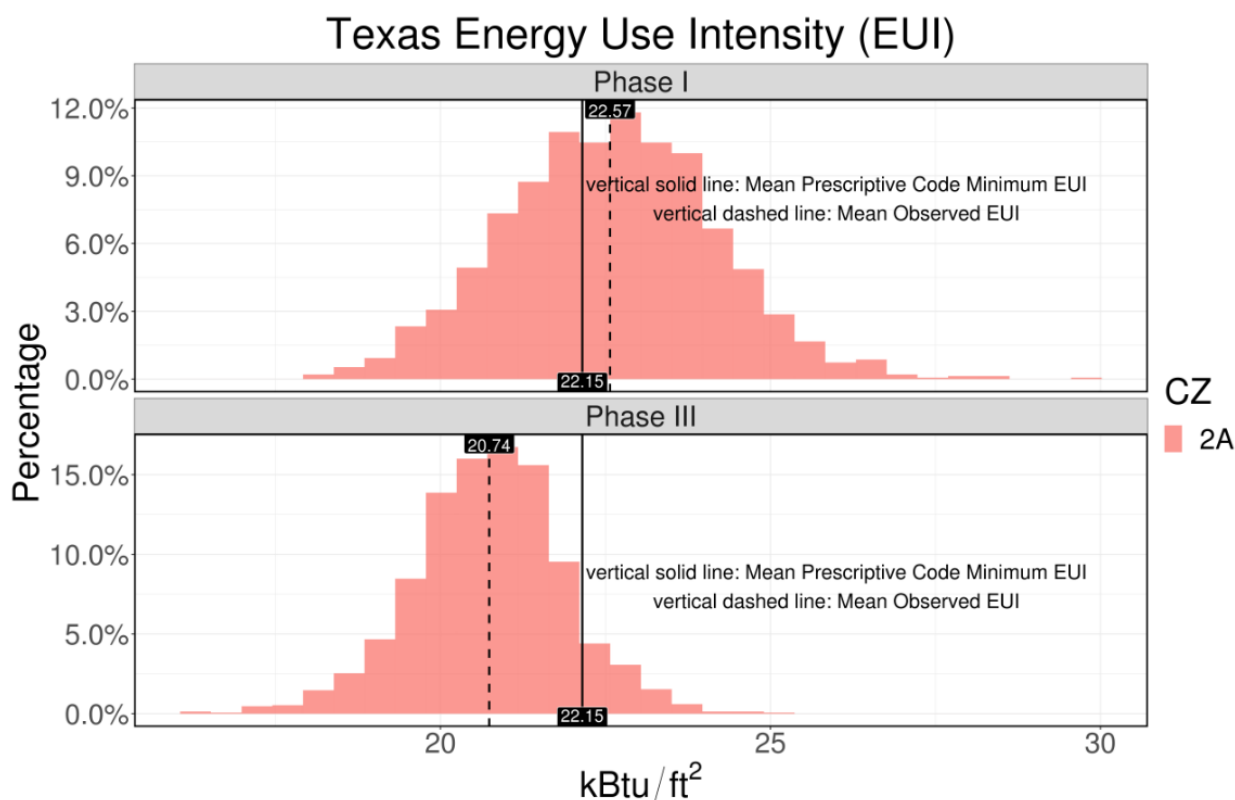


Figure 3.10. Comparison of Phase I and Phase III EUI for Texas CZ2A

Table 3.16. Texas CZ2A EUI in Phase I and Phase III

| Prescriptive EUI⁵ | Phase I | Differential (Phase I vs. Prescriptive) | Phase III | Differential (Phase III vs. Prescriptive) | % Change (Phase III vs. I) |
|-------------------------------------|----------------|--|------------------|--|-----------------------------------|
| 22.15 | 22.57 | +1.9% | 20.74 | -6.4% | -8.1% |

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 potential⁶, shown below followed by the percent that met code, were further analyzed to estimate the associated savings potential for energy, cost and environmental impacts.

Table 3.17. Comparison of Phase I and Phase III Compliance Rates by Measure in Texas CZ2A

| Measure | Phase I Compliance Rate | Phase III Compliance Rate | Phase III to Phase I Difference in Compliance Rate |
|-----------------------------------|--------------------------------|----------------------------------|---|
| Envelope Air Tightness | 60% | 92% | +32% |
| Exterior Wall Insulation | 65% | 68% | +3% |
| Duct Tightness⁷ | 19% | 84% | +65% |
| Lighting | 48% | 98% | +50% |
| Ceiling Insulation | 59% | 43% | -16% |

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 estimates are shown in Table 3.18. The results indicate that the Phase II education and training activities were successful in reducing the overall savings potential for all measures except ceiling insulation. Improvement is measured by a reduction in measure-level savings potential between Phase I and Phase III.

⁵ Calculated based on the minimum prescriptive requirements of the state energy code.

⁶ Defined here as those with less than 85% of observations meeting the prescriptive code requirement

⁷ This compliance rate is for adjusted duct leakage observations.

Table 3.18. Comparison of Phase I and Phase III Estimated Annual Savings Potential Texas CZ2A

| Measure | Potential Total Energy Savings (MMBtu) | | Potential Total Energy Cost Savings (\$) | | Potential Total State Emissions Reduction (MT CO2e) | |
|--------------------------|--|---------------|--|--------------------|---|---------------|
| | Phase I | Phase III | Phase I | Phase III | Phase I | Phase III |
| Envelope Air Tightness | 39,493 | 10,295 | 654,623 | 170,471 | 15,910 | 4,135 |
| Exterior Wall Insulation | 27,090 | 19,009 | 511,748 | 359,086 | 15,239 | 10,692 |
| Duct Tightness | 89,058 | 7,896 | 1,914,867 | 170,171 | 66,132 | 5,891 |
| Lighting | 40,483 | 105 | 1,550,412 | 4,050 | 76,960 | 202 |
| Ceiling Insulation | 10,942 | 27,367 | 216,147 | 540,180 | 6,806 | 16,994 |
| TOTAL | 207,065 | 64,672 | \$4,847,797 | \$1,243,958 | 181,047 | 37,914 |

Overall measure-level energy cost savings potential showed a 74% 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 3.19). 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 how the total savings and emissions reductions accumulate over 5, 10, and 30 years of construction. See Appendix E for measure level savings results extrapolated to Texas Statewide.

