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A Study on Residential Construction Energy Code Compliance in Nebraska

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A STUDY ON RESIDENTIAL CONSTRUCTION ENERGY CODE

COMPLIANCE IN NEBRASKA

by

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A STUDY ON RESIDENTIAL CONSTRUCTION ENERGY CODE COMPLIANCE IN NEBRASKA

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Energy codes are easy to implement, but how effectively are they being followed? To determine energy code compliance of residential construction in Nebraska, a study was conducted in which seven key areas having the most effect on energy savings were analyzed. The study examined both urban and rural areas of the state and compared Nebraska to other states' energy code compliance studies. The study found an eighty-eight percent average compliance in the key areas. Urban areas tended to be more compliant than rural areas. Nebraska is comparative in energy code compliance to other states. Yet, the state of Nebraska, code jurisdictions and builders still have room for improvement.

Keywords: Energy codes, Compliance, Residential, Construction, IECC

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Chapter 1

Introduction

According to the US Department of Energy (DOE), "Building energy codes represent a significant savings opportunity for U.S. home and business owners. Model energy codes for residential and commercial buildings are projected to save $126 billion in energy costs, 841 MMT of avoided CO2 emissions and 12.82 quads of primary energy between 2010-2014" (US Department of Energy, 2017-a). The International Energy Conservation Code (IECC) is in use or adopted in 48 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. Nebraska's current energy code is the 2009 IECC.

In order to determine residential construction compliance with the current 2009 IECC in Nebraska, a study was funded by a grant from the US Department of Energy. This study was a collaboration between the Nebraska Energy Office (NEO) and the University of Nebraska-Lincoln (UNL). Interns from UNL in the Architecture and Construction Management programs collected energy data. NEO provided project oversight and trained weatherization experts to conduct blower door and duct leakage testing. In addition to comparing IECC compliance rates to other states, study objectives also included: differences between urban (Douglas, Hall, Lancaster, and Sarpy counties) and rural code compliance, and differences between performance code compliance by means of REScheck software and prescriptive code compliance for Lancaster County Nebraska.

Using a DOE prescribed data collection protocol developed by Pacific Northwest National Laboratory (PNNL), data was collected for each of seven key energy code compliance categories, which had the greatest direct impact on energy use:

- Envelope Tightness (ACH50)
- Window U-Factor
- Ceiling Insulation R-value
- Basement Wall Insulation R-value
- Exterior Wall Insulation R-value
- High Efficacy Lighting
- Duct Leakage

Under the DOE protocol, each home could be visited only once. As a result, no single house provided data for all of the key items show above since it would be impossible to collect all the data at the same stage of construction (e.g. wall insulation and lighting).

Chapter 2

Literature Review

2.1 History of Energy Codes

Economics is a driving factor for most people when it comes to making houses more energy efficient. Energy has traditionally been cheaper in the United States compared to other countries. For this reason, before the 1970's, there was little incentive to build energy efficient housing. The oil embargo of 1973 alerted the United States to the fact that there would not always be an endless supply of energy.

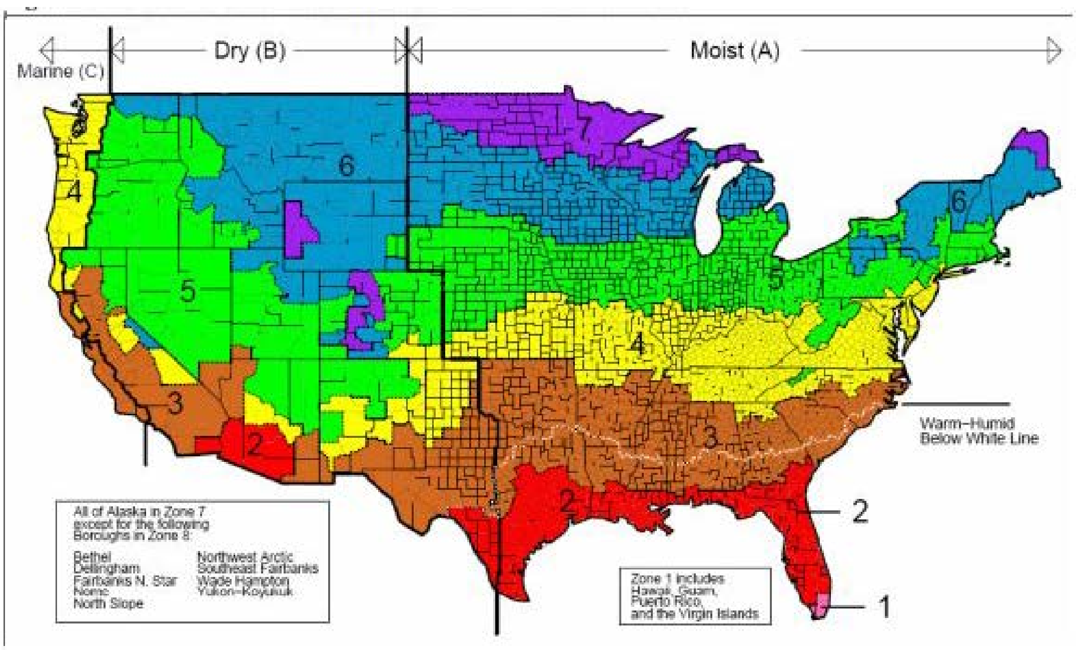
Residential energy standards were established in the 1950's by the Housing and Home Finance Agency because of mortgage defaults on federally insured loans on houses with high utility bills. Commercial energy standards were first enacted by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) in response to the New York Blackout of 1970. (Alliance Commission on National Energy Efficiency Policy, 2013)

In 1975, ASHRAE published Standard 90.1, Energy Conservation in New Building Design. Standard 90.1 has continued to be updated and used as the standard for commercial building energy codes. In 1976, the first federal legislation called for national building codes to be passed. The building industry opposed this policy because of the requirements of fixed energy ratios per square foot of building, and all buildings had to be modeled by a computer. Ultimately, these standards were relaxed and changed to voluntary guidelines and design tools. (Alliance Commission on National Energy Efficiency Policy, 2013)

In 1977, President Carter issued an executive order regarding energy efficiency and presented a National Energy Plan to Congress. The US Department of Energy (DOE) was also established that year. The DOE was given authority to establish energy standards. In 1978, Congress passed the National Energy Act (NEA), which included the National Energy Conservation Policy Act (NECPA) and encouraged residential energy efficiency. (Alliance Commission on National Energy Efficiency Policy, 2013)

In 1983, the Model Energy Code (MEC) was developed jointly by the Council of American Building Officials (CABO), Building Officials, and Code Administrators International Inc. (ICBO), National Conference of States on Building Codes and Standards (NCSBCS), and Southern Building Code Congress International (SBCCI), under a contract funded by the DOE. The MEC was published in 1983, 1986, 1989, 1992, 1993, and 1995 (US Department of Energy, 1999). In 1994, the International Code Council (ICC), was established as a "nonprofit entity to develop a single set of comprehensive and coordinated national model construction codes" (Alliance Commission on National Energy Efficiency Policy, 2013, p. 9). In 1998, the first version of the International Energy Conservation Code (IECC) was released, which is revised every three years (Alliance Commission on National Energy Efficiency Policy, 2013). The IECC 2004 Supplement was the first energy code to adopt a climate zone map followed by ASHRAE 90.1 (see Figure 2.1 and Table 2.1 below) (Halverson, Shui, & Evans, 2009). This helped the IECC be equitable across all states regardless of climate. The IECC is the current standard for residential energy codes.

Figure 2.1 Climate Zones in ASHRAE 90.1 – 2007 and IECC 2006



Source: ASHRAE 90.1-2007

Table 2.1 Climate Zone Definitions

	Thermal Criteria in SI Units
1	5,000 < CDD 10 °C
2	3,500 < CDD 10 °C <= 5,000
3A and 3B	2,500 < CDD 10 °C <= 3,500 and HDD 18 °C <= 3,000
4A and 4B	CDD 10 °C <= 2,500 and HDD 18 °C <= 3,000
3C	HDD 18 °C <= 2000
4C	2,000 < HDD 18 °C <= 3,000
5	3,000 < HDD 18 °C <=4,000
6	4,000 < HDD 18 °C <= 5,000
7	5,000 < HDD 18 °C <= 7,000
8	7,000 < HDD 18 °C

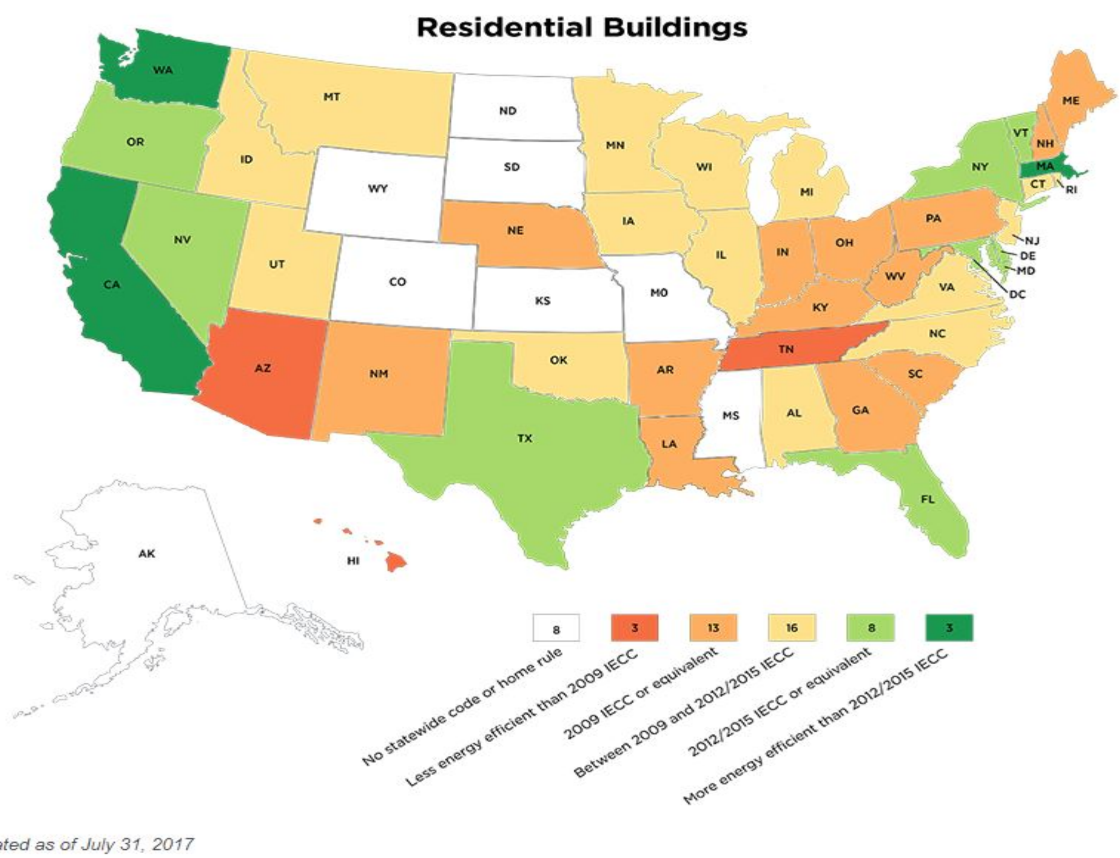
Source: IECC 2006

Source: (Halverson, Shui, & Evans, 2009)

The Energy Policy Act of 1992 states, “All States must review and consider adopting the national model energy standard” (Building Codes Assistance Project, 2017-a). The

Energy Policy Act of 2005 specified the most current model energy codes: the International Energy Conservation Code (IECC) for residential and ASHRAE Standard 90.1 for commercial construction (Building Codes Assistance Project, 2017-b). The American Recovery and Reinvestment Act of 2009 (ARRA 2009) helped to ensure all states adopted energy codes. The ARRA 2009 directed states to adopt the 2009 IECC and ASHRAE 90.1-2007 and achieve 90 percent compliance for all new construction in 2017 (Building Codes Assistance Project, 2017-c). See Figure 2.2 below for the current map of states that have adopted the IECC. The states in white have not adopted the IECC statewide, but generally have adopted them locally because of the home rule.

Figure 2.2 Status of State Energy Code Adoption



Source: https://www.energycodes.gov/status-state-energy-code-adoption

2.2 Energy Code Enforcement and Compliance

The Building Codes Assistance Project (BCAP) (2008) conducted a study of residential building energy codes enforcement and compliance. These were the findings:

Finding # 1- The 2006 IECC had the highest rate of compliance.

Finding #2 –Code officials reported a high level of knowledge of the codes they use.

Finding #3 - "Lack of manpower" was the third largest barrier to enforcing residential building energy codes.

Finding #4 - The typical profile for a code official was one who not only enforced both the residential and commercial codes, but also enforced mechanical, electrical, and/or structural codes.

Finding #5 – Code officials reported insufficient time available to spend on project sites to inspect for energy code compliance.

Finding #6 - Because it does not qualify as a life-health safety code, the energy code was reported to be a lower priority, receiving less attention from inspectors, resulting in a lower likelihood of compliance.

Finding #7 - Code officials wanted to improve their enforcement but report they have been limited by their workloads.

Finding #8 – Overwhelmingly, code officials believed energy code training is essential to effective energy code enforcement.

Finding #9 – The majority of code officials indicated their jurisdiction has a mandated program for certification/licensing that includes continuing education for energy.

Finding #10 - Building code officials indicated inadequate time for training needed to ensure that the provisions of an energy code are complied with.

Finding #11 - Code officials preferred information delivered through in-person workshops but also want more state-specific online workshops.

Finding#12 - Code officials requested state-specific in-person training on codes.

Finding #13 - The majority of code officials use cell phones and about half use computerized inspection documents, both of which are viewed as useful tools.

Finding #14 – Most code officials indicated compliance rates will increase if building departments make guidance documents and other information materials more readily available to builders, contractors, and tradespeople.

Finding #15 – The most effective outreach method for the public was reported as providing education materials and guidance in the form of pamphlets through the internet/website. (pgs. 5-6)

A webinar given by National League of Cities found three strategies were effective in improving energy code compliance. The first was to have design professional accountability. Part of this, was to involve them in the inspection process so they can get a better understanding of the energy code provisions. Second, streamline the compliance process by improving the building regulatory processes, and remove overlap and duplication in building departments. Third, was third-party enforcement. The third-party could take on plan review, performance testing, and energy code inspections. The third-party would have more time to insure and work toward compliance rather than the building inspector, who has to verify compliance of many other building codes as well. (National League of Cities, 2012)

As part of the American Recovery and Reinvestment Act of 2009, each of the 50 states accepting funding gave assurances to implement a plan to achieve 90% compliance with model energy codes by 2017. This included active training and enforcement programs and annual measurement of the rate of compliance (US Department of Energy, 2013). Compliance rates have been notable lower than 100%. The cost of enforcing the energy code has been raised as one reason of lower compliance. For a residential home, plan review and inspections can typically cost between $50 and $200. The general attitude is that health and safety codes are treated more seriously than energy codes (Vine, Williams, & Price, 2017).

2.3 Effectiveness of Energy Codes

The primary policy instrument for influencing energy efficiency are energy codes. Evaluations to determine effectiveness of the energy codes are typically performed using energy simulation models. Jacobsen and Kotchen found that energy models inaccurately predict future energy consumption. Many times, energy models over predicted savings. Their study in Florida looked at residential billing data of electricity and natural gas consumption of houses built within three years before the 2002 state-wide energy code that took effect compared to houses built after the energy code change. The results were a four percent decrease in annual electricity consumption and a six percent decrease in annual natural gas consumption (Jacobsen & Kotchen, 2013). A study by Arroonruengsawat et al. in 2009 found similar results that the per capita electricity consumption in 48 U.S. states decreased between three and five percent in states that had adopted energy codes (Jacobsen & Kotchen, 2013). A study looking at electrical energy bills for homes in Austin, Texas found that the adoption of the 2000 IECC resulted in a reduction of 5.8 percent annual home energy use compared to homes built under the 1993 MEC (Trowbridge, 2009).

