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 that would have the most effect on energy savings were analyzed. The study included looking at both urban and rural areas of the state and comparing 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, for the state of Nebraska, code jurisdictions and builders still have room for improvement.

Key Words: Energy codes, Compliance, Residential, Construction, IECC

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 CO_2 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 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). Students in UNL's architecture and construction management programs collected the field energy data. NEO provided project oversight and contracted independent, 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 assessing differences between urban and rural code compliance.

Using a DOE prescribed data collection protocol developed by Pacific Northwest National Laboratory (PNNL), data was collected for each of seven (7) key energy code compliance categories:

- 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 key items shown above, since it would be impossible to collect all the data at the same stage of construction (e.g. wall insulation and lighting).

Method

Sampling Plan

In order to obtain a statistically significant sample of observations, a statewide sampling plan was developed by PNNL. An initial sampling plan was based off US Census Bureau numbers along with single family homes, by county, constructed over the last three years. This initial sampling plan was then shared at stakeholder meetings. Based on feedback from stakeholder meetings, a final sampling plan identified how many data sets were required to be collected from each county (Appendix A). 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. Naturally, many counties in Nebraska were not selected at all. Other states have performed similar studies and were also required to collect a minimum of 63 data sets for the whole state regardless of population or size.

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 IEEC 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).

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, and local code jurisdictions in order to find available houses in the appropriate stage of construction for data collection.

Houses for the study were chosen by county and availability rather than by floor area or builder. Finding single-family residential homes in all of the selected counties for data collection was a challenge, 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 normally 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.

Data Collection

Data collection concentrated first on Douglas, Lancaster, and Sarpy Counties since the majority of the data sets required were in those counties. Inspections 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.

Insulation Inspection

The following information was collected at the insulation stage:

- Basement wall insulation R-value
- Exterior wall insulation R-value
- Duct insulation R-value (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. For fiberglass, the R-value was verified by reading the printed R-value on the face of the batt. The window U-value was determined by reading the manufacturer's label affixed to the windows. 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.

Final Inspection

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

- 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 were installed in the attic to help verify the thickness. 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). Then air changes per hour (ACH) was calculated based on the volume of the house. 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. The 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.

Results

Categories At or Above 90 Percent Compliance

Envelope Tightness (ACH50)

All houses tested for envelope tightness met the 2009 IEEC requirement of seven (7) ACH at 50 Pa of pressure maximum. The average was 3 ACH.

Window U-Factor

All houses tested for window U-factor compliance met the 2009 IEEC requirement of a maximum U-factor of 0.35. The average was a 0.30 U-factor.

Duct Tightness

All houses visited for data collection complied with the 2009 IECC because all ductwork was contained in the conditioned area. If 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 less than 12 CFM/100 SF @ 25 Pa.

Ceiling Insulation R-value

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

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).

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).

High Efficacy Lighting

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

Urban Code Compliance vs Rural Code Compliance

Envelope Tightness (ACH50)

Houses in urban and rural areas were both compliant with the 2009 IEEC maximum of 7 ACH50, but rural houses had lower overall numbers and tighter envelopes.

Window U-factor

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

Duct Tightness

All of the 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 and had leaky ductwork above the 12 CFM/125 SF @25 Pa that the 2009 IECC requires for ductwork outside of the conditioned area. The rural houses had a higher percentage of leaky ductwork including some that were so leaky that a reading could not be achieved.

High Efficacy Lighting

Urban houses had a 75% compliance rate compared to rural houses, which had a 63% compliance rate with the 2009 IECC for a minimum 50% high efficacy lighting.

Ceiling Insulation R-value

Urban houses had a 94% compliance rate compared to rural houses, which had a 87% compliance rate with the 2009 IECC for ceiling insulation.

Basement Wall Insulation R-value

Urban houses had a 91% compliance rate compared to rural houses, which had a 80% compliance rate with the 2009 IECC for basement wall insulation.

Exterior Wall Insulation R-value

Urban houses had a 71% compliance rate compared to rural houses, which had a 55% compliance rate with the 2009 IECC for exterior wall insulation.

Nebraska vs Other States' Compliance

Eight other states have conducted similar DOE funded residential energy code compliance studies since 2014 (Table 1).

Table 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	92%	100%	16%	95%	35%	87%
Arkansas	81%	100%	57%	98%	57%	73%
Georgia	96%	100%	17%	83%	38%	69%
Kentucky	70%	98%	28%	90%	31%	61%
Maryland	54%	98%	25%	72%	61%	49%
Nebraska	100%	100%	67%	92%	72%	100%
North Carolina	88%	99%	12%	92%	57%	64%
Pennsylvania	93%	97%	23%	90%	62%	37%
Texas	97%	100%	65%	95%	62%	91%
Average	86%	99%	34%	90%	53%	70%

Discussion

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. A concern is what happens if a house is too tight and there is no 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 indoor air quality issues if there is not adequate ventilation.

Window U-factor

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 that their windows will work in the majority of climate zones in the continential 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 is due to Nebraska still 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 too hot or too cold because the conditioned air is being lost to a less habited basement space, 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 were probably 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.

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 lower numbers in 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 in the middle of compliance compared to the other areas of insulation. 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. Recessed can lights are very popular in most houses. These fixtures traditionally used incandescent lamps instead of LED or compact fluorescent because of the dimming and color qualities although LEDs are catching up. 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 84%. This trend is possibly attributed to lower code enforcement. 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.

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 down graded, 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 who built on foundations that required ductwork to be run in unconditioned spaces. The only reason Nebraska had a 100% compliance rate was because observed houses ran the ductwork in conditioned space.

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

Nebraska Sampling Plan