Table 3.19. Comparison of Five-years, Ten-years, and Thirty-years Cumulative Annual Savings Potential in Texas CZ2A 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 |
| Envelope Air Tightness | 9,819,345 | 2,557,065 | 36,004,265 | 9,375,905 | 304,399,695 | 79,269,015 |
| Exterior Wall Insulation | 7,676,220 | 5,386,290 | 28,146,140 | 19,749,730 | 237,962,820 | 166,974,990 |
| Duct Tightness | 28,723,005 | 2,552,565 | 105,317,685 | 9,359,405 | 890,413,155 | 79,129,515 |
| Lighting | 23,256,180 | 60,750 | 85,272,660 | 222,750 | 720,941,580 | 1,883,250 |
| Ceiling Insulation | 3,242,205 | 8,102,700 | 11,888,085 | 29,709,900 | 100,508,355 | 251,183,700 |
| TOTAL | 72,716,955 | 18,659,370 | 266,628,835 | 68,417,690 | 2,254,225,605 | 578,440,470 |

4.0 Conclusions

The Texas field study is unique in that data was not collected statewide and the state experienced a code change during the project. Given both the large geographic size and population of Texas, the project team decided to limit data collection to an area comprising 30 counties in south central and southeast Texas anchored on Houston (all CZ2A). It includes dense metropolitan areas, small- to mid-size cities and towns and unincorporated areas of counties and has a population of approximately 7 million, about 25% of the state population and approximately 50% of the new residential permits in the state.

For purposes of the study, stakeholders agreed that this area could be used to represent the entire state as it includes a broad range of the energy codes in use and levels of enforcement seen across the state. At the project team’s request, the analytical results were calculated in two ways: CZ2A results only and results extrapolated statewide from the CZ2A data. For the statewide results, the CZ2A data were used as observed values in all of the climate zones and analytical results were extrapolated statewide. This extrapolation was repeated in Phase III. See Section 2.4.1 for additional details. The results in the main body of this report are presented for the CZ2A data. Statewide results are presented in Appendix E.

At the time of Phase I data collection, the state had the 2009 IECC, but had moved to the 2015 IECC before Phase III. Therefore, the Phase I data was collected from homes permitted under the 2009 code, while the Phase III data was collected from homes permitted under the 2015 code. However, Phase I savings potential was calculated against the 2015 code as that was the code that homes would need to comply with in the future, and so a direct comparison between Phase I and Phase III savings potential can be made.

The Texas field study successfully achieved a measurable decrease in 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 Texas consumes 6.4 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 approximately 8.1 percent between Phase I and III.

Table 4.1. Average Modeled Energy Use Intensity in Texas CZ2A (kBtu/ft²-yr)

| Prescriptive EUI¹ | Phase I | Differential (Phase I vs. Prescriptive) | Phase III | Differential (Phase III vs. Prescriptive) | % Change (Phase III vs. I) |
|---|--------------------|--|----------------------|--|---|
| 22.15 | 22.57 | +1.9% | 20.74 | -6.4% | -8.1% |

This results in over \$3.6 million in annual achieved savings, an improvement of 74% following the Phase II targeted education and training activities (Table 4.2).²

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

² See Table 3.18 for potential total energy cost savings in each phase.

Table 4.2. Estimated Annual Cost Savings Potential in Texas CZ2A

| Measure | % Change |
|--------------------------|------------------------|
| | Phase III vs. I |
| Envelope Air Tightness | -74.0% |
| Exterior Wall Insulation | -29.8% |
| Duct Tightness | -91.1% |
| Lighting | -99.7% |
| Ceiling Insulation | +149.9% |
| TOTAL | -74.3% |

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 education and training programs.

5.0 References

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

DOE Building Energy Codes Program’s residential field study website is available at <https://www.energycodes.gov/residential-energy-code-field-studies>.

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Appendix A

Stakeholder Participation

Appendix A

Stakeholder Participation

A.1 Stakeholder Participation

Table A.1. Stakeholder Participation in Project Kickoff Meeting

| Stakeholder | Description |
|--|--|
| TX State Energy Conservation Office (SECO) | Key state agency responsible for regulating code adoption and compliance in Texas. SECO manages and allocates resources for training and outreach regarding codes. |
| Electric Utility Marketing Managers of Texas (EUMMOT) | The industry group that oversees the development and implementation of energy efficiency programs and incentives for investor owned electric utilities in TX |
| International Code Council local chapters, Brazos Valley Inspectors' Association, Bay Area Inspectors' Association, Bluebonnet Inspectors' Association and Golden Triangle Inspectors' Association | Represent building officials in the TX Field Study area and act as the anchors for the Regional Working Groups. Regional Working Groups hosted trainings, acted as a conduit to code officials and generally provided promotion and support for the project. |
| Greater Houston Home Builders' Association (GHBA) | The organization that represents a large number of the homebuilders who participated in the Field Study |

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* |
|---|-----------|------------|
| Harris County Unincorporated Area, Harris | 13 | 13 |
| Fort Bend County Unincorporated Area, Fort Bend | 5 | 5 |
| Montgomery County Unincorporated Area, Montgomery | 3 | 3 |
| Houston, Harris | 17 | 17 |
| Pearland, Brazoria | 5 | 6 |
| League City, Galveston | 3 | 4.5 |
| College Station, Brazos | 2 | 2 |
| Fulshear, Fort Bend | 1 | 1 |
| Conroe, Montgomery | 2 | 2 |
| Beaumont, Jefferson | 3 | 2 |
| Galveston, Galveston | 1 | 3 |
| Port Arthur, Jefferson | 1 | 1 |
| Texas City, Galveston | 1 | 1.5 |
| Baytown, Harris | 1 | 1 |
| Katy, Harris | 1 | 1 |
| Alvin, Brazoria | 1 | 1 |
| Dickinson, Galveston | 1 | 0 |
| Lumberton, Hardin | 1 | 2 |
| Pasadena, Harris | 1 | 0 |
| Total | 63 | 66 |

*Counts marked in bold indicate a substitution was made in Phase I.