"Aggressive building codes and equipment standards significantly reduce the amount of energy consumed in building and produce significant net monetary savings compared with current standards" (Scott, et al., 2015, p. 1688). Building energy codes are a cost-effective way to save energy. The continuation of improving building codes from 2005 to 2050 could save between 4.9 and 5.2 percent of total building energy (Scott, et al., 2015). The DOE estimates the payback of adopting the 2009 or 2012 IECC would pay for itself in one to two years. After that, would be continued savings to the homebuyer (Vaughan & Turner, 2013).

2.4 Past Compliance Studies

Energy code evaluation studies were reviewed in 2005 by the Building Codes Assistance Project (BCAP). They found that not many energy code studies had been conducted because of the expense. The cost was estimated to be between $500 to $1000 per home per site visit. There was no standard energy software to use or protocol established for a baseline study. Obtaining a good sampling was also problematic and prone to self-selection bias because of builders and building officials being unwilling to cooperate. (Building Codes Assistance Project, 2005)

Sixteen states participated in energy code studies typically measuring compliance against the IECC, MEC, Title 24, or their state energy code. Depending on the study, the definition of compliance rates differed. Most of the states were at relatively low compliance, with exceptions of Montana, Oregon, Washington, and California. (Building Codes Assistance Project, 2005)

There are several misconceptions that builders have related to energy codes. The majority of surveyed builders claimed the homes they built exceeded energy codes. A study found that most of the components did not exceed energy codes but instead only met the minimum. The findings were that training for builders was necessary to educate them on energy codes and for improved compliance. (Building Codes Assistance Project, 2005)

Misuriello, Penney, Eldridge, and Foster examined fifty studies of state energy code compliance and enforcement. The results found that as-built conditions were different than the plans, substitution of non-compliant products was common, and training and education efforts needed to be strengthened. Many of the studies were one-time collections with lack of uniformity or standards between states, which makes comparison extremely difficult. This demonstrates the importance of a standard method of compliance measurement. (Misuriello, Penney, Eldridge, & Foster, 2010)

2.5 Recent Compliance Studies and Comparison

The US Department of Energy (DOE) Building Energy Codes Program conducted a series of research studies investigating energy code implementation in residential buildings. The goal of the study was to help document baseline practices, target areas for improvement, and quantify related savings potential. This information was intended to assist states in measuring energy code compliance and to identify areas of focus for future education and training initiatives. The following states were selected to participate in the study: Alabama, Arkansas, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, and Texas. Several additional states have also initiated their own studies based on the DOE Methodology and most are still in the process: Delaware, Michigan, Missouri, Nebraska, Tennessee, Virginia, and West Virginia. (US Department of Energy, 2017-b)

Alabama

At the time of the study, the state energy code was the 2009 International Energy Conservation Code (IECC). Alabama is comprised of climate zones 2 and 3. Ninety percent of predominant foundation observations were slab-on-grade. Since Alabama has no insulation requirement for slab insulation, no data was collected. Alabama was 92% compliant on envelope tightness, 92% compliant on window SHGC, 100% compliant on window U-factor, 16% compliant on wall U-factor, 95% compliant on ceiling R-value, 35% compliant on high-efficacy lighting, and 87% compliant on duct tightness. (PNNL-26168) (Bartlett, et al., 2017-a)

Arkansas

At the time of the study, the state energy code was the 2014 Arkansas State Energy Code, which is similar to the 2009 IECC. Arkansas is comprised of climate zone 3 and 4. Ninety percent of predominate foundation observations were slab-on-grade. Only four had observed insulation so foundation insulation data was not included. Arkansas was 81% compliant on envelope tightness, 78% compliant on SHGC, 100% compliant on window U-factor, 57% compliant on wall U-factor, 98% compliant on ceiling R-value, 57% compliant on high-efficacy lighting, and 73% compliant on duct tightness (PNNL-26546) (Bartlett, et al., 2017-b).

Georgia

At the time of the study, the state energy code was the 2011 Georgia State Energy Code, which is similar to the 2009 IECC. Georgia is in climate zones 2, 3, and 4. Because of the variety of foundation types observed, there was not enough data collected on one specific type to make any conclusions. Georgia was 96% compliant on envelope tightness, 98% compliant on SHGC, 100% compliant on window U-factor, 17% compliant on wall U-factor, 83% compliant on ceiling R-value, 38% compliant on high-efficacy lighting, and 69% compliant on duct tightness. (PNNL-26590) (Bartlett, et al., 2017-c)

Kentucky

At the time of the study, the state energy code was the 2009 IECC. Kentucky is in climate zone 4. There is no SHGC requirement in this zone. Kentucky was 70% compliant on envelope tightness, 98% compliant on window U-factor, 28% compliant on wall U-factor, 90% compliant on ceiling R-value, 31% compliant on high-efficacy lighting, 18% compliant on foundation wall U-factor, 20% compliant on floor U-factor, 20% compliant on slab edge R-value, and 61% compliant on duct tightness. (PNNL-26272) (Bartlett, et al., 2017-d)

Maryland

At the time of the study, the state energy code was the 2015 IECC. Maryland is in climate zone 4. Because of the variety of foundation types observed, there was not enough data collected on one specific type to make any conclusions. There is no SHGC requirement in this zone. Maryland was 54% compliant on envelope tightness, 98% compliant on window U-factor, 25% compliant on wall U-factor, 72% compliant on ceiling R-value, 61% compliant on high-efficacy lighting, and 49% compliant on duct tightness. (PNNL-25970) (Bartlett, et al., 2016)

Missouri

The data collected and presented below is benchmarked against the 2009 IECC. Missouri is comprised of climate zones 3 and 4. Window SHGC data was not collected. Missouri was 97% compliant on envelope tightness, 81% compliant on window U-factor, 100% compliant on wall R-value, 72% compliant on ceiling R-value, 6% compliant on high-efficacy lighting, 28% compliant on basement wall R-value, and 28% compliant on duct tightness. (Midwest Energy Efficiency Alliance, 2016)

North Carolina

At the time of the study, the state energy code was the 2012 North Carolina State Code. North Carolina is comprised of climate zones 3, 4 and 5. North Carolina was 88% compliant on envelope tightness, 99% compliant on SHGC, 99% compliant on window U-factor, 12% compliant on wall U-factor, 92% compliant on ceiling R-value, 57% compliant on high-efficacy lighting, 88% compliant on slab edge R-value, 60% on floor U-factor, and 64% compliant on duct tightness. (PNNL-26752) (Bartlett, et al., 2017-e)

Pennsylvania

At the time of the study, the state energy code was the 2009 IECC. Pennsylvania is comprised of climate zones 3 and 4. There is no SHGC requirement in these climate zones. Pennsylvania was 93% compliant on envelope tightness, 97% compliant on window U-factor, 23% compliant on wall U-factor, 90% compliant on ceiling R-value, 62% compliant on high-efficacy lighting, 79% compliant on basement wall U-factor, 31% on floor U-factor, and 37% compliant on duct tightness. (PNNL-26450) (Bartlett, et al., 2017-f)

Texas

At the time of the study, the state energy code was the 2015 Texas Energy Code but the data collected and presented was benchmarked against the 2009 IECC. All of the Texas data was gathered in climate zone 2. The predominant foundation type is slab-on-grade. Since Texas has no insulation requirement for slab insulation, no data was collected. Texas was 97% compliant on envelope tightness, 100% compliant on SHGC, 100% compliant on window U-factor, 65% compliant on wall U-factor, 95% compliant on ceiling R-value, 62% compliant on high-efficacy lighting, and 91% compliant on duct tightness. (PNNL-26219) (Bartlett, et al., 2017-g)

Chapter 3

Methods

3.1 Sampling Plan

The DOE and PNNL put together a Residential Energy Code Sampling and Data Collection Guidance for Project Teams Document to help guide states with their studies. This document outlines a DOE-developed methodology that provides state-wide results with a 90/10 statistical reliability. PNNL did not share the population size *N*, which was based off building permit numbers, not state populations, for the states participating in the study, but did specify the sample size n = 63 observations for each of the seven key items. Only new, site-built single family homes were to be analyzed with the unit of analysis being code requirements. This required a single site visit and only the items that were available at the inspection date were recorded. Making multiple visits could influence the builder to be more conscientious after the first visit and bias the results. (Halverson, Mendon, Bartlett, Hathaway, & Xie, 2015)

In order to obtain a statistically significant sample of observations, a statewide sampling plan was developed by PNNL for Nebraska. PNNL developed an initial sampling plan using a proportional random sample approach based on the place-level data (cities and areas within counties). PNNL calculated the average number of single-family homes constructed in each place over the last 3 years and used that number as the basis of the proportional random sample. The initial sampling plan was focused solely on achieving a statistically significant sample at the state level. It was then shared at stakeholder meetings in order to take into account any special considerations within a state (such as systematic energy code implementation differences across county or climate zone boundaries), which could then be discussed. The key was that the sampling plan must be representative of the entire state. (Halverson, Mendon, Bartlett, Hathaway, & Xie, 2015)

Based on feedback from stakeholder meetings, PNNL determined whether changes to the initial sampling plan were necessary based on:

1) Census Bureau data may not cover the entire state, perhaps some counties do not issue building permits. Counties that do not issue building permits would not report any building permits to the Census Bureau. A possible solution would be to identify permits from another source within the state (e.g. plumbing system, HVAC system permits, etc.) that can be used to construct an alternative random sample that covers the entire state.

2) Census Bureau data may cover the entire state but travel to some remote locations may be overly burdensome. A possible solution would be to substitute a less remote location for a more remote location, ensuring that the substitution is still representative.

3) The state may have large sections of unincorporated areas where building permits are issued but no further code enforcement is conducted. Given that the unincorporated areas do represent what is happening in the state, one solution may be to encourage the Project Teams to try to sample these areas even if it may be harder to get contact information for homes. Ignoring the unincorporated areas

> would not be representative of the state. (Halverson, Mendon, Bartlett, Hathaway, & Xie, 2015, pp. 5-6)

A final sampling plan identified how many complete data sets were required to be collected from each county. It was determined that a minimum of 63 data sets needed to be collected for the entire state. One data set consisted of one observation of each of the above seven key items. The counties of Lancaster, Douglas, and Sarpy, which contain the most populous cities of Lincoln and Omaha, required the most data sets to be collected. Many counties in Nebraska were not selected at all. Other states who performed similar studies were also required to collect a minimum of 63 data sets for the whole state regardless of average number of building permits or size. The sampling plan is included in Appendix A.

3.2 Training

Prior to onsite data collection, student interns received training from Cadmus, an independent energy services contractor that has conducted similar studies. UNL interns were trained to use the DOE data collection protocol for two days. Training focused on completing the state specific data collection forms and insuring the interns understood the type of information to be collected. Another part of the training was understanding the 2009 IECC and what constituted compliance.

Two more days of training were spent at job sites along with the NEO contracted weatherization team. UNL interns learned how to complete the data collection sheet, understand required information, and assess compliance on actual installation. The interns were then trained to set up blower door and duct tightness testing equipment and learned proper testing protocols so they would be able to assist the NEO contracted weatherization team responsible for testing. The NEO contracted weatherization team performed blower door and duct tightness testing according to standards set by the Building Performance Institute (BPI).

3.3 Recruitment

For recruitment of houses and scheduling of the site visits, one of the student interns was selected as the coordinator who worked with NEO. The student coordinator and NEO contacted builders, realtors, banks, or local code jurisdictions in order to find available houses in the appropriate stage for data collection.

Houses for the study were chosen by county and availability rather than by square footage or builder. Finding single-family residential homes in all of the selected counties for data collection was somewhat challenging, especially in the less populated areas with fewer construction projects. Local jurisdictions did not know actual construction schedules to the day and as a result, many site visits found energy code compliance items either incomplete or covered over (e.g. insulation). Generally, those contacted were helpful and interested in the data collection. Some builders asked questions about their methods of installation or performance, which were shared individually. The builder or a representative was usually there for the final testing to provide access to the house. Code jurisdictions were helpful in recruiting and were interested in general compliance. All participants were assured that the data collection was aggregated and that code compliance for individual builders would not be disclosed.

3.4 Data Collection

Data collection concentrated first on Douglas, Lancaster, and Sarpy Counties since the majority of the data sets required were in those counties. Collections in the remaining rural counties were conducted as projects became available. Data was collected on a total of 156 units and lasted approximately six months. Data was either collected at the insulation stage or at the final stage of construction in order to be most efficient. After data was collected by UNL interns, it was entered into the data collection database and reviewed by NEO for quality assurance. The data collection instrument is included in Appendix B.

Insulation Inspection

The following information was collected when the house was at the insulation stage:

- Foundation type and wall insulation R-value
- Slab edge insulation R-value
- Exterior wall insulation R-value
- Duct insulation R-value for ductwork outside of the conditioned space
- Window U-factor
- Ductwork sealing

The basement and exterior wall insulation R-values were determined by identifying the type of insulation and then measuring the thickness (Figures 3.1, 3.2 and 3.3). For fiberglass, the R-value was verified by reading the printed R-value on the face of the batt.

Figure 3.1 Basement Wall Fiberglass Batt Insulation Verification

Figure 3.2 Exterior Wall Fiberglass Batt Insulation Verification

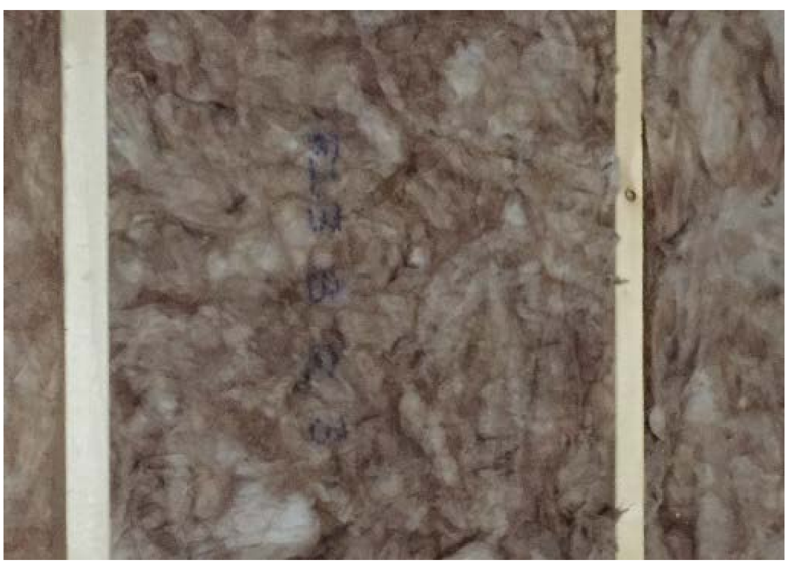


Figure 3.3 Exterior Wall Blown-in Insulation Verification

The window U-value and SHGC were determined by reading the manufacturer's label affixed to the windows (Figure 3.4).

Figure 3.4 Window U-factor Verification

Ductwork sealing was confirmed by a visual inspection to verify mastic and rated foil tape were used to seal supply ductwork. Return air ductwork in wall cavities was also noted (Figure 3.5).

Figure 3.5 Duct Sealing Verification

Final Inspection

The following information was collected at the final stage of construction after floor coverings and all HVAC equipment was operating.

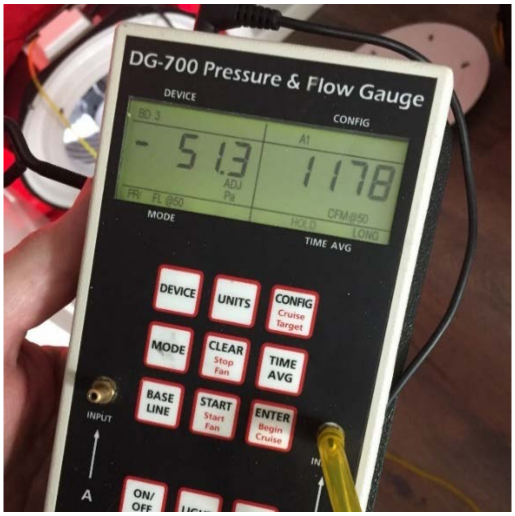
- Ceiling insulation R-value
- Envelope tightness (ACH50)
- Duct leakage
- Percentage of high efficacy lighting
- HVAC and water heater equipment and type

Ceiling insulation R-value was determined by identifying the type of insulation and measuring its thickness to calculate an R-value. Depth gauges installed around the attic helped verify the thickness (Figure 3.6).

