Energy Impact Study of the 2009 IECC and 2015 IECC Energy Codes for Nebraska

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Executive Summary

The focus of this report is annual residential energy consumption under two energy code conditions. The codes compared are:

- Nebraska's current residential energy code, the 2009 International Energy Conservation Code (IECC), and
- The 2015 International Energy Conservation Code (IECC).

2015 IECC performs best

The findings of this study indicate that the 2015 International Energy Conservation Code would result in less energy consumption for homes in all areas of the state. Most of the savings is related to heating. There is little change in cooling energy use, and a comparatively small savings in lighting energy. The largest contribution to the energy savings is achieved by increasing airtightness to 3 air changes per hour at 50 Pa pressure difference (ACH50), compared to the existing 7 ACH50 airtightness limit in the current code. The next largest contributors to savings are foundation wall insulation, duct leakage, windows, ceiling insulation, and increased high efficacy lighting.

The average overall energy savings was 19.5%, ranging from 16% for the smallest house in Omaha to 25% for the largest house in Chadron. The average savings in whole-house energy cost was 9.6%. Depending on house size and location, the savings range from $148 to $564 per year, with an average annual savings of $283.

While there are significant opportunities to save energy with the 2015 IECC, these savings do not come without challenges. The 3 ACH50 target is a difficult but achievable