Table B.2. Phase III State Sampling Plan

| Location | Sample | Actual |
|--|--------|--------|
| Houston, Harris County | 16 | 16 |
| Harris County Unincorporated Area, Harris County | 9 | 9 |
| Fort Bend County Unincorporated Area, Fort Bend County | 8 | 8 |
| Montgomery County Unincorporated Area, Montgomery County | 4 | 4 |
| Pearland, Brazoria County | 2 | 2 |
| League City, Galveston County | 2 | 2 |
| College Station, Brazos County | 5 | 5 |

| Location | Sample | Actual |
|---------------------------------|---------------|---------------|
| Fulshear, Fort Bend County | 3 | 2 |
| Conroe, Montgomery County | 2 | 2 |
| Missouri City, Fort Bend County | 2 | 2 |
| Rosenberg, Fort Bend County | 3 | 3 |
| Texas City, Galveston County | 1 | 1 |
| Beaumont, Jefferson County | 1 | 1 |
| Baytown, Harris County | 1 | 1 |
| Galveston, Galveston County | 1 | 0 |
| Friendswood, Galveston County | 1 | 1 |
| Bellaire, Harris County | 1 | 1 |
| La Porte, Harris County | 1 | 1 |
| Huntsville, Walker County | 0 | 1 |
| Brookshire, Waller County | 0 | 1 |
| Total | 63 | 63 |

B.2 Substitutions

In Phase I, several locations targeted by the original sampling plan (as illustrated in Table B.1 above) could not be met due to a lack of either available homes or builder cooperation. For each of these locations, alternatives (listed below) were determined to have the same socioeconomic and demographic characteristics. The project team, following DOE guidelines on substitutions, consolidated the alternatives and considered them as one location for sampling purposes. The numbers in parentheses repeat the data in the “Sample” and “Actual” column in Table B.1¹ to illustrate what was originally targeted compared to what was successfully collected:

- Beaumont (3/2), Lumberton (1/2)
- Pasadena (1/0), Pearland (5/6)
- Galveston (1/3), League City (3/4.5), Texas City (1/1.5).

In Phase III, DOE had revised its methodology to no longer accept “partial” replacements (as collected in various Texas cities in Phase I). The project team had issues with sampling in several locations. Specifically, problems were experienced in Galveston and Fulshear and substitutions were made.

The data collection team was unable to obtain one of the three final site visits in Fulshear due to a lack of available homes at the final stage of construction. The team heavily researched building practices in Fulshear and found that most new construction in that area was occurring in Brookshire, a town roughly five miles north of Fulshear. SPEER confirmed that increased building in Brookshire was due to the expansion of Fulshear and that the same builders were building in the two cities, using the same subcontractors, materials, and technologies. The team also confirmed with SPEER that Brookshire is similar to Fulshear in size, growth, and socioeconomic measures, and would serve as the best substitute for Fulshear. As such, the team obtained one of the three required full data sets in Fulshear from Brookshire (insulation and final) and completed the other two full data sets from Fulshear, as sampled.

¹ A partial sample (e.g., 1.5) indicates that not all of the key items were collected.

The data collection team found that construction practices in Galveston include a stilt-style home that is not prevalent in other areas of the state. Since the purpose of the study is to gather data representative of construction throughout the state, the team sought a substitute for Galveston. The team gathered one complete data set from Huntsville.

B.3 Oversampling

The data collection team oversampled in five jurisdictions; this is due to the use of substitutions and having two teams in the field at one time. The following cities or counties were oversampled:

- Conroe
- Fulshear
- Pearland
- Montgomery County
- Rosenberg.

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 Texas 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 |
|---|---------|-----------|
| Number of Observations | 133 | 136 |
| Average Square Footage (ft ²) | 2708 | 2680 |
| Number of Stories | 1.8 | 1.8 |

Table C.2. Conditioned Floor Area (ft²)

| Conditioned Floor Area (ft ²) | < 1000 | 1000 to 1999 | 2000 to 2999 | 3000 to 3999 | 4000+ |
|---|--------|--------------|--------------|--------------|-------|
| Percentage (Phase I) | 1% | 21% | 49% | 22% | 7% |
| Percentage (Phase III) | 2% | 23% | 45% | 20% | 10% |

Table C.3. Number of Stories

| No. of Stories | 1 | 2 | 3 | 4+ |
|------------------------|-----|-----|-----|----|
| Percentage (Phase I) | 39% | 39% | 22% | 0% |
| Percentage (Phase III) | 38% | 50% | 10% | 2% |

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 | | | 125 | 136 |
| Frame Walls | 99% | 100% | | |
| Mass Walls | 1% | 0% | | |
| Framing Material | | | 132 | 72 |
| Wood | 100% | 100% | | |
| Steel | 0% | 0% | | |
| Framing Depth | | | 133 | 72 |
| 4 inch | 97% | 97% | | |
| 6 inch | 3% | 3% | | |
| Type of Wall Insulation | | | 62 | 71 |
| Cavity Only | 81% | 77% | | |
| Cavity + Continuous | 19% | 23% | | |
| Continuous Only | 0% | 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 | | | 133 | 136 |
| Slab on Grade | 100% | 100% | | |