Figure 3.6 Ceiling Insulation Verification

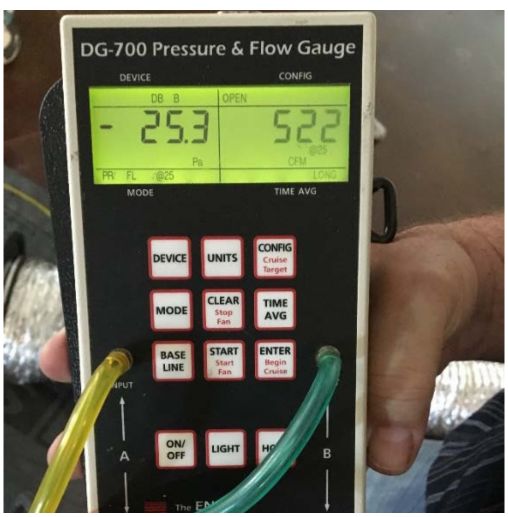
Envelope tightness was determined by conducting a blower door test at 50 Pa according to BPI standards and observing the air infiltration rate in cubic feet per minute (CFM) (Figure 3.7). Then air changes per hour (ACH) was calculated based on the volume of the house.

Figure 3.7 Envelope Tightness Verification



Duct leakage was determined by conducting a duct leakage test according to BPI standards at 25 Pa and observing the duct leakage rate in CFM in relation to square feet of conditioned area (Figure 3.8).

Figure 3.8 Duct Tightness Verification



Percentage of high efficacy lighting was determined by counting all of the interior and exterior lamps and determining how many were fluorescent or LED compared to incandescent (Figure 3.9).

Figure 3.9 High Efficacy Lighting Verification

Chapter 4

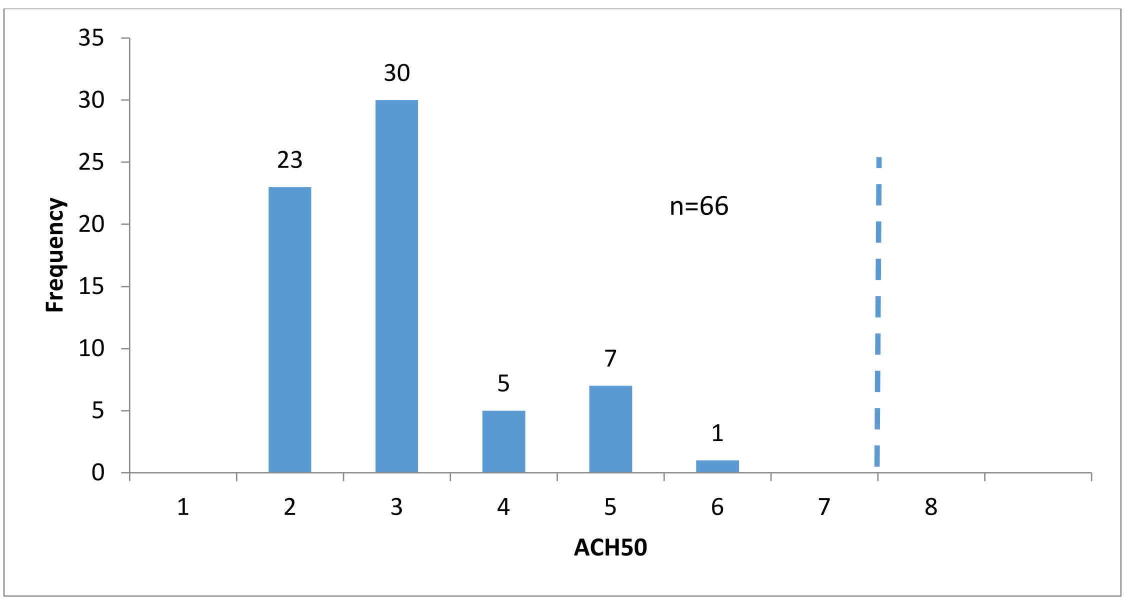
Results

4.1 Categories At or Above 90% Compliance

Envelope Tightness (ACH50)

All houses tested for envelope tightness met the 2009 IECC requirement of seven ACH at 50 Pa of pressure maximum (Figure 4.1). The average was 3 ACH. The NEO performed all blower door calculations and the results are shown below.

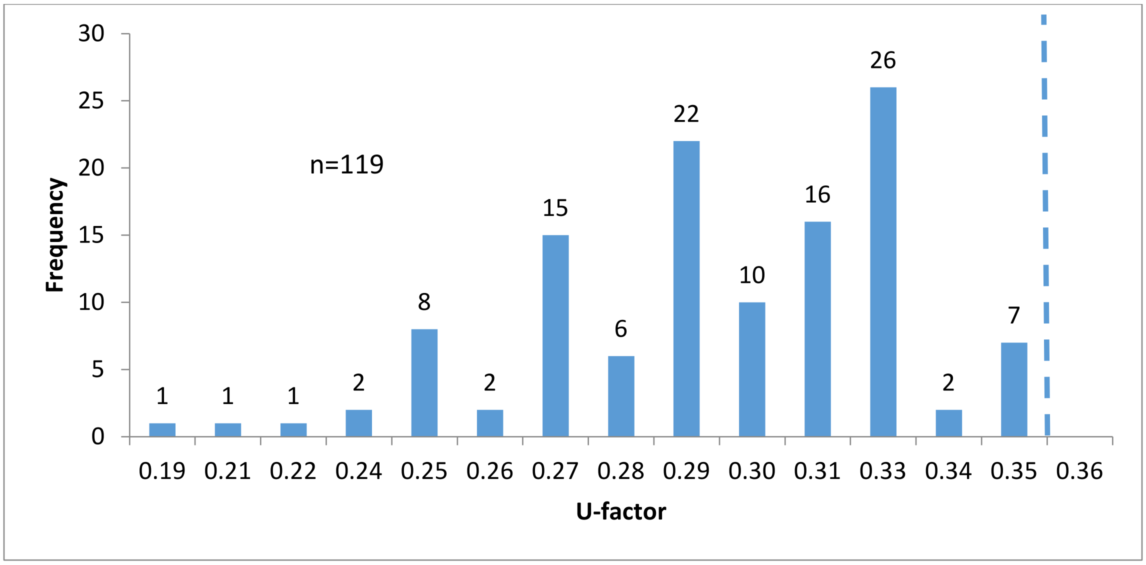
Figure 4.1 Envelope Tightness (ACH50)



Window U-Factor

All houses tested for window U-factor compliance met the 2009 IECC requirement of a maximum U-factor of 0.35 (Figure 4.2). The average was a 0.30 U-factor.

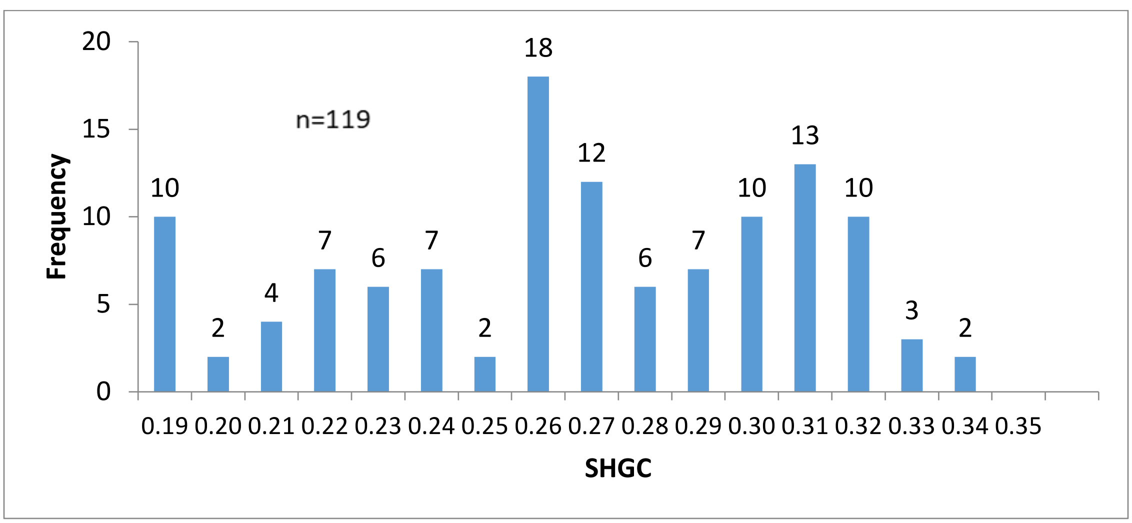
Figure 4.2 Window U-factor



Window SHGC

Since Nebraska is in climate zone 5 of the United States, there is no required minimum SHGC on windows. Therefore, all houses complied with the 2009 IECC (Figure 4.3). Climate zones 1-3 require a maximum of 0.30 SHGC for compliance. The average was a 0.27 SHGC.

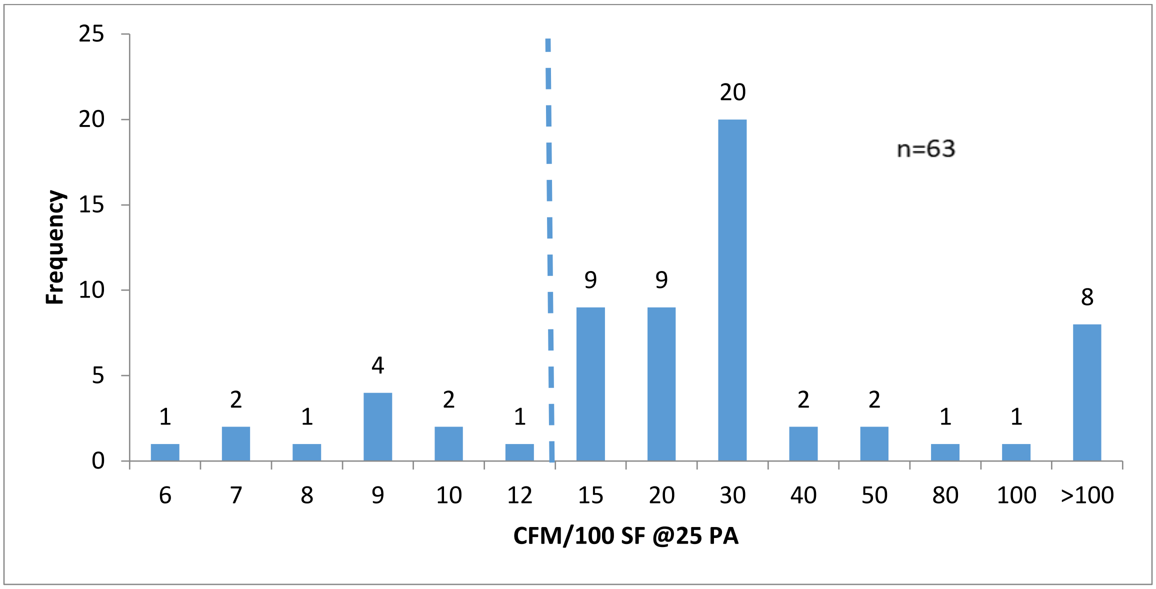
Figure 4.3 Window SHGC



Duct Tightness

All houses visited for data collection complied with the 2009 IECC because all of the ductwork was contained in the conditioned area. If the ductwork is outside of the conditioned areas, then it must be equal to or less than 12 CFM/100 SF @ 25 Pa. However, only 17% of houses had duct leakage tested less than 12 CFM/100 SF @ 25 Pa (Figure 4.4). The NEO performed all duct tightness calculations and the results are shown below.

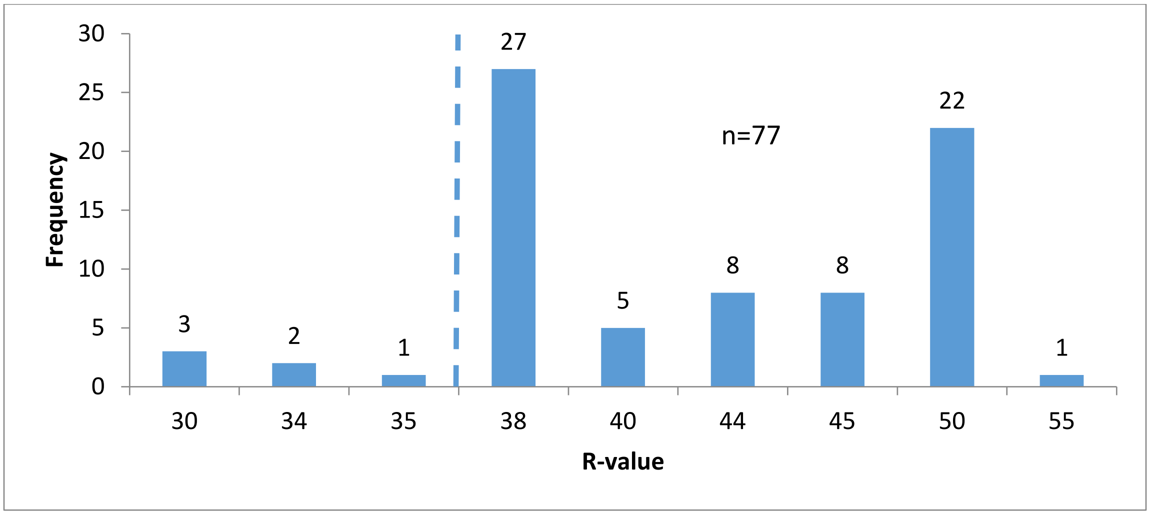
Figure 4.4 Duct Tightness Conditioned Area



Ceiling Insulation R-value

Ninety-two percent of the houses complied with the prescriptive 2009 IECC minimum ceiling insulation of R-38 (Figure 4.5).

Figure 4.5 Ceiling Insulation R-value

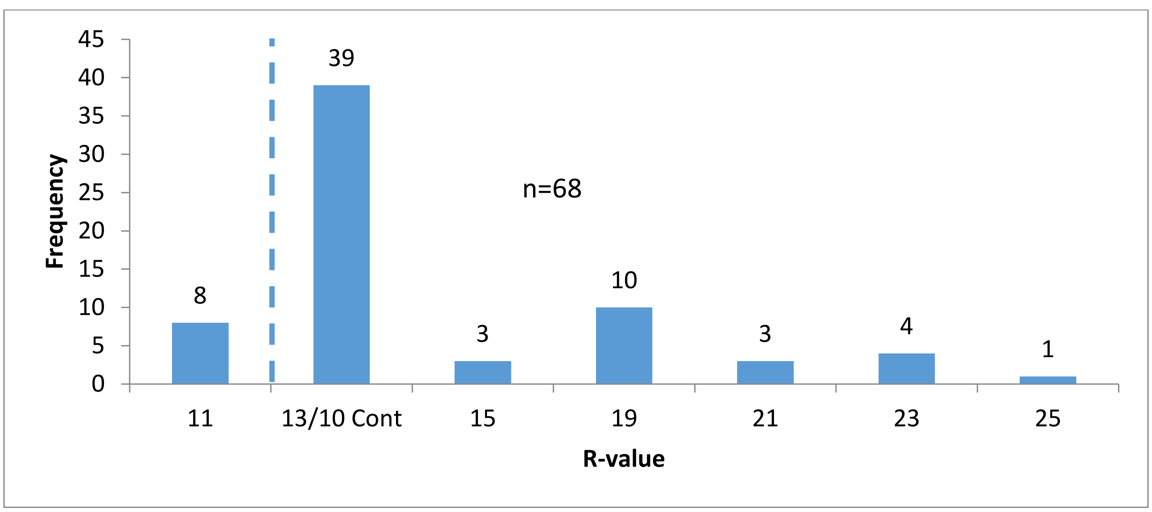


4.2 Categories Below 90 Percent Compliance

Basement Wall Insulation R-value

Eighty-eight percent of houses complied with the prescriptive 2009 IECC minimum basement wall insulation of R-13/10 (R-13 between studs or R-10 continuous insulation) (Figure 4.6).

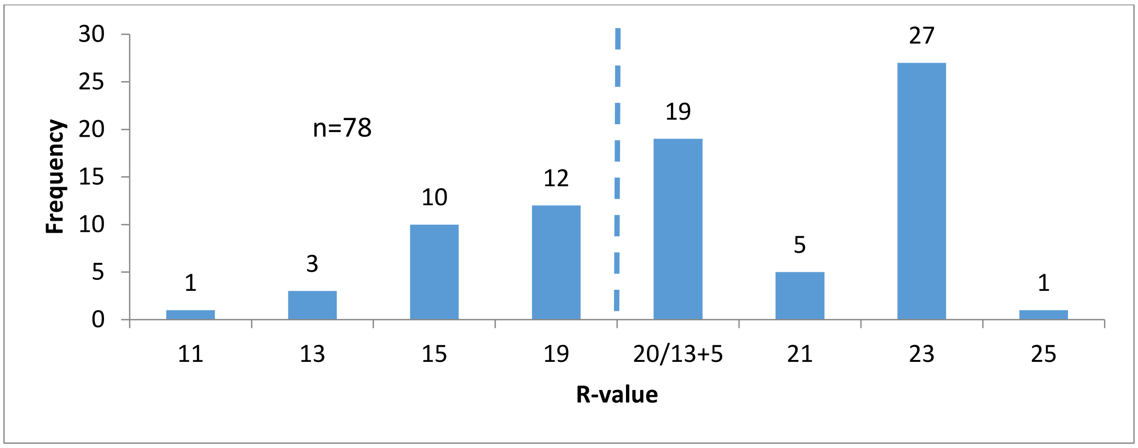
Figure 4.6 Basement Wall Insulation R-value



Exterior Wall Insulation R-value

Sixty-seven percent of houses complied with the prescriptive 2009 IECC minimum exterior wall insulation of R-20/13+5 (R-20 between the studs or R-13 between the studs with R-5 continuous insulation) (Figure 4.7).

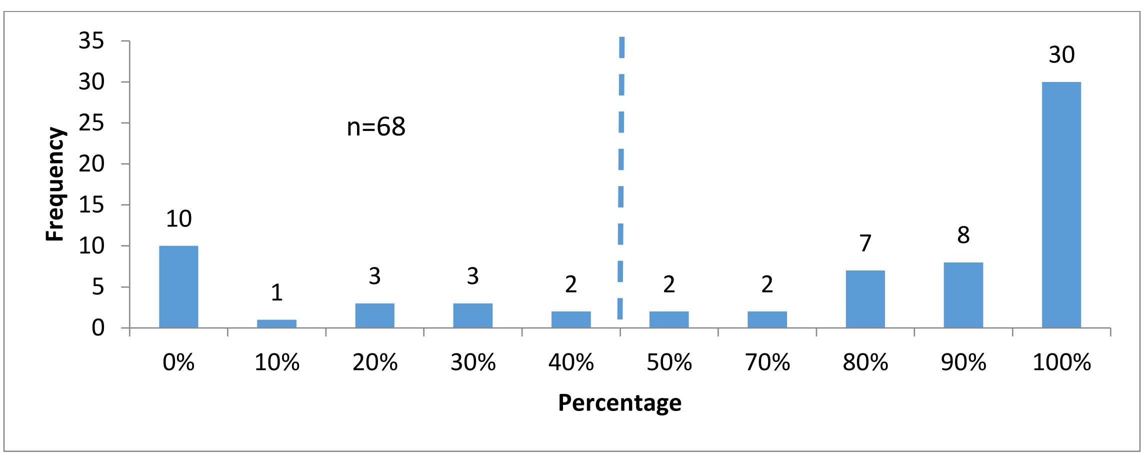
Figure 4.7 Exterior Wall Insulation R-value



High Efficacy Lighting

Seventy-two percent of the houses complied with the 2009 IECC minimum 50% high efficacy lighting (Figure 4.8).

Figure 4.8 High Efficacy Lighting



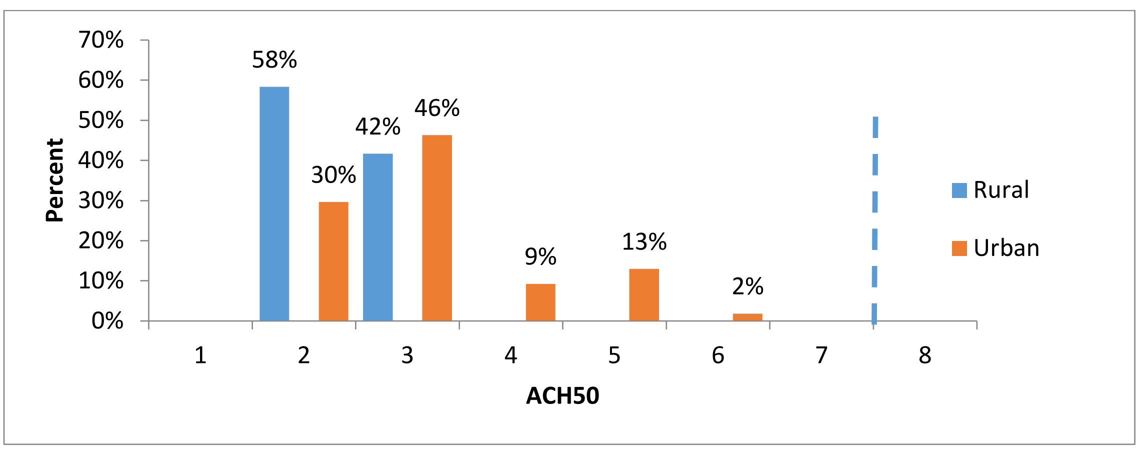
4.3 Urban Code Compliance vs Rural Code Compliance

Deciding which counties were urban versus those that were rural was determined based of the US Census definition that an area with a population greater than or equal to 50,000 is considered urban. Any county with a population less than 50,000 was considered rural (US Census Bureau, 2018). The counties of Douglas, Hall, Lancaster, and Sarpy were determined to be urban counties. The other counties on the sampling plan were considered rural.

Envelope Tightness (ACH50)

Houses in urban and rural areas were both compliant with the 2009 IECC maximum of seven ACH50, but rural houses had lower overall numbers and tighter envelopes (Figure 4.9).

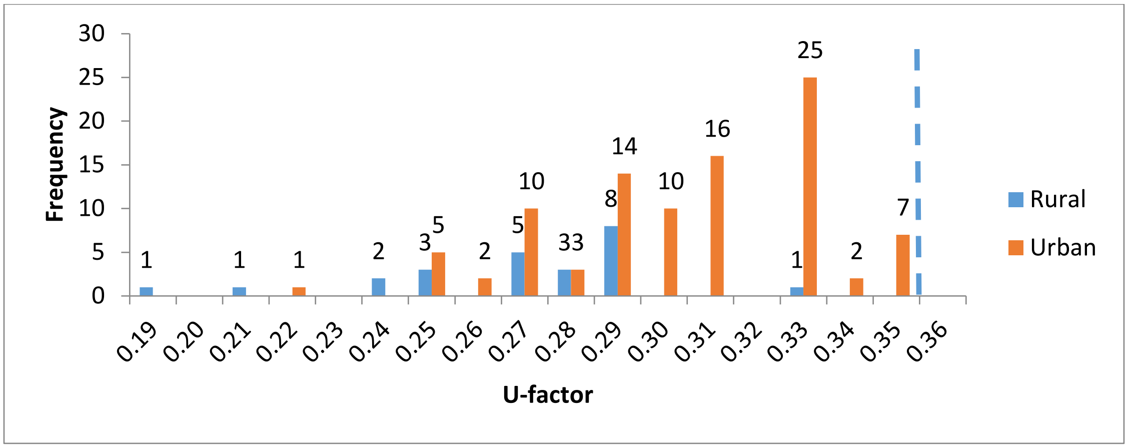
Figure 4.9 Envelope Tightness(ACH50)



Window U-factor

Both urban and rural houses were compliant with the 2009 IECC maximum U-factor of 0.35 (Figure 4.10). The rural houses had a higher percentage of lower U-factors than urban houses.

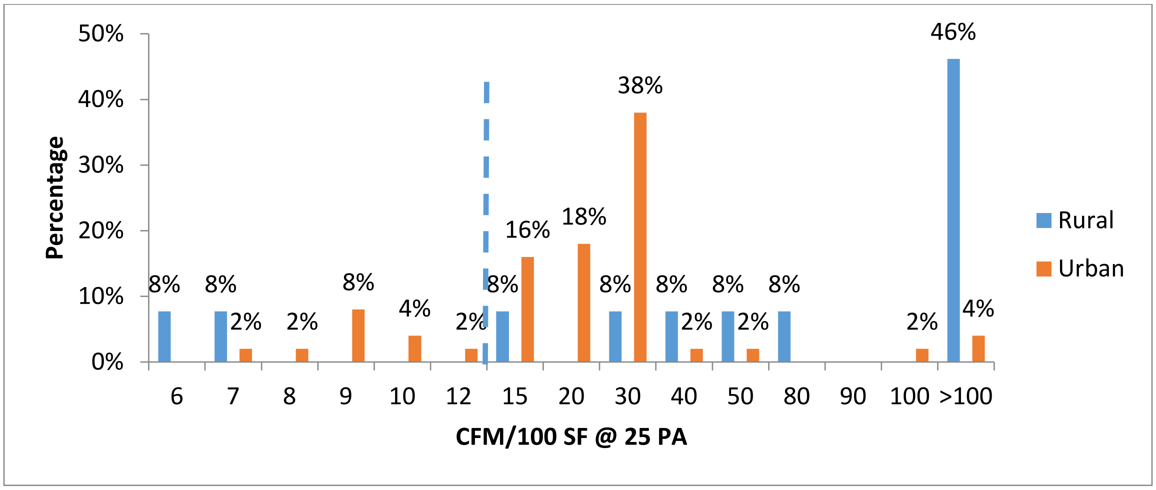
Figure 4.10 Window U-factor



Duct Tightness

All houses observed did not require the ductwork to pass a duct tightness test since all of the ductwork was in the conditioned area. The majority of both urban and rural houses had leaky ductwork above the 12 CFM/125 SF @25 Pa that the 2009 IECC requires for ductwork outside of the conditioned area (Figure 4.11). Rural houses had a higher percentage of leaky ductwork, including some that were too leaky to measure a reading.

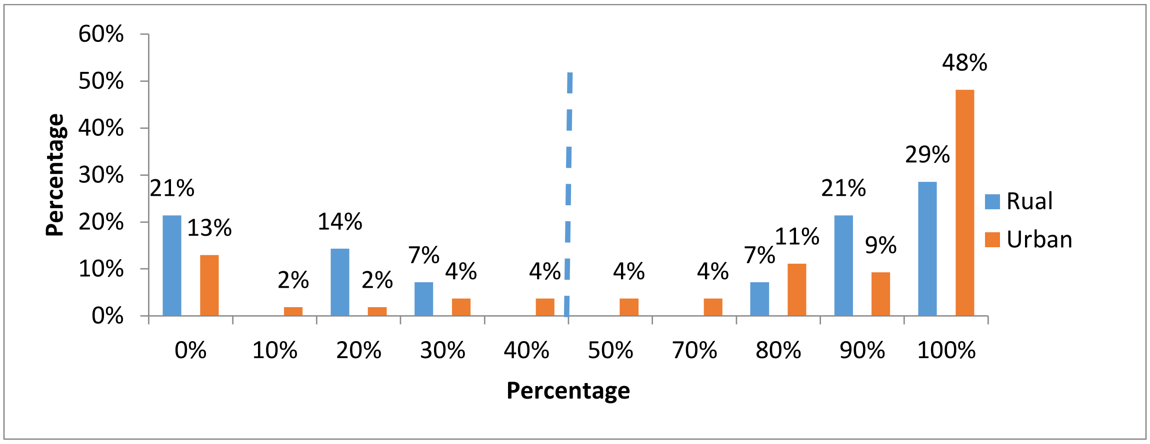
Figure 4.11 Duct Tightness



High Efficacy Lighting

Urban houses had a 76% compliance rate compared to rural houses, which had a 57% compliance rate with the 2009 IECC for high efficacy lighting (Figure 4.12).

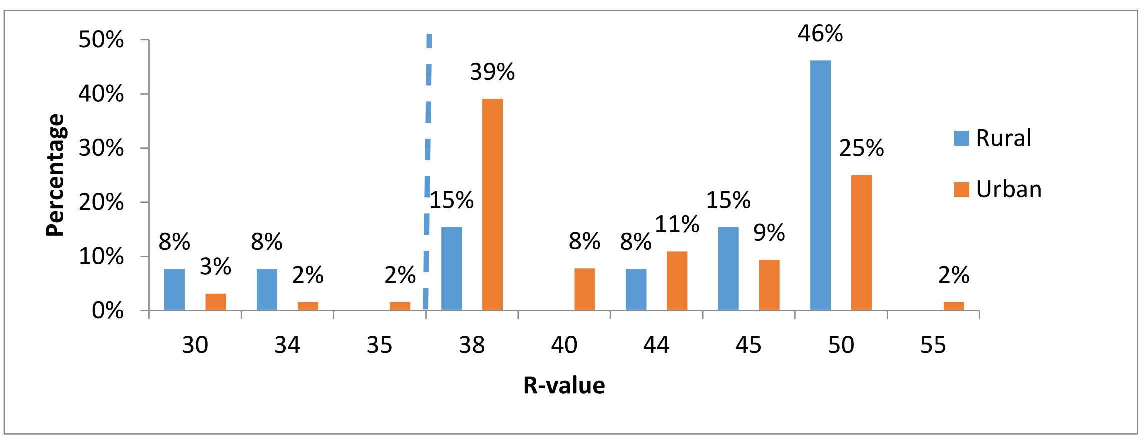
Figure 4.12 High Efficacy Lighting



Ceiling Insulation R-value

Urban houses had a 94% compliance rate compared to rural houses, which had an 85% compliance rate with the 2009 IECC for ceiling insulation (Figure 4.13).

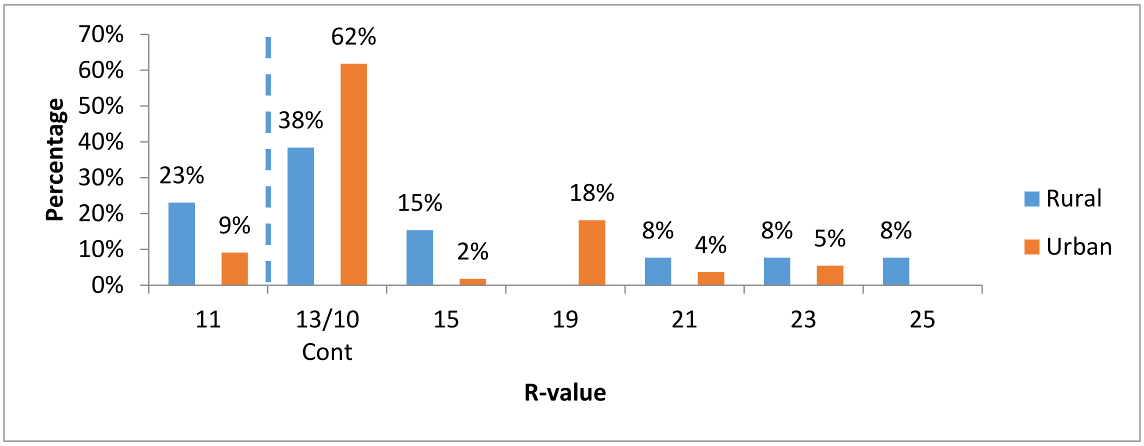
Figure 4.13 Ceiling Insulation R-value



Basement Wall Insulation R-value

Urban houses had a 91% compliance rate compared to rural houses, which had an 77% compliance rate with the 2009 IECC for basement wall insulation (Figure 4.14).