C.1.1.4 Builder Profile

Table C.6. Builder Characteristics

| Builder Characteristic | Phase I Observations | Phase III Observations | Number of Phase I Observations | Number of Phase III Observations |
|---|----------------------|------------------------|--------------------------------|----------------------------------|
| Number of Homes Built Annually | 61 | NA* | 36 | NA* |
| Distribution of Number of Homes Built Annually | | | 36 | NA* |
| Less than 10 | 3% | NA* | | |
| 10 to 50 | 28% | NA* | | |
| 50 to 99 | 61% | NA* | | |
| 100+ | 8% | NA* | | |

*Data not collected

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.7. 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 | | | 38 | 136 |
| 2009 IECC | 89% | 0% | | |
| 2012 IECC | 11% | 0% | | |
| 2015 IECC | 0% | 100% | | |
| Was home participating in an above code program? | | | 35* | 83* |
| Yes | 26% | 0% | | |
| No | 74% | 100% | | |

*No specific above-code programs were reported

C.1.3 Envelope

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

Table C.8. 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? | | | 75 | 70 |
| Yes | 97% | 99% | | |
| No | 3% | 1% | | |
| Did the attic hatch/door exhibit the correct insulation value?¹ | | | 50 | 64 |
| Yes | 42% | 2% | | |
| No | 58% | 98% | | |
| Air Sealing in accordance with checklist² | | | | |
| Thermal Envelope sealed? | 74% | 59% | 82 | 71 |
| Fenestration Sealed? | 96% | 100% | 53 | 23 |

¹ The project team noted that the question was phrased slightly differently in Phase III, and the data collection team had a different interpretation of what constituted “correct.”

² 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.

| Thermal Envelope Characteristic | Phase I Observations | Phase III Observations | Number of Phase I Observations | Number of Phase III Observations |
|---|-----------------------------|-------------------------------|---------------------------------------|---|
| Openings around doors and windows sealed? | 96% | 96% | 83 | 71 |
| Utility penetrations sealed? | 93% | 100% | 101 | 71 |
| Dropped ceilings sealed? | 74% | 93% | 70 | 54 |
| Knee walls sealed? | 67% | 96% | 73 | 75 |
| Garage walls sealed? | 92% | 65% | 51 | 40 |
| Tubs and showers sealed? | 92% | 91% | 83 | 68 |
| Attic access openings sealed? | 82% | 93% | 55 | 83 |
| Rim joists sealed? | 87% | 94% | 70 | 51 |
| Other sources of infiltration sealed? | 71% | 84% | 89 | 70 |
| IC-rated light fixtures sealed? | 98% | 100% | 98 | 55 |

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.9. 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 | 34% | 41% | 134 | 165 |
| Return | 34% | 40% | 134 | 165 |
| Ducts entirely in conditioned space (number and percentage) | | | | |
| Supply | 7 (5%) | 27 (16%) | 134 | 165 |
| Return | 9 (7%) | 27 (16%) | 134 | 165 |
| Ducts in unconditioned space insulation (R-value) | | | | |
| Supply | 6 | 6 | 12 | 23 |
| Return | 6 | 6 | 11 | 23 |
| Ducts in attic insulation (R-value) | | | | |
| Supply | 6.1 | 6.2 | 128 | 118 |
| Return | 6.1 | 6.2 | 128 | 118 |
| Pipe insulation (R-value) | | | | |
| Average | R-2.7 | R-3 | 126 | 97 |
| Range | R-2 to R-3 | R-3 to R-3 | 126 | 97 |
| Building cavities used as supply ducts | 0% | 1% | 113 | 136 |
| Air ducts sealed | 83% | 98% | 111 | 136 |
| Air handlers sealed | 90% | 97% | 129 | 134 |
| Filter boxes sealed | 90% | 98% | 129 | 134 |

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.10. Heating Equipment Characteristics

| Item | Phase I Observations | Phase III Observations | Number of Phase I Observations | Number of Phase III Observations |
|----------------------------------|----------------------|------------------------|--------------------------------|----------------------------------|
| Fuel Source | | | 124 | 125 |
| Gas | 89% | 93% | | |
| Electricity | 11% | 7% | | |
| System Type | | | 122 | 165 |
| Furnace | 95% | 98% | | |
| Heat Pump | 5% | 2% | | |
| Average System Capacity | | | 77 | 137 |
| Furnace | 83,000 Btu/hr | 73,100 Btu/hr | | |
| Heat Pump | 54,000 Btu/hr | 22,750 Btu/hr | | |
| Average System Efficiency | | | 122 | 140 |
| Furnace | 83 AFUE | 82 AFUE | | |
| Heat Pump | 8.8 HSPF | NA* | | |

*Heat pumps and electric furnaces listed as "100"

C.1.5.2 Cooling

Table C.11. Cooling Equipment Characteristics

| Item | Phase I Observations | Phase III Observations | Number of Phase I Observations | Number of Phase III Observations |
|----------------------------------|----------------------|------------------------|--------------------------------|----------------------------------|
| System Type | | | 116 | 115 |
| Central AC | 94% | 100% | | |
| Heat Pump | 5% | 0% | | |
| Room AC | 1% | 0% | | |
| Average System Capacity | | | 73 | 86 |
| Central AC | 52,800 Btu/hr | 39,600 Btu/hr | | |
| Heat Pump | 50,000 Btu/hr | NA | | |
| Room AC | 60,000 Btu/hr | | | |
| Average System Efficiency | | | 70 | 88 |
| Central AC | 15 SEER | 14.7 SEER | | |
| Heat Pump | 16 SEER | NA | | |
| Room AC | 14 SEER | NA | | |