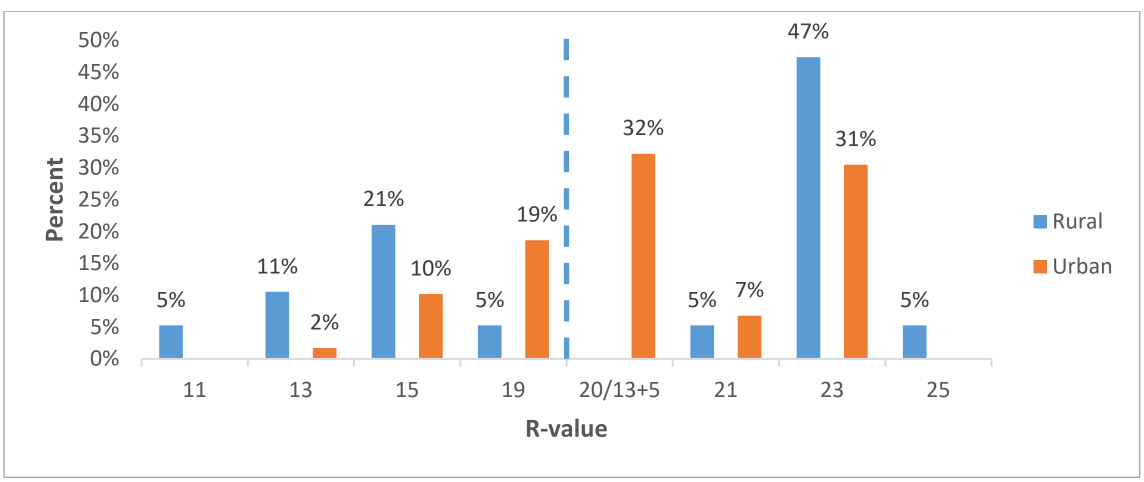
Figure 4.14 Basement Wall Insulation R-value



Exterior Wall Insulation R-value

Urban houses had a 69% compliance rate compared to rural houses, which had a 58% compliance rate with the 2009 IECC for exterior wall insulation (Figure 4.15).

Figure 4.15 Exterior Wall Insulation R-value

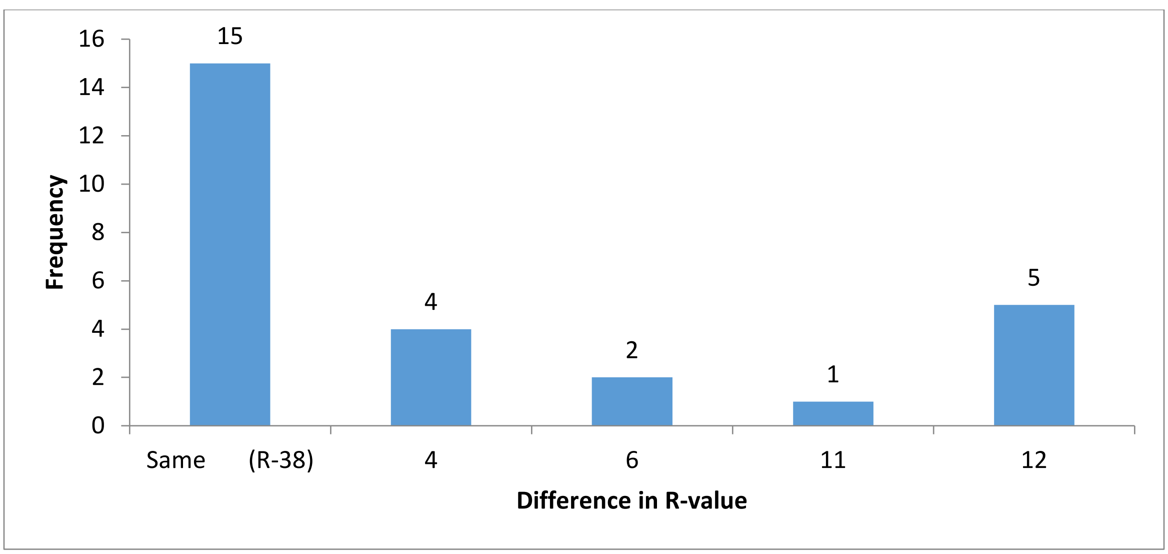


4.4 Performance vs. Prescriptive Compliance

Lancaster County requires builders to submit a REScheck report in order to apply for a building permit. REScheck allows a builder to meet energy codes by performance rather than prescriptive compliance. This allows a builder to install less insulation than code requires in some areas, like wall insulation, and instead add more insulation than is required in other areas, like the ceiling or order more efficient windows to make up the difference through energy performance. Twenty-seven houses were evaluated in Lancaster County, but not all seven data items were collected on each house.

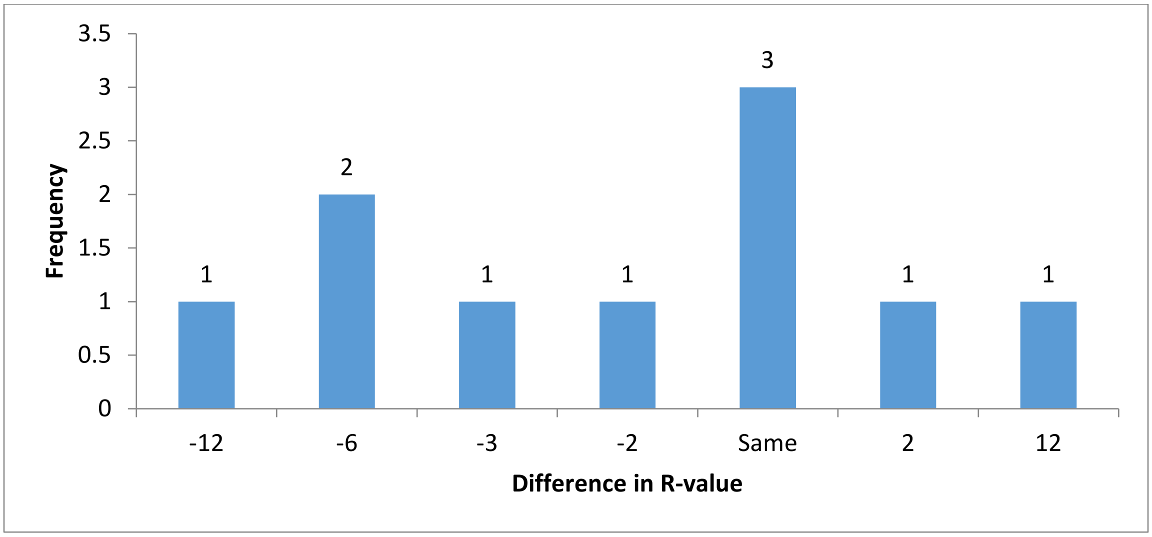
Forty-four percent of the houses had proposed performance ceiling insulation R-values higher than the prescriptive code (Figure 4.16).

Figure 4.16 Performance Ceiling R-value vs Prescriptive



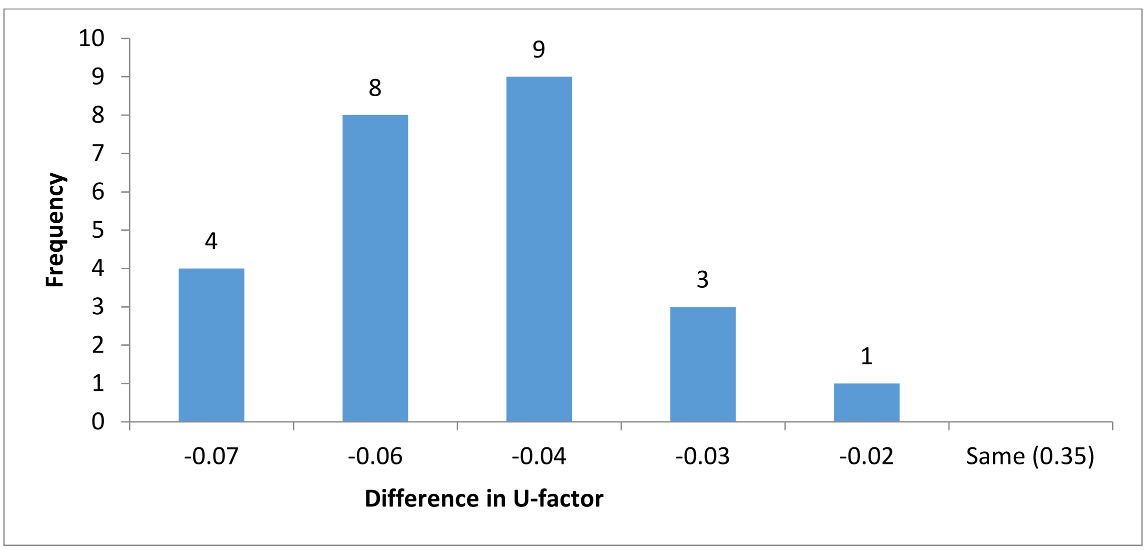
Not all houses had ceiling insulation installed as proposed with REScheck. Fifty percent of ten observed houses were compliant (Figure 4.17).

Figure 4.17 Actual Ceiling R-value vs. Proposed Performance



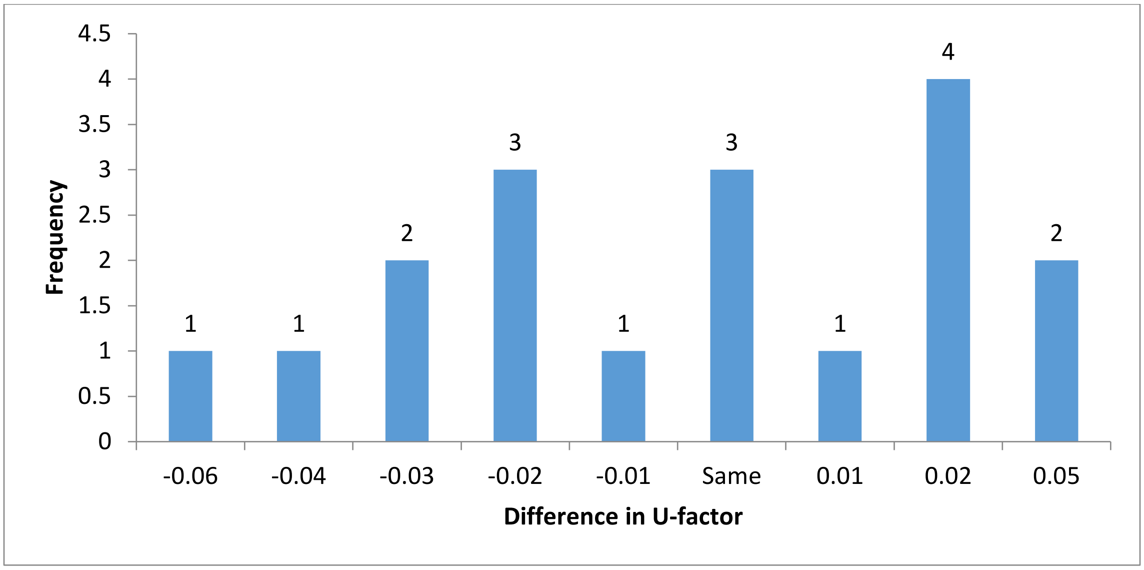
One hundred percent of the houses had proposed performance window U-factors lower than the prescriptive code (Figure 4.18).

Figure 4.18 Performance Window U-value vs Prescriptive



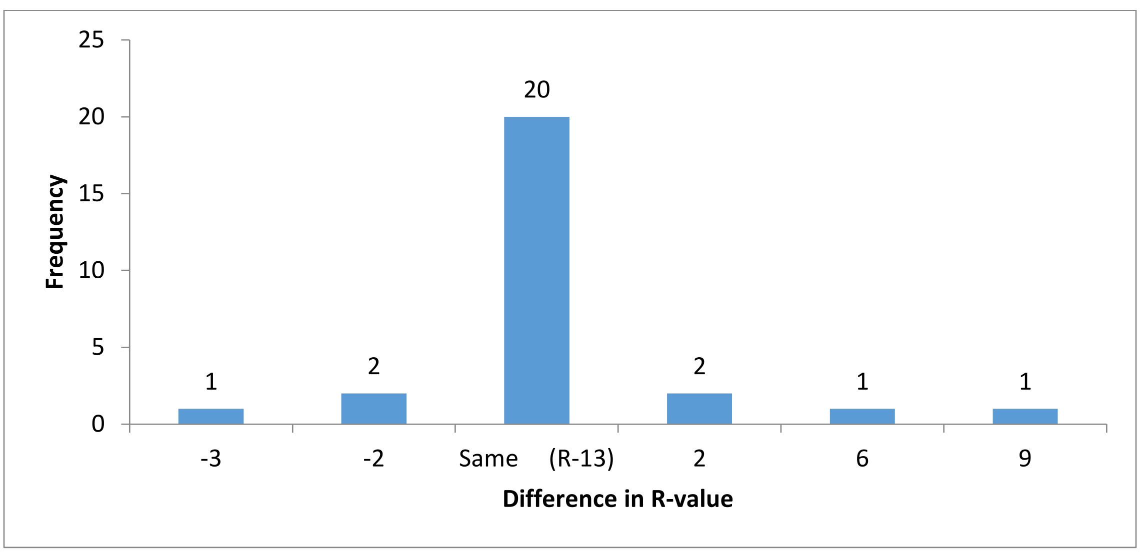
Not all houses had window U-factors installed as proposed with REScheck. Sixty-one percent of the 18 observed houses were compliant (Figure 4.19).

Figure 4.19 Actual Window U-factor vs Proposed Performance



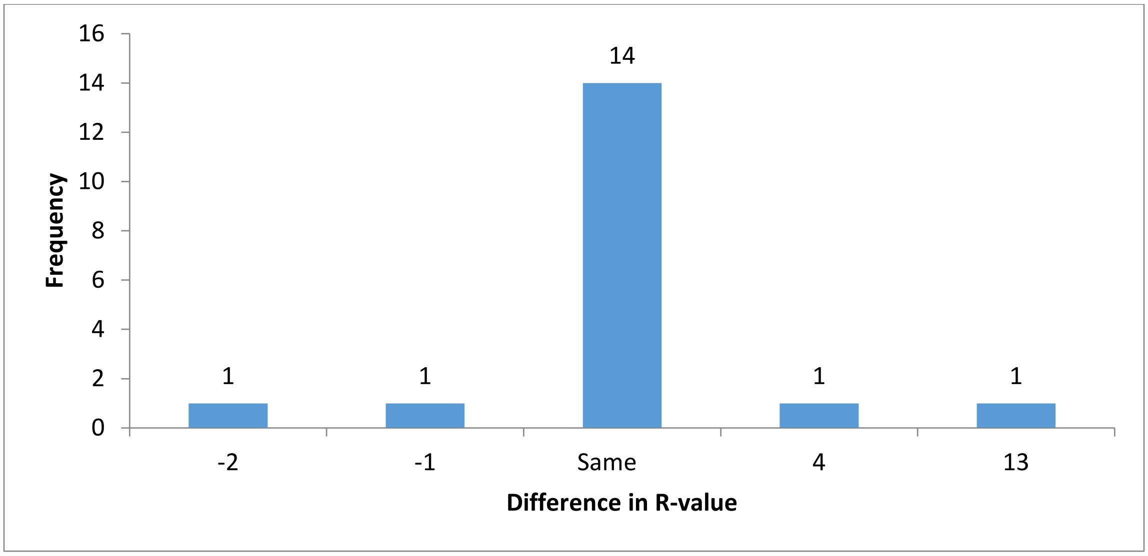
Fifteen percent of houses had proposed performance basement wall insulation R-values higher than the prescriptive code (Figure 4.20).

Figure 4.20 Performance Bsmt. Wall R-value vs Prescriptive



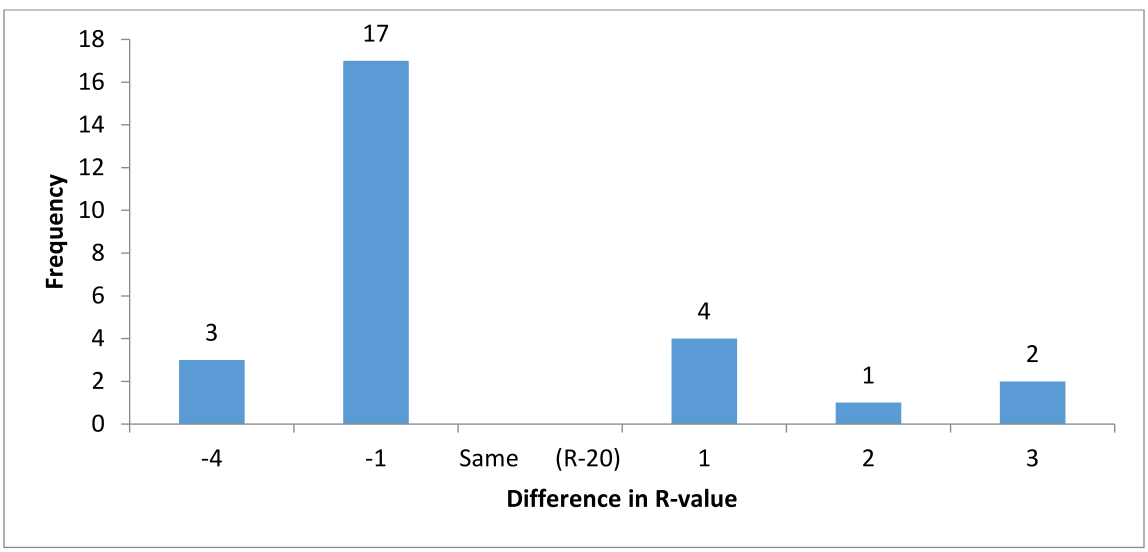
Not all of the houses had basement wall insulation installed as proposed with REScheck. Eighty-nine percent of the observed 18 houses were compliant (Figure 4.21).

Figure 4.21 Actual Bsmt. Wall R-value vs Proposed Performance



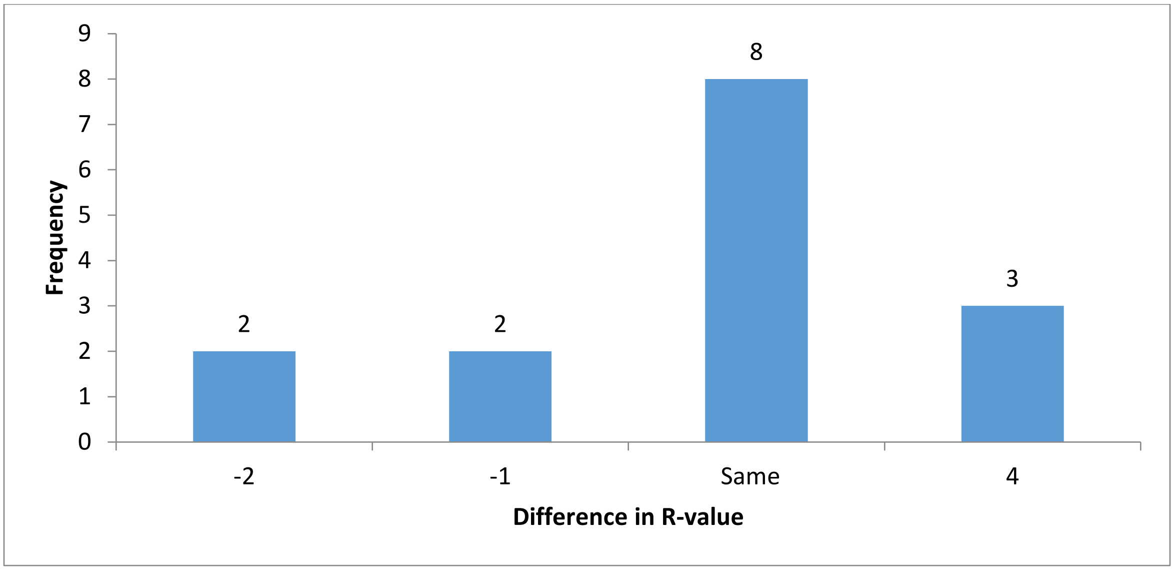
Twenty-six percent of houses had proposed performance exterior wall insulation R-values higher than the prescriptive code (Figure 4.22).

Figure 4.22 Performance Ext. Wall R-value vs Prescriptive



Not all of the houses had exterior wall insulation installed as proposed with REScheck. Seventy-three percent of the 15 observed houses were compliant (Figure 4.23).

Figure 4.23 Actual Ext. Wall R-value vs Proposed Performance



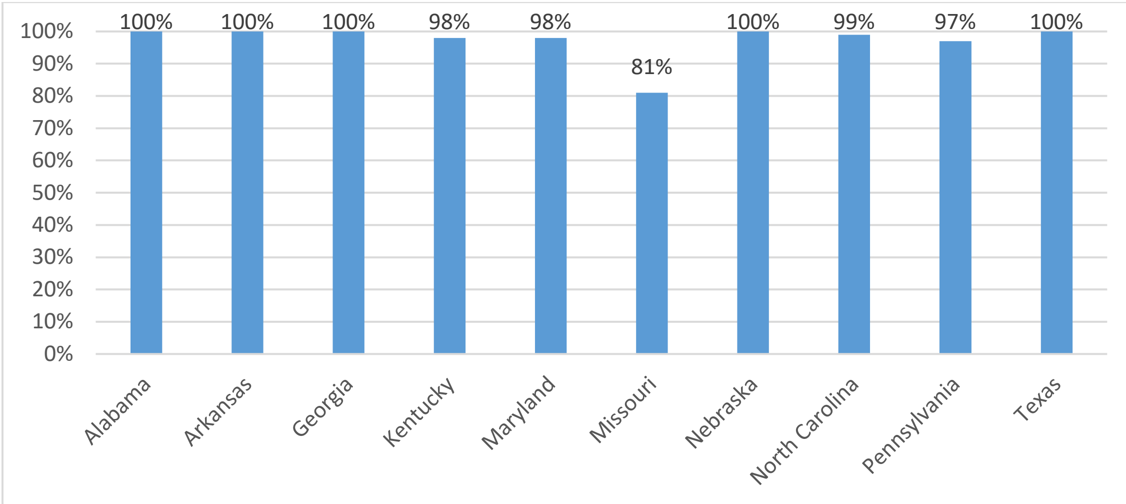
4.5 Nebraska vs. Other States' Compliance

The following figures are a comparison of ten states that have completed their energy code baseline studies. The comparisons are percentages of compliance for each key item in each state based on their current adopted energy code.

Window U-factor

For window U-factor the majority of the states were above 90% compliance except for Missouri, which was above 80%. Nebraska was at 100% compliance along with five other states (Figure 4.24).

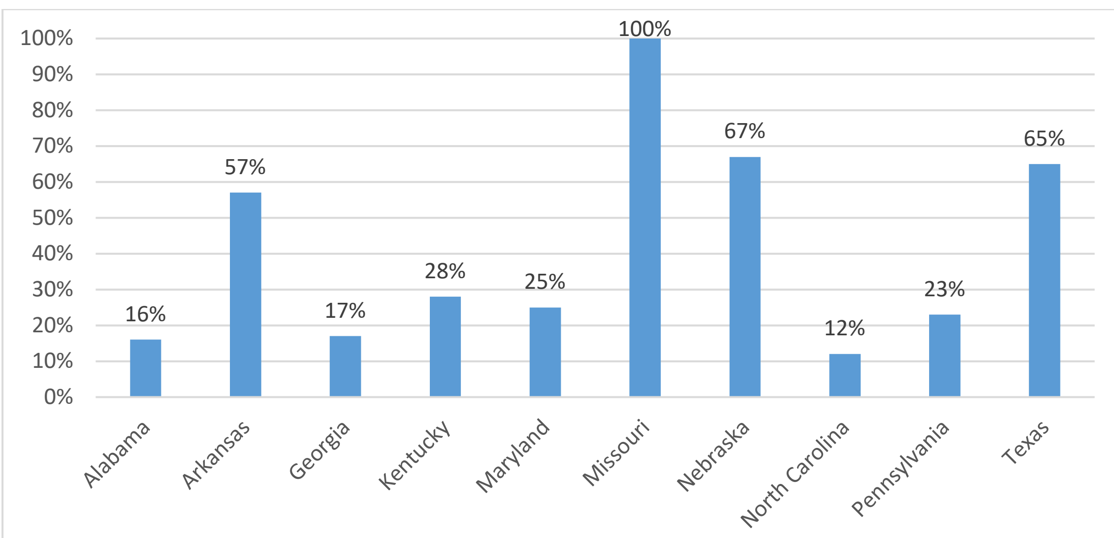
Figure 4.24 Window U-factor



Wall U-factor

The lowest category of compliance among the states was wall U-factor. The nine states involved in the DOE study all figured a wall U-factor with an adjustment for insulation installation quality. Nebraska and Missouri walls were originally calculated as an R-value and then were converted to a U-factor for comparison and did not use an adjustment. Nebraska had one of the highest compliance rates of 67% (Figure 4.25).

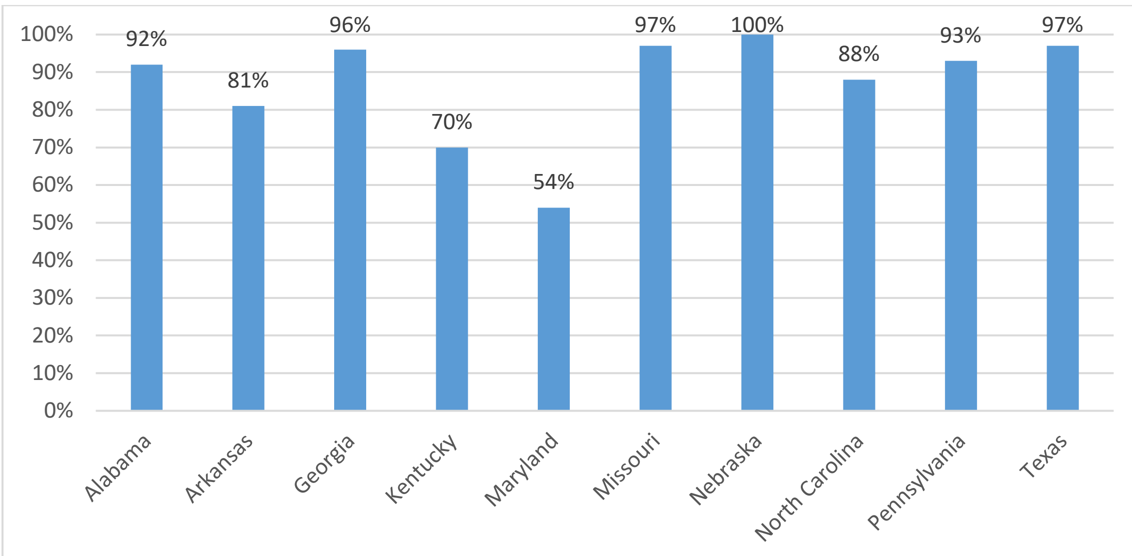
Figure 4.25 Wall U-factor



Envelope Tightness

Nebraska did really well in this area compared to the other states with 100% compliance. Since Maryland's baseline for envelope tightness was based off of the 2015 IECC versus all other states compared against the 2009 IECC its compliance is just above 50%. If compared to the 2009 IECC, Maryland would be close to 90% compliance (Figure 4.26).

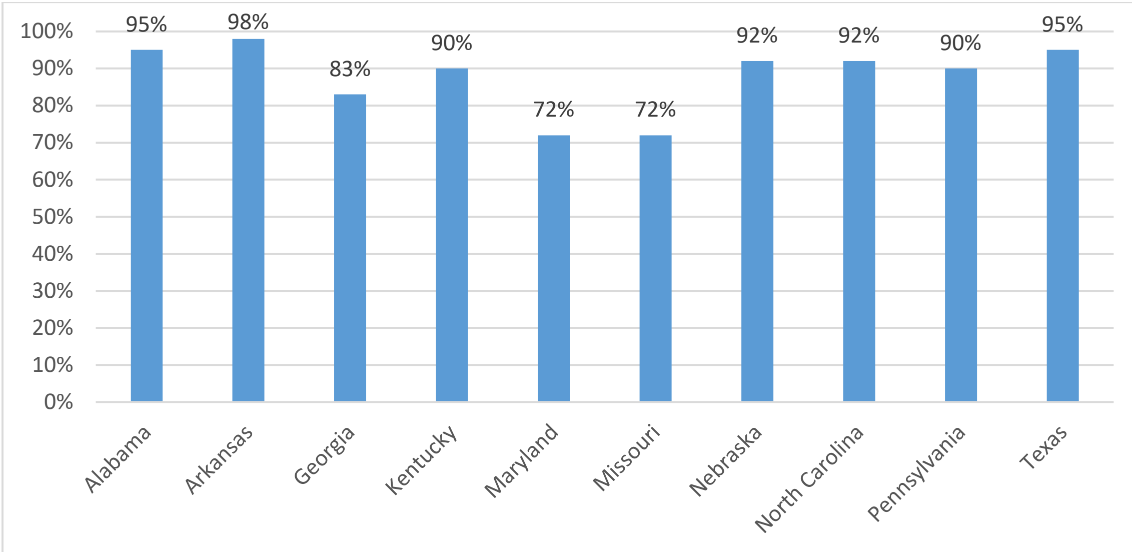
Figure 4.26 Envelope Tightness



Ceiling R-value

Nebraska falls in the average range of all of the states for ceiling R-value. All states' ceiling R-value compliance were above 70% (Figure 4.27). This category had one of the higher compliance rates for all states.

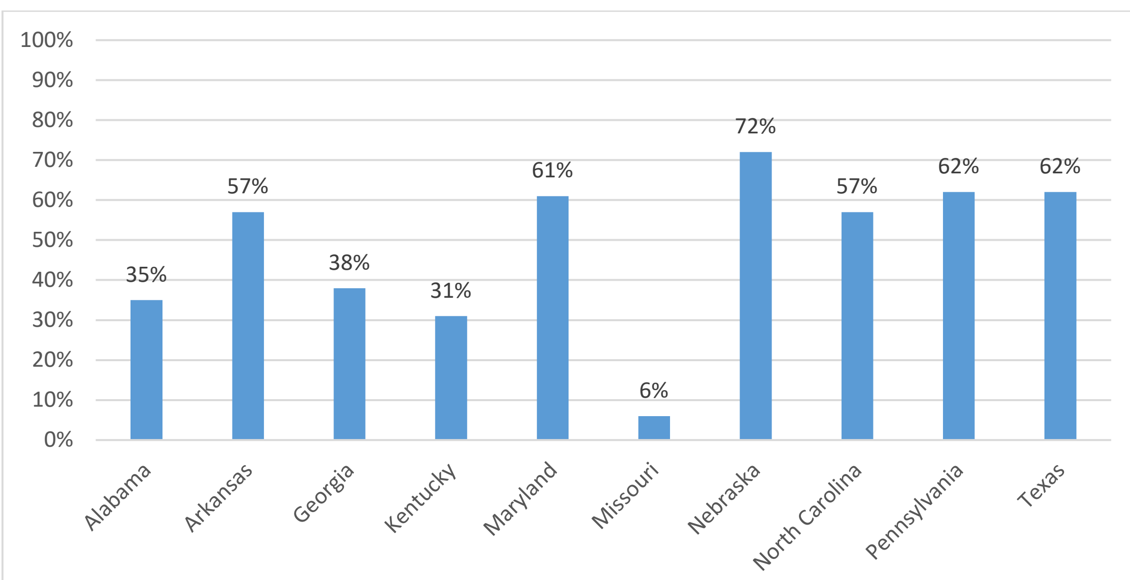
Figure 4.27 Ceiling R-value



High Efficacy Lightning

Nebraska had the highest compliance for high efficacy lighting compared to the other states. Missouri barely met 6% compliance. All states can improve in this area (Figure 4.28).