C.1.5.3 Water Heating

Table C.12. Water Heating Equipment Characteristics

| Item | Phase I Observations | Phase III Observations | Number of Phase I Observations | Number of Phase III Observations |
|----------------------------------|----------------------|------------------------|--------------------------------|----------------------------------|
| Fuel Source | | | 115 | 102 |
| Gas | 94% | 88% | | |
| Electricity | 6% | 12% | | |
| System Type | | | 114 | 85 |
| Storage | 91% | 80% | | |
| Tankless | 9% | 20% | | |
| Average System Capacity | 54 gal | 49 gal | 102 | 64 |
| Average System Efficiency | | | 69 | 16 |
| Electric Storage (non-heat pump) | EF 0.86 | EF 0.92 | | |
| Gas Storage | EF 0.63 | EF 0.63 | | |
| Gas Tankless | EF 0.69 | NA | | |

Table C.13. 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 | 26% | 53% | 0% | 0% | 18% | 3% |
| Phase III Percentage | 97% | 0% | 0% | 0% | 1.5% | 1.5% ¹ |

C.1.5.4 Ventilation

Table C.14. Ventilation Characteristics

| Item | Phase I Observations | Phase III Observations | Number of Phase I Observations | Number of Phase III Observations |
|-------------------------|----------------------|------------------------|--------------------------------|----------------------------------|
| System Type | | | 101 | 118 |
| Exhaust Only | 84% | 27% | | |
| AHU-Integrated | 16% | 73% ² | | |
| Exhaust Fan Type | | | 85 | 32 |
| Dedicated Exhaust | 0% | 3% | | |
| Bathroom Fan | 100% | 97% | | |

¹ The project team speculated that the shift in capacity size from Phase I to Phase III may be due to a change in standards.

² The project team noted that going from the 2009 IECC to the 2015 in CZ2 triggers ventilation which was previously not required and is likely the reason for the shift between Phase I and Phase III. Additionally, the 16% in Phase I was likely from a jurisdiction on the 2012 IECC, which was the first to require ventilation in CZ2.

Appendix D
Energy Savings

Appendix D

Energy Savings

D.1 Measure-Level Savings

This appendix contains detailed measure-level annual savings results based on CZ2A for both Phase I (Table D.1 and Phase III (Table D.2) for Texas. 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). See Appendix E for results based on a statewide extrapolation of CZ2A results.

Table D.1. Phase I Annual Measure-Level Savings Potential for Texas CZ2A

| Measure | 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 CO ₂ e) |
|--------------------------|--------------------------------|-----------------------------------|---------------------------|-----------------|------------------------------|--------------------------------|--|
| Envelope Air Tightness | 54 | 5 | 719 | 54,937 | 39,493 | 654,623 | 15,910 |
| Exterior Wall Insulation | 52 | 3 | 493 | 54,937 | 27,090 | 511,748 | 15,239 |
| Duct Tightness | 226 | 9 | 1,621 | 54,937 | 89,058 | 1,914,867 | 66,132 |
| Lighting* | 264 | -2 | 737 | 54,937 | 40,483 | 1,550,412 | 76,960 |
| Ceiling Insulation | 23 | 1 | 199 | 54,937 | 10,942 | 216,147 | 6,806 |
| TOTAL | 619 | 17 | 3769 | 54,937 | 207,065 | 4,847,797 | 181,047 |

* Negative values mean that savings or reductions decrease if the measure is brought up to code. For example, for lighting, increasing the amount of high-efficacy lighting reduces electrical usage, but increases natural gas usage for heating, as the heat from less efficient bulbs must be replaced.

Table D.2. Phase III Annual Measure-Level Savings Potential for Texas CZ2A

| Measure | 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) |
|---------------------------------|---------------------------------------|--|----------------------------------|------------------------|-------------------------------------|---------------------------------------|--|
| Envelope Air Tightness | 14 | 1 | 187 | 54,937 | 10,295 | 170,471 | 4,135 |
| Exterior Wall Insulation | 36 | 2 | 346 | 54,937 | 19,009 | 359,086 | 10,692 |
| Duct Tightness | 20 | 1 | 144 | 54,937 | 7,896 | 170,171 | 5,891 |
| Lighting* | 1 | 0 | 2 | 54,937 | 105 | 4,050 | 202 |
| Ceiling Insulation | 58 | 3 | 498 | 54,937 | 27,367 | 540,180 | 16,994 |
| TOTAL | 129 | 7 | 1,178 | 54,937 | 64,673 | 1,243,958 | 37,913 |

* Negative values mean that savings or reductions decrease if the measure is brought up to code. For example, for lighting, increasing the amount of high-efficiency lighting reduces electrical usage, but increases natural gas usage for heating, as the heat from less efficient bulbs must be replaced.

Table D.3. Phase I Five-years, Ten-years, and Thirty-years Cumulative Annual Savings Potential for Texas CZ2A

| Measure | Total Energy Savings (MMBtu) | | | Total Energy Cost Savings (\$) | | | Total State Emissions Reduction (MT CO2e) | | |
|---------------------------------|-------------------------------------|-------------------|-------------------|---------------------------------------|--------------------|----------------------|--|------------------|-------------------|
| | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr |
| Envelope Air Tightness | 592,395 | 2,172,115 | 18,364,245 | 9,819,345 | 36,004,265 | 304,399,695 | 238,650 | 875,050 | 7,398,150 |
| Exterior Wall Insulation | 406,350 | 1,489,950 | 12,596,850 | 7,676,220 | 28,146,140 | 237,962,820 | 228,585 | 838,145 | 7,086,135 |
| Duct Tightness | 1,335,870 | 4,898,190 | 41,411,970 | 28,723,005 | 105,317,685 | 890,413,155 | 991,980 | 3,637,260 | 30,751,380 |
| Lighting | 607,245 | 2,226,565 | 18,824,595 | 23,256,180 | 85,272,660 | 720,941,580 | 1,154,400 | 4,232,800 | 35,786,400 |
| Ceiling Insulation | 164,130 | 601,810 | 5,088,030 | 3,242,205 | 11,888,085 | 100,508,355 | 102,090 | 374,330 | 3,164,790 |
| TOTAL | 3,105,975 | 11,388,575 | 96,285,225 | 72,716,955 | 266,628,835 | 2,254,225,605 | 2,715,705 | 9,957,585 | 84,186,855 |