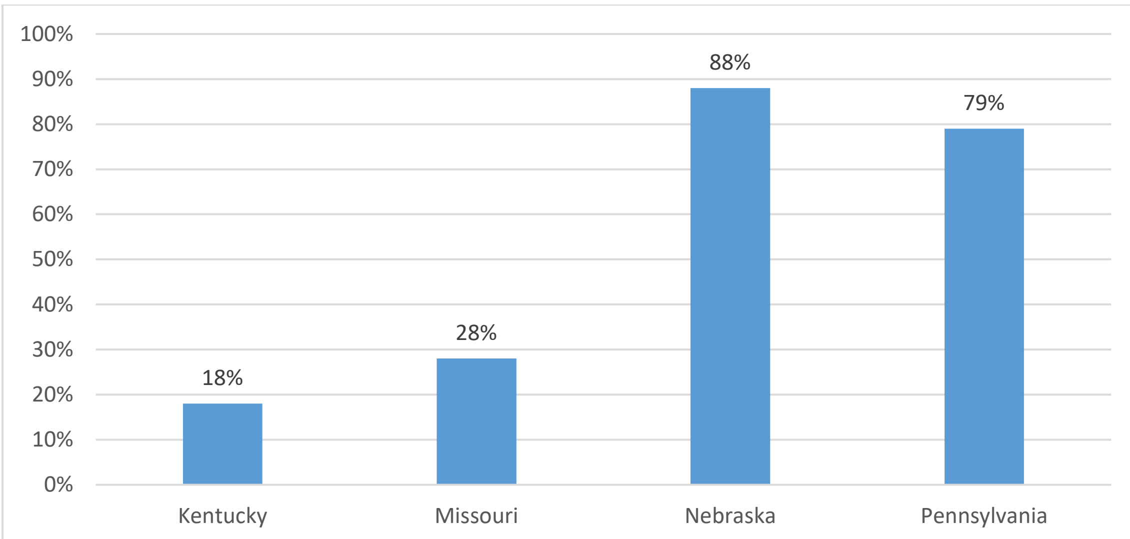
Figure 4.28 High Efficacy Lightning



Basement Wall U-factor

The states in the warmer climate zones had predominately slab foundations. Either no slab insulation was required or it was difficult to observe so no data was collected. Four states had measurable basement wall U-factor compliance (Figure 4.29).

Figure 4.29 Basement Wall U-factor



Duct Tightness

All of the ducktwork tested in Nebraska was in conditioned space. Ductwork contained in conditioned space is not required to meet a certain tightness per the 2009 IECC. For this reason Nebraska had the highest compliance rate compared to other states. If there was no exemption for ductwork being in conditioned space, Nebraska would only be at 17% compliance. Maryland's average compliance would also be higher if compared to the 2009 IECC versus the 2015 IECC (Figure 4.30).

Figure 4.30 Duct Tightness

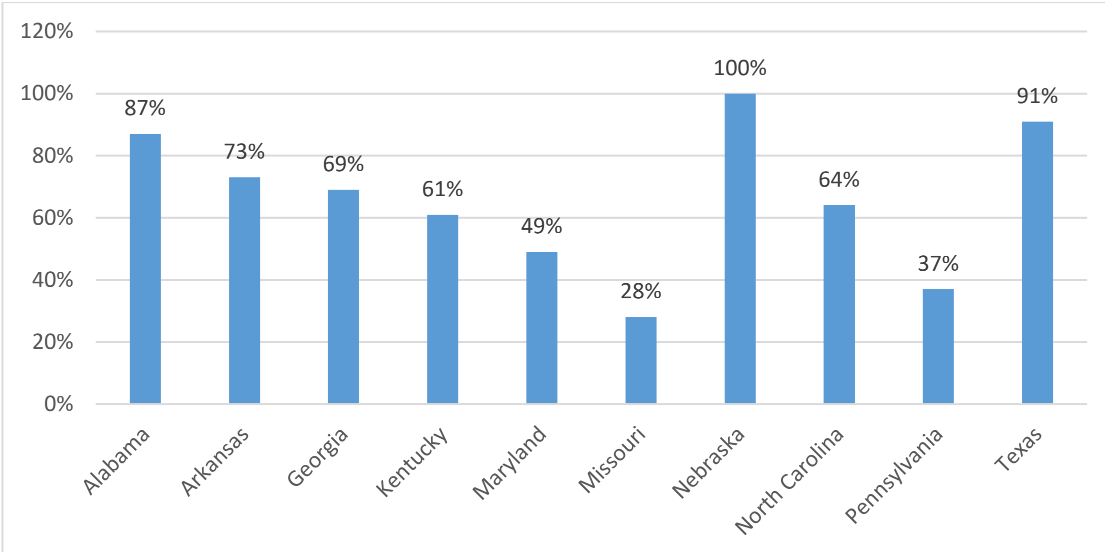


Table 4.1 Comparison of States' Energy Compliance (US Department of Energy, 2017-b)

State	Envelope Tightness	Window U-factor	Wall U-factor	Ceiling R-factor	High Efficacy Lighting	Duct Tightness
Alabama (2009 IECC)	92%	100%	16%	95%	35%	87%
Arkansas (2009 IECC)	81%	100%	57%	98%	57%	73%
Georgia (2009 IECC)	96%	100%	17%	83%	38%	69%
Kentucky (2009 IECC)	70%	98%	28%	90%	31%	61%
Maryland (2015 IECC)	54%	98%	25%	72%	61%	49%
Missouri (2009 IECC)	97%	81%	100%	72%	6%	28%
Nebraska (2009 IECC)	100%	100%	67%	92%	72%	100%
North Carolina (2012 State Code)	88%	99%	12%	92%	57%	64%
Pennsylvania (2009 IECC)	93%	97%	23%	90%	62%	37%
Texas (2009 IECC)	97%	100%	65%	95%	62%	91%
Average	87%	97%	41%	88%	48%	66%

Chapter 5

Discussion

5.1 Analysis

Envelope Tightness

All houses tested recorded five air changes per hour (ACH) or less, or, two ACH better than is required by the 2009 IECC. Building methods and practices are improving. Builders may be resistant to adopt energy codes because of the opinion that some may be difficult to achieve. The 2012 IECC requires all houses in climate zone 5 (Nebraska) to be at three ACH or less. The results show that this could be very achievable without much extra effort. However, a concern is a house being too tight with lack of makeup air or ventilation. The 2012 International Residential Code (IRC) states in section R303.4 Mechanical Ventilation “where the air infiltration rate of a dwelling unit is less than 5 air changes per hour when tested with a blower door at a pressure of 0.2 inch w.c (50 Pa) in accordance with Section N1102.4.1.2, the dwelling unit shall be provided with whole-house mechanical ventilation in accordance with Section M1507.3” (International Code Council, 2017). Very few houses had energy recovery ventilators (ERV’s) installed with their mechanical systems. An ERV will increase the cost of a house, but there is a potential for poor indoor air quality if there is not adequate ventilation.

Window U-factor and SHGC

With all the houses tested coming under the 0.35 required U-factor for windows, this shows there are many efficient window options available. Window manufacturers, for simplicity and availability, tend to conform to the strictest standards so their windows will work in the majority of climate zones in the contiguous United States.

Duct Tightness

The majority of the houses tested had leaky ductwork, even though the ductwork was in the conditioned space. Some of this was due to the Nebraska code allowing air returns in wall cavities rather than sealed ductwork. Also, some houses, mainly in rural areas, were not using rated foil tape or mastic to seal the ductwork. Leaky ductwork in a conditioned areas leads to comfort issues, which often leads to increased energy usage. If a space is not comfortable becauce the conditioned air is being lost to a less-habited basement, then the thermostat is adjusted to compensate and deliver more conditioned air to that space. Tighter ductwork and right-sizing equipment saves on cost of installation and increases comfort, which then saves energy.

Ceiling Insulation R-value

Ceiling insulation R-value had the highest percentage of compliance compared to the other areas of insulation. The majority of the observed houses had blown-in ceiling insulation installed. Some of the lower readings could have been due to installer error. Blown-in insulation is difficult to achieve a uniform depth in all areas. There is more chance of installer error if insulation depth gauges are not installed throughout the entire attic space. A ceiling is not like a wall that the installer can just fill. Many times, while collecting data, the attic access was located in the garage and it was difficult to check all areas of the ceiling insulation for compliance. Ceilings are easy places to add additional insulation at little extra cost to improve the energy performance of houses. There was one house that was visited at the final stage, which had no ceiling insulation observed. The NEO asked the builder after the visit and the reason for non-compliance was because the builder had forgotten. This happens sometimes since ceiling insualation does not usually get installed until the end of construction.

Exterior Wall Insulation R-value

Exterior wall insulation R-value had the lowest percentage of compliance compared to the other areas of insulation. This may be due to the practice of 2x6 exterior walls with fiberglass batt insulation installed between the studs. R-19 insulation is the most available and most commonly used. R-21 insulation will also work in a 2x6 wall and meets the 2009 IECC. Building inspectors may not take the time to look at what is stamped on the batt and instead may just look to make sure there is insulation in the wall. Blown-in fiberglass in a 2x6 wall (R-23) will meet the energy code requirement easily. Another option when using R-19 cavity insulation is to install ½" of rigid foam insulation to the outside of the sheathing to meet the energy code. Some of the reason for prescriptive non-complianc on exterior wall insulation can be attributed to some builders complying by performance means. In Lancaster County, the majority of the houses used R-19 insulation in their walls and increased ceiling insulation R-value or used windows with a lower U-factor to be compliant.

Basement Wall Insulation R-value

Basement wall insulation R-value was better in compliance compared to exterior wall insulation R-value but less than ceiling insulation R-value. R-13 insulation between studs or a R-10 continuous draped insulation were the common methods of complying with the energy code. Sometimes R-11,which is the same thickness as R-13, might be used because it costs less. This small difference may be easy for an inspector to overlook. All of the houses not in compliance used R-11 instead of R-13 insulation.

High Efficacy Lighting

High efficacy lighting had higher compliance in Douglas and Sarpy counties (Omaha) but sporatic compliance in most of the other counties. One reason for non-compliance is that recessed can lights are popular in most houses. These fixtures traditionally use halogen lamps instead of LED or compact fluorescent because of the dimming and color qualities although, more LED's were noted in the study. Compliance greater than 70% shows that there is a trend toward more efficient lighting.

Urban vs Rural Compliance

The average urban compliance was 90% compared to the average rural compliance rate of 82%. This trend is possibly attributed to lower code enforcement because of reduced manpower and fewer full-time code enforcement officials. Douglas, Lancaster, and Sarpy Counties require REScheck for all building permits. The Omaha code jurisdiction contracts with American Energy Advisors who works with the Omaha builders as an independent auditing agency to improve compliance. This third-party company has helped the builders in the Omaha area achieve higher IECC compliance.

Performance vs. Prescriptive

Lancaster County builders do not necessarily install the insulation that is listed on their REScheck report. The county uses REScheck as a way to meet the code by performance rather than prescriptively, but if it is not enforced, it may not happen. The other issue with using REScheck is that Lancaster County does not run the REScheck report themselves to verify that is was done correctly. REScheck can have false data entered, which may make the house appear conforming. One of the observed REScheck reports did not even have any ceiling insulation listed, yet it showed the house as being conforming.

The performance method can be useful for builders who want to continue to use R-19 insulation in the walls without having to go to R-21 or by adding rigid foam insulation to the outside. The submitted REScheck reports showed the majority of builders chose to leave their basement wall insulation at R-13, their exterior wall insulation at R-19 and then put in more efficient windows with U-factors between 0.27 and 0.30 and have ceiling insulation between R-45 to R-50.

Nebraska vs Other States' Compliance

For envelope tightness, the majority of the states, including Nebraska, had high compliance. Most of the houses tested in Nebraska had basements, which tend to have tighter envelopes. All states did well in window U-factor compliance. As stated before, window manufacutrers tend to make windows that are compliant across all continential U.S. climate zones. For comparison purposes, with the other state studies, Nebraska's exterior wall R-value was converted to a U-factor. Wall U-factor had the lowest compliance among the state studies with Nebraska being the highest. The other states were additionally graded on their wall insulation installation. Based on their grade, the wall U-factor could be downgraded, even though the right thickness of insulation was installed to meet the energy code. For ceiling R-factor, the majority of the states, including Nebraska, had high compliance. For high efficacy lighting, Nebraska had the highest compliance compared to all the other states, but none were close to 90 percent compliance. For duct tightness, there seemed to be a relationship between states that built on foundations requiring ductwork run in unconditioned spaces. The only reason Nebraska had a 100% compliance rate was because observed houses ran the ductwork in conditioned space.

Key Items

The seven key items were chosen by DOE because they had the greatest impact on energy savings. Other items could be measured to help give a more complete energy analysis if time and funding allowed. One could be the U-factors of doors. Many houses have doors made almost entirely of glass and other low insulating materials where a lot of energy is lost and sometimes more than through the windows. Other items to measure are whole unit U-factor and the air infiltration rates of windows and doors. Window and door manufactures make units that have low U-factors measured at the center of glass where they are most efficient but do not take into account uninsulated frames or air tightness. Recording efficiency of HVAC equipment would also be beneficial. In the study, it was noted what type of HVAC equipment was in the house if any was observed, but the specific manufacturer and efficiency was not recorded. More efficient HVAC equipment has an impact on energy usage.

No correlation could be established between the seven key items. This is due to how the study was performed. No single house was visited more than once, so on average, only three of the items could be collected at one time. If it were possible to collect all seven key items for each house, along with an energy model and a year's worth of utility bills, then a correlation could possibly be established between some of the items. There would definitely be a correlation between the key items and energy usage.

If one wanted to combine the seven key items into a composite score, my recommendation would be to weigh them all the same since they are all equally important in reducing energy usage. I would give each category one point per percentage of compliance. For example, an item with 90% compliance would receive 9 points or 10 points for 100% compliance. Based on that rationale, Nebraska's composite score would be nine (Table 5.1).

Table 5.1 Nebraska Energy Code Composite Score

Envelope Tightness	Window U-factor	Wall R-value	Ceiling R-value	High Efficacy Lighting	Duct Tightness	Composite Score
10	10	6.7	9.2	7.2	10	9

5.2 Lessons Learned

No study is perfect. I have a few suggestions to improve future studies. Using interns was a good idea for cost savings and data collection, but many of the interns had no construction experience nor understood the different types of insulation. I would suggest having them take a class longer than two days to get more familiar. Then I would have them go out to a couple of houses on their own and do a test to see how they perform. I would also suggest having the interns take a picture of each and every data collection. This was not done very well, so it was difficult for the NEO to do quality control. Some houses had less than ten pictures taken, and many of these pictures were of things other than the data items. In addition, I would require an accurate set of plans for every house and accurate measurements of the volume of each house. The interns were supposed to measure every house, but this did not happen. They relied on the assessors' reports for floor area. The NEO then performed air tightness and duct tightness calculations based on those numbers. I am suspicious of the good air tightness numbers for Nebraska. I did not perform the calculations, but I had to rely on the results the NEO furnished.

5.3 Future Research

For future Nebraska energy code studies, it is recommended for each house tested, to create an energy model in order to predict energy consumption based on observed conditions in the field. Then calculate the potential energy savings, consumer cost savings, and avoided carbon emissions associated with increased code compliance. This was already done for the eight states above, not including Missouri and Nebraska.

A future study of interest would be to examine effective methods of increasing code compliance. This could be accomplished by looking at the currently established baseline. Then educate builders and building officials on the energy code implementation and compliance. The other part of this study could include using a third-party to perform the energy code plan review, inspections, and compliance testing. Then new results would be gathered to measure whether those efforts increased compliance. In addition, developing methods to increase compliance without increasing costs would also be beneficial.

The null test hypothesis would be no improvement in code compliance following the education and third-party assistance. The alternate hypothesis would be an expected improvement in code compliance from the established baseline.

Threats to validity of this study could include not all counties in the state being sampled. Those performing the sampling may exhibit sampling bias. Inexperience by those collecting the data may not report it accurately and may not having photographic evidence of every data collection. Those performing the training to builders and the jurisdictions not being able to do all of the training for the whole state so there may be some differences in training between companies. Not all of the builders whose houses would be sampled would be trained. Funding may not allow third-party companies to assist all the jurisdictions.

Methodology improvements would be to make sure those collecting the data are familiar with construction and insulation installation. Eliminate as much sampling bias as necessary when deciding which houses to sample. The recruiter position would contact jurisdictions, builders, real estate agents, bankers, etc. to find single-family new construction houses. The recruiter would then fill out a spreadsheet of available houses to visit by county. No identifying information would be on the spreadsheet given to the data collectors as to the jurisdiction or builder. A random number generator would pick which houses to visit. This way those performing the actual data collection would not be influenced on which houses to visit. Accurate plans would be required for every house. The recruiter would remove any identifying information if shared with the data collectors.

5.4 Conclusion

This study of residential construction energy code compliance in Nebraska has shown areas in need of improvement. Houses observed in Nebraska were 90% compliant in four of the seven areas studied, and were lowest in compliance in the area of exterior wall insulation. Some of this may be due to the REScheck requirement in Lancaster County, which allows builders to put in less exterior wall insulation if more is added to other areas.