Table D.4. Phase III Five-years, Ten-years, and Thirty-years Cumulative Annual Savings Potential for Texas CZ2A

| Measure | Total Energy Savings (MMBtu) | | | Total Energy Cost Savings (\$) | | | Total State Emissions Reduction (MT CO2e) | | |
|--------------------------|------------------------------|------------------|-------------------|--------------------------------|-------------------|--------------------|---|------------------|-------------------|
| | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr |
| Envelope Air Tightness | 154,425 | 566,225 | 4,787,175 | 2,557,065 | 9,375,905 | 79,269,015 | 62,025 | 227,425 | 1,922,775 |
| Exterior Wall Insulation | 285,135 | 1,045,495 | 8,839,185 | 5,386,290 | 19,749,730 | 166,974,990 | 160,380 | 588,060 | 4,971,780 |
| Duct Tightness | 118,440 | 434,280 | 3,671,640 | 2,552,565 | 9,359,405 | 79,129,515 | 88,365 | 324,005 | 2,739,315 |
| Lighting | 1,575 | 5,775 | 48,825 | 60,750 | 222,750 | 1,883,250 | 3,030 | 11,110 | 93,930 |
| Ceiling Insulation | 410,505 | 1,505,185 | 12,725,655 | 8,102,700 | 29,709,900 | 251,183,700 | 254,910 | 934,670 | 7,902,210 |
| TOTAL | 970,095 | 3,557,015 | 30,072,945 | 18,659,370 | 68,417,690 | 578,440,470 | 568,695 | 2,085,215 | 17,629,545 |

Table D.5. Difference between Five-years, Ten-years, and Thirty-years Cumulative Annual Texas CZ2A Savings Potential Phase III vs. Phase I

| Measure | Total Energy Savings (MMBtu) | | | Total Energy Cost Savings (\$) | | | Total State Emissions Reduction (MT CO2e) | | |
|--------------------------|------------------------------|------------------|-------------------|--------------------------------|--------------------|----------------------|---|------------------|-------------------|
| | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr |
| Envelope Air Tightness | 437,970 | 1,605,890 | 13,577,070 | 7,262,280 | 26,628,360 | 225,130,680 | 176,625 | 647,625 | 5,475,375 |
| Exterior Wall Insulation | 121,215 | 444,455 | 3,757,665 | 2,289,930 | 8,396,410 | 70,987,830 | 68,205 | 250,085 | 2,114,355 |
| Duct Tightness | 1,217,430 | 4,463,910 | 37,740,330 | 26,170,440 | 95,958,280 | 811,283,640 | 903,615 | 3,313,255 | 28,012,065 |
| Lighting | 605,670 | 2,220,790 | 18,775,770 | 23,195,430 | 85,049,910 | 719,058,330 | 1,151,370 | 4,221,690 | 35,692,470 |
| Ceiling Insulation | -246,375 | -903,375 | -7,637,62 | -4,860,495 | -17,821,815 | -150,675,345 | -152,820 | -560,340 | -4,737,420 |
| TOTAL | 2,135,880 | 7,831,560 | 66,212,280 | 54,057,585 | 198,211,145 | 1,675,785,135 | 2,147,010 | 7,872,370 | 66,557,310 |

Appendix E
Statewide Results

Appendix E

Statewide Results

As noted previously, the results shown in the main body of the report are based only on CZ2A. The project team and the stakeholders were also interested in results assuming construction trends would remain similar across climate zones. This appendix includes the extrapolated statewide EUI and measure savings results.

E.1 Statewide Energy Use Intensity

The energy analysis results in Figure E.1 based on extrapolated statewide results show an estimated decrease in EUI between Phase I and II of 2.07 kBtu/ft², which surpasses the 1.25 kBtu/ft² 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 9% between Phase I and Phase III. Table E.1 compares the Phase I and Phase III results.