Residential construction envelopes will continue to get tighter, but mechanical ventilation must be installed. Ductwork is often leaky, even though it is in conditioned space. Mastic should be used to seal all joints. It should also be required to use hard ducted HVAC returns instead of wall cavities.

Inspectors, builders, and installers need to be vigilant of the R-value of insulation being installed and required for compliance. Rural code jurisdictions can increase quality of energy code compliance inspections. If REScheck reports are submitted, they should be double checked by the code jurisdictions and also verified at inspection.

Nebraska is performing at the same level as other states in energy code compliance but not above 90% compliance in all seven key areas. States are less compliant in the areas of exterior wall U-factor, high efficacy lighting, and duct tightness.

Energy costs will continue to increase and conservation will continue to be important for the future. States will continue to adopt stricter energy codes, but compliance is key.

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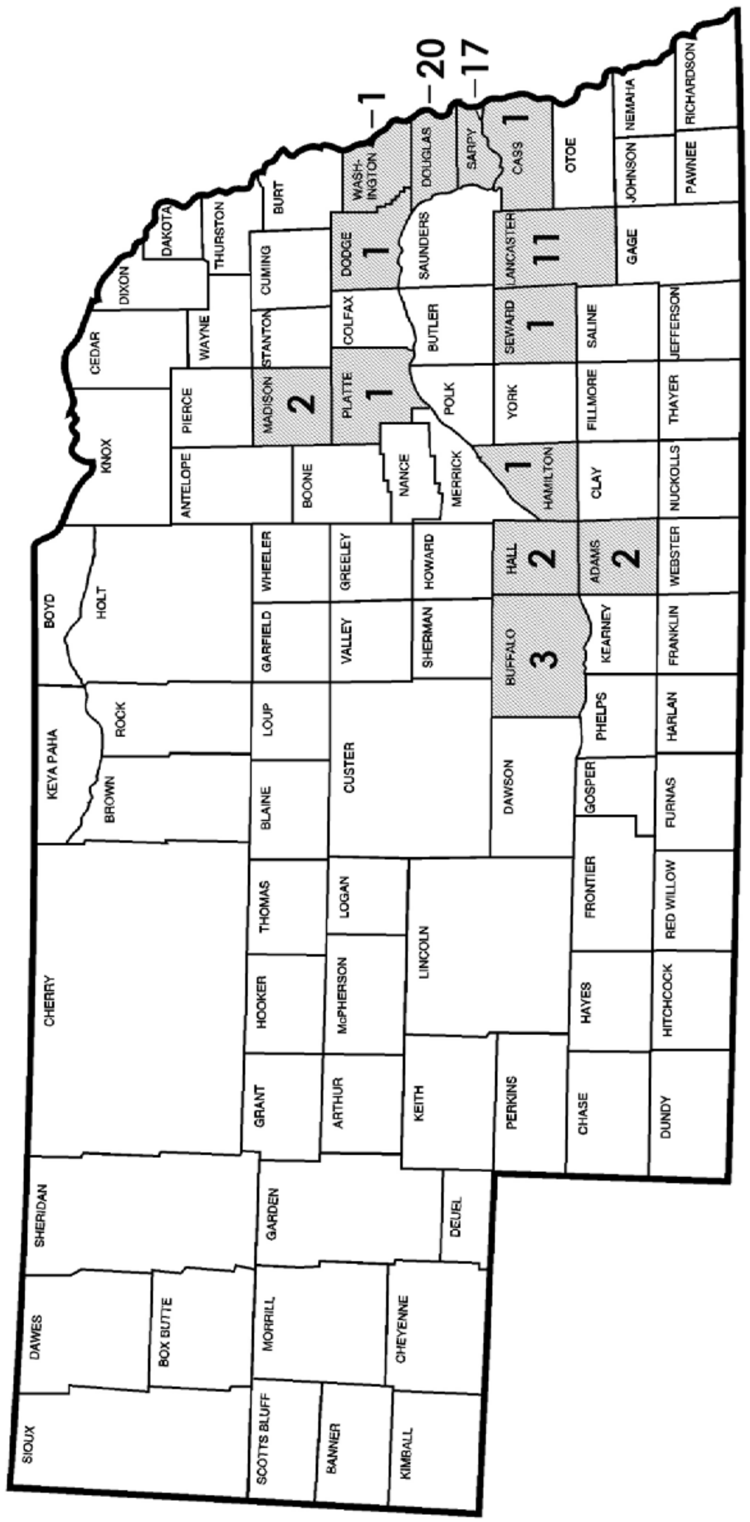
Appendix A

Nebraska Sampling Plan



Appendix B

Data Collection Instrument

2009 IECC Residential Data Collection Form - Home

ID	Code Section	Description	Phase of Construction	Building System	Building System Subcategory	Meets Requirement	Not Applicable	Not Observable	Observation	Format	Units	Comments
Home Documentation - General												
LOC1	NA	State where home is located	Pre-Inspection	Home	General				NE	Text		
LOC2	NA	Climate zone where home is located	Pre-Inspection	Home	General				Zone 5	Text		
LOC3	NA	Does the home fall in the Warm-Humid Zone (question applicable only to zone 3)	Pre-Inspection	Home	General				None	Yes or No		
LOC4	NA	County where home is located	Pre-Inspection	Home	General					Text		
LOC6	NA	Identification Code for home	Pre-Inspection	Home	General					Text		
Home Documentation - Compliance												
Comp1	NA	Energy code to which the home is permitted	Pre-Inspection	Home	Compliance				2009	Text		
Comp3	NA	Did this or will this home use REScheck for compliance?	Pre-Inspection	Home	Compliance					Yes or No		
Comp6	NA	Compliance documentation with energy code details (e.g., plans, REScheck report, etc.) was available and reviewed for this home.	Pre-Inspection	Home	Compliance					Yes or No		
Home Documentation - Size and Shape												
Geo1	NA	Total Conditioned Floor Area for the building (intended or actual)	Pre-Inspection	Home	Size and Shape					Number	Square feet	
Geo2	NA	Number of stories above grade (intended or actual)	Pre-Inspection	Home	Size and Shape					Number	Stories	
Geo3	NA	Number of bedrooms	Pre-Inspection	Home	Size and Shape					Number	Bedrooms	

General Comments

The cell below is intended for use by the Project Team to provide any additional general information that may be of use when the data is analyzed. Please do not provide any personally identifiable information such as homeowner or builder names or addresses.

2009 IECC Residential Data Collection Form - Envelope

ID	Code Section	Description	Phase of Construction	Building System	Building System Subcategory	Key Item or Key Item Modifier or Result Weighter	Meets Requirement	Not Applicable	Not Observable	Field Observation	Format	Units	Comments
Envelope Air Leakage													
FI17	***402.4.2.1***	***Blower door test results from Project Team test using RESNET Protocol (ACH @ 50 PA)***	Final Inspection	Envelope	Air Leakage	Key Item					***Number***	***ACH50***	
Envelope Ceiling and Attic													
BG15	NA	Is the insulation located on the ceiling or at the rafters?	Insulation	Envelope	Ceiling and Attic						Text		
FI1	***402.1.1, 402.2.1, 402.2.2, 402.2.5***	***Predominant ceiling insulation Total R-value (cavity and continuous insulation)***	Final Inspection	Envelope	Ceiling and Attic	Key Item					***Number***	***R-value***	
M1	NA	What is the attic framing material - wood or steel?	Framing Rough-In	Envelope	Ceiling and Attic						Text		
IQ1	NA	What is the roof cavity insulation quality? (I,II,III) - see INFO - Insulation Grading tab	Insulation	Envelope	Ceiling and Attic	Key Item Modifier					Text		
Envelope Fenestration													
FR2	***402.1.1, 402.3.1, 402.3.3, 402.5***	***Window NFRC-rated U-factor (area-weighted average)***	Framing Rough-In	Envelope	Fenestration	Key Item					***Number***	***U-factor***	
FR3	***402.1.1, 402.3.2, 402.3.3, 402.5***	***Glazed fenestration (including windows, glazed doors, and skylights) NFRC-rated SHGC value (area-weighted average)***	Framing Rough-In	Envelope	Fenestration	Key Item					***Number***	***SHGC***	
Envelope Foundation All Foundations													
BG17	**NA**	**Predominant (most common) foundation type - Slab-on-grade, Unvented crawlspace, Vented Crawlspace, Heated basement, Unheated basement**	Foundation	Envelope	All Foundations	Result Weighter					Text		
Envelope Foundation Basement													
FO4a	***402.1.1***	***Heated basement wall insulation R-value (cavity insulation)***	Foundation	Envelope	Basement	Key Item					***Number***	***R-value***	
FO4b	***402.1.1***	***Heated basement wall insulation R-value (continuous insulation)***	Foundation	Envelope	Basement	Key Item					***Number***	***R-value***	
IQ4	NA	What is the basement cavity insulation quality? (I,II,III) - see INFO - Insulation Grading tab	Insulation	Envelope	Basement	Key Item Modifier					Text		

Envelope Foundation Crawlspace														
FO7a	***402.2.9***	***Unvented crawl space wall insulation R-value (cavity insulation)***	Foundation	Envelope	Crawlspace	Key Item					***Number***	***R-value***	
FO7b	***402.2.9***	***Unvented crawl space wall insulation R-value (continuous insulation)***	Foundation	Envelope	Crawlspace	Key Item					***Number***	***R-value***	
CSIQ1	NA	What is the crawl space wall cavity insulation quality? (I,II,III) - see INFO - Insulation Grading tab	Foundation	Envelope	Crawlspace	Key Item Modifier					Text		
Envelope Foundation Floor														
IN1a	***402.1.1, 402.2.5, 402.2.6***	***Floor insulation R-value (cavity insulation)***	Insulation	Envelope	Floor	Key Item					***Number***	***R-value***	
IN1b	***402.1.1, 402.2.5, 402.2.6***	***Floor insulation R-value (continuous insulation)***	Insulation	Envelope	Floor	Key Item					***Number***	***R-value***	
M2	NA	What is the floor framing material wood or steel?	Framing Rough-In	Envelope	Floor						Text		
IN2	402.2.6	Floor insulation installed in substantial contact with the underside of the subfloor	Insulation	Envelope	Floor						Check Box		
IQ2	NA	What is the floor cavity insulation quality? (I,II,III) - see INFO - Insulation Grading tab	Insulation	Envelope	Floor	Key Item Modifier					Text		
Envelope Foundation Slab														
FO1	***402.1.1***	***Slab edge insulation R-value***	Foundation	Envelope	Slab-On-Grade	Key Item					***Number***	***R-value***	
Slab1	NA	Is the slab heated?	Foundation	Envelope	Slab-On-Grade						Yes or No		
Envelope Wall Frame (Does not include knee walls)														
IN3a	***402.1.1, 402.2.5***	***Frame Wall insulation R-value (cavity insulation)***	Insulation	Envelope	Frame Wall	Key Item					***Number***	***R-value***	
IN3b	***402.1.1, 402.2.5***	***Frame Wall insulation R-value (continuous insulation)***	Insulation	Envelope	Frame Wall	Key Item					***Number***	***R-value***	
M3	NA	What is the wall framing material - wood or steel?	Framing Rough-In	Envelope	Frame Wall						Text		
IQ3	NA	What is the frame wall insulation quality? (I,II,III) - see INFO - Insulation Grading tab	Insulation	Envelope	Frame Wall	Key Item Modifier					Text		
Envelope Wall Mass (Does not include knee walls)														
FR10a	***402.1.1***	***Mass wall insulation R-value (cavity insulation)***	Framing Rough-In	Envelope	Mass Wall	Key Item					***Number***		
FR10b	***402.1.1***	***Mass wall insulation R-value (continuous insulation)***	Framing Rough-In	Envelope	Mass Wall	Key Item					***Number***	***R-value***	

2009 IECC Residential Data Collection Form - Mechanical

Key Items marked in bold and italics

ID	Code Section	Description	Phase of Construction	Building System	Building System Subcategory	Key Item or Key Item Modifier or Result Weighter	Meets Requirement	Not Applicable	Not Observable	Field Observation	Format	Units	Comments
Mechanical Ducts													
FI4a	***403.2.2***	***First Duct System - Duct tightness test result (postconstruction total leakage) by Project Team using RESNET Protocol (CFM/100 ft^2 floor area @ 25 Pa) (for systems with portion of ducts outside conditioned area)***	Final Inspection	Mechanical	Ducts	Key Item					***Number***	***CFM/100 ft^2***	
FR13a	403.2.2	All joints and seams of air ducts are sealed	Framing Rough-In	Mechanical	Ducts						Check Box		
FR15	403.2.3	Building cavities are not used as supply ducts or plenums	Framing Rough-In	Mechanical	Ducts						Check Box		
FR12a	403.2.1	Supply duct in unconditioned space or outside insulation R-	Framing Rough-In	Mechanical	Ducts						Number	R-value	
FR12b	403.2.1	Return duct in unconditioned space or outside insulation R-	Framing Rough-In	Mechanical	Ducts						Number	R-value	
DP5	NA	Rough percentage of supply duct in conditioned space	Framing Rough-In	Mechanical	Ducts	Key Item Modifier					Number	Percent	
DP9	NA	Rough percentage of return duct in conditioned space	Framing Rough-In	Mechanical	Ducts	Key Item Modifier					Number	Percent	
Mechanical Equipment													
EQ1	NA	Predominant heating Source - gas, oil, electricity, wood	Pre-Inspection	Mechanical	Equipment						Text		
EQ2a	NA	First Heating System - Heating system type - furnace, boiler, heat pump, electric resistance strip heat, woodstove	Pre-Inspection	Mechanical	Equipment	Result Weighter					Text		
EQ5a	NA	First Cooling System - Cooling system type - central ac, room ac, heat pump	Pre-Inspection	Mechanical	Equipment						Text		
EQ8	NA	Predominant hot water heating source - gas, oil, electricity, wood, solar	Pre-Inspection	Mechanical	Equipment						Text		
EQ9	NA	Water heating system type - storage, tankless	Pre-Inspection	Mechanical	Equipment						Text		

2009 IECC Residential Data Collection Form - Lighting

Key Items marked in bold and italics

ID	Code Section	Description	Phase of Construction	Building System	Building System Subcategory	Key Item or Key Item Modifier or Result Weighter	Meets Requirement	Not Applicable	Not Observable	Field Observation	Value Format	Units	Comments
Lighting Documentation													
FI6	***404.1***	***Percentage of permanently installed fixtures that have high-efficacy lamps***	Final Inspection	Lighting	Documentation	Key Item					***Number***	***Percent***	

2009 IECC Residential Compliance Evaluation Forms - Insulation Grading

Cavity Insulation Grading Definitions per https://staging.remrate.com/Wiki/Cavity-Insulation-Grade.ashx

Grade I: Grade I shall be used to describe insulation that is generally installed according to manufacturers instructions and/or industry standards. A "Grade I" installation requires that the insulation material uniformly fills each cavity side-to-side and top-to-bottom, without substantial gaps or voids around obstructions (such as blocking or bridging), and is split, installed, and/or fitted tightly around wiring and other services in the cavity.

To obtain a "Grade I", wall insulation shall be enclosed on all six sides, and shall be in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity. For exterior applications of rigid insulation, insulation shall be in firm contact with the structural sheathing materials and tightly fitted at joints. For faced batt insulation, Grade I can be designated for side-stapled tabs, provided the tabs are stapled neatly (no buckling), and provided the batt is only compressed at the edges of each cavity, to the depth of the tab itself. For sprayed and blown-in insulation, density shall be sufficient that the fill material springs back when compressed slightly with a hand or finger.

Grade II: Grade II shall be used to describe an installation with moderate to frequent installation defects: gaps around wiring, electrical outlets, plumbing and other intrusions; rounded edges or "shoulders"; or incomplete fill amounting to 10% or more of the area with less than 70% of the intended thickness (i.e., 30% compressed); or gaps and spaces running clear through the insulation amounting to no more than 2% of the total surface area covered by the insulation.

Grade III: Grade III shall be used to describe an installation with substantial gaps and voids, with missing insulation amounting to greater than 2% of the area but less than 5% of the surface area it is intended to occupy. More than 5% missing insulation shall be measured and modeled as separate, uninsulated surfaces.

The insulation grade is applied to foundation wall, frame floor, above grade wall, and ceiling cavity insulation only.