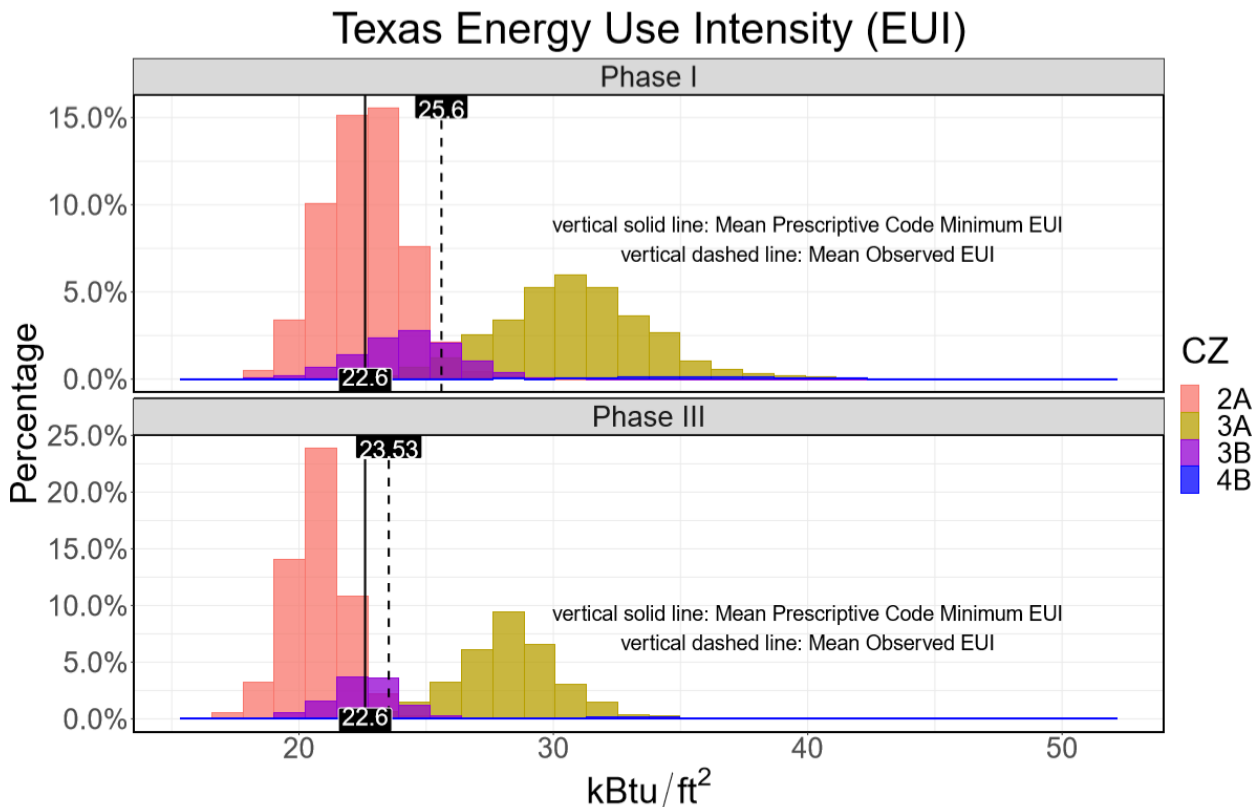


Figure E.1. Comparison of Phase I and Phase III Statewide EUI for Texas Statewide

Table E.1. Texas 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) |
|-------------------------------|---------|---|-----------|---|----------------------------|
| 22.6 | 25.6 | -13.3% | 23.53 | -4.1% | 9.2% |

E.2 Statewide Savings Potential

Table E.2. Comparison of Phase I and Phase III Estimated Annual Savings Potential Texas Statewide

| Measure | Potential Total Energy Savings (MMBtu) | | Potential Total Energy Cost Savings (\$) | | Potential Total State Emissions Reduction (MT CO ₂ e) | |
|--------------------------|--|----------------|--|------------------|--|----------------|
| | Phase I | Phase III | Phase I | Phase III | Phase I | Phase III |
| Envelope Air Tightness | 314,889 | 217,253 | 4,656,869 | 3,179,965 | 88,045 | 58,441 |
| Exterior Wall Insulation | 293,040 | 258,485 | 5,029,864 | 4,426,562 | 129,948 | 113,892 |
| Duct Tightness | 181,188 | 15,958 | 3,582,893 | 316,613 | 112,965 | 10,021 |
| Lighting | 70,571 | 183 | 2,774,421 | 7,249 | 139,105 | 364 |
| Ceiling Insulation | 23,677 | 58,222 | 443,058 | 1,090,432 | 13,027 | 32,095 |
| TOTAL | 883,365 | 550,101 | 16,487,105 | 9,020,821 | 483,090 | 214,811 |

Detailed measure-level annual savings results based on statewide extrapolation are provided for both Phase I (Table E.4) and Phase III (Table E.5) for Texas. Also included are multi-year (5-year, 10-year, and 30-year) aggregations of the annual results in Table E.6, Table E.7, and Table E.8. 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). See Appendix D for results based on CZ2A results.

Table E.3. Estimated Annual Statewide Savings Potential Texas Statewide

| Measure | Total Energy Cost Savings Potential (\$) | | \$ Change | % Change |
|--------------------------|--|--------------------|--------------------|-----------------|
| | Phase I | Phase III | Phase III vs. I | Phase III vs. I |
| Envelope Air Tightness | 4,656,869 | 3,179,965 | 1,476,904 | 31.7% |
| Exterior Wall Insulation | 5,029,864 | 4,426,562 | 603,302 | 12.0 |
| Duct Tightness | 3,582,893 | 316,613 | 3,266,280 | 91.1 |
| Lighting | 2,774,421 | 7,249 | 2,767,172 | 99.7 |
| Ceiling Insulation | 443,058 | 1,090,432 | -647,374 | -146.1% |
| TOTAL | \$16,487,105 | \$9,020,821 | \$7,466,284 | 45.2% |

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

Table E.4. Phase I Statewide Annual Measure-Level Savings Potential for Texas Statewide

| Measure | 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 CO ₂ e) |
|--------------------------|--------------------------------|-----------------------------------|---------------------------|-----------------|------------------------------|--------------------------------|--|
| Envelope Air Tightness | 162 | 26 | 3,130 | 100,608 | 314,889 | 4,656,869 | 88,045 |
| Exterior Wall Insulation | 241 | 21 | 2,913 | 100,608 | 293,040 | 5,029,864 | 129,948 |
| Duct Tightness | 210 | 11 | 1,801 | 100,608 | 181,188 | 3,582,893 | 112,965 |
| Lighting* | 261 | -2 | 701 | 100,608 | 70,571 | 2,774,421 | 139,105 |
| Ceiling Insulation | 24 | 2 | 235 | 100,608 | 23,677 | 443,058 | 13,027 |
| TOTAL | 898 | 58 | 8,780 | 100,608 | 883,365 | 16,487,105 | 483,090 |

* Negative values mean that savings or reductions decrease if the measure is brought up to code. For example, for lighting, increasing the amount of high-efficacy lighting reduces electrical usage, but increases natural gas usage for heating, as the heat from less efficient bulbs must be replaced.

Table E.5. Phase III Statewide Annual Measure-Level Savings Potential for Texas Statewide

| Measure | 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 CO ₂ e) |
|--------------------------|--------------------------------|-----------------------------------|---------------------------|-----------------|------------------------------|--------------------------------|--|
| Envelope Air Tightness | 106 | 18 | 2,141 | 100,608 | 217,253 | 3,179,965 | 58,441 |
| Exterior Wall Insulation | 210 | 18 | 2,549 | 100,608 | 258,485 | 4,426,562 | 113,892 |
| Duct Tightness | 19 | 1 | 158 | 100,608 | 15,958 | 316,613 | 10,021 |
| Lighting* | 1 | 0 | 2 | 100,608 | 183 | 7,249 | 364 |
| Ceiling Insulation | 60 | 4 | 577 | 100,608 | 58,222 | 1,090,432 | 32,095 |
| TOTAL | 395 | 41 | 5,427 | 100,608 | 550,101 | 9,020,821 | 214,811 |

* Negative values mean that savings or reductions decrease if the measure is brought up to code. For example, for lighting, increasing the amount of high-efficacy lighting reduces electrical usage, but increases natural gas usage for heating, as the heat from less efficient bulbs must be replaced.

Table E.6. Phase I Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential for Texas Statewide

| Measure | Total Energy Savings (MMBtu) | | | Total Energy Cost Savings (\$) | | | Total State Emissions Reduction (MT CO2e) | | |
|---------------------------------|-------------------------------------|-------------------|--------------------|---------------------------------------|--------------------|----------------------|--|-------------------|--------------------|
| | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr |
| Envelope | | | | | | | | | |
| Air Tightness | 4,723,335 | 17,318,895 | 146,423,385 | 69,853,035 | 256,127,795 | 2,165,444,085 | 1,320,675 | 4,842,475 | 40,940,925 |
| Exterior Wall Insulation | 4,395,600 | 16,117,200 | 136,263,600 | 75,447,960 | 276,642,520 | 2,338,886,760 | 1,949,220 | 7,147,140 | 60,425,820 |
| Duct Tightness | 2,717,820 | 9,965,340 | 84,252,420 | 53,743,395 | 197,059,115 | 1,666,045,245 | 1,694,475 | 6,213,075 | 52,528,725 |
| Lighting | 1,058,565 | 3,881,405 | 32,815,515 | 41,616,315 | 152,593,155 | 1,290,105,765 | 2,086,575 | 7,650,775 | 64,683,825 |
| Ceiling Insulation | 355,155 | 1,302,235 | 11,009,805 | 6,645,870 | 24,368,190 | 206,021,970 | 195,405 | 716,485 | 6,057,555 |
| TOTAL | 13,250,475 | 48,585,075 | 410,764,725 | 247,306,575 | 906,790,775 | 7,666,503,825 | 7,246,350 | 26,569,950 | 224,636,850 |

Table E.7. Phase III Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential for Texas Statewide

| Measure | Total Energy Savings (MMBtu) | | | Total Energy Cost Savings (\$) | | | Total State Emissions Reduction (MT CO2e) | | |
|---------------------------------|------------------------------|-------------------|--------------------|--------------------------------|--------------------|----------------------|---|-------------------|-------------------|
| | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr |
| Envelope | | | | | | | | | |
| Air Tightness | 3,258,795 | 11,948,915 | 101,022,645 | 47,699,475 | 174,898,075 | 1,478,683,725 | 876,615 | 3,214,255 | 27,175,065 |
| Exterior Wall Insulation | 3,877,275 | 14,216,675 | 120,195,525 | 66,398,430 | 243,460,910 | 2,058,351,330 | 1,708,380 | 6,264,060 | 52,959,780 |
| Duct Tightness | 239,370 | 877,690 | 7,420,470 | 4,749,195 | 17,413,715 | 147,225,045 | 150,315 | 551,155 | 4,659,765 |
| Lighting | 2,745 | 10,065 | 85,095 | 108,735 | 398,695 | 3,370,785 | 5,460 | 20,020 | 169,260 |
| Ceiling Insulation | 873,330 | 3,202,210 | 27,073,230 | 16,356,480 | 59,973,760 | 507,050,880 | 481,425 | 1,765,225 | 14,924,175 |
| TOTAL | 8,251,515 | 30,255,555 | 255,796,965 | 135,312,315 | 496,145,155 | 4,194,681,765 | 3,222,195 | 11,814,715 | 99,888,045 |

Table E.8. Difference between Five-years, Ten-years, and Thirty-years Cumulative Annual Statewide Savings Potential Texas Statewide Phase III vs. Phase I

| Measure | Total Energy Savings (MMBtu) | | | Total Energy Cost Savings (\$) | | | Total State Emissions Reduction (MT CO2e) | | |
|---------------------------------|------------------------------|-------------------|--------------------|--------------------------------|--------------------|----------------------|---|-------------------|--------------------|
| | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr | 5yr | 10yr | 30yr |
| Envelope | | | | | | | | | |
| Air Tightness | 1,464,540 | 5,369,980 | 45,400,740 | 22,153,560 | 81,229,720 | 686,760,360 | 444,060 | 1,628,220 | 13,765,860 |
| Exterior Wall Insulation | 518,325 | 1,900,525 | 16,068,075 | 9,049,530 | 33,181,610 | 280,535,430 | 240,840 | 883,080 | 7,466,040 |
| Duct Tightness | 2,478,450 | 9,087,650 | 76,831,950 | 48,994,200 | 179,645,400 | 1,518,820,200 | 1,544,160 | 5,661,920 | 47,868,960 |
| Lighting | 1,055,820 | 3,871,340 | 32,730,420 | 41,507,580 | 152,194,460 | 1,286,734,980 | 2,081,115 | 7,630,755 | 64,514,565 |
| Ceiling Insulation | -518,175 | -1,899,975 | -16,063,425 | -9,710,610 | -35,605,570 | -301,028,910 | -286,020 | -1,048,740 | -8,866,620 |
| TOTAL | 4,998,960 | 18,329,520 | 154,967,760 | 111,994,260 | 410,645,620 | 3,471,822,060 | 4,024,155 | 14,755,235 | 124,748,805 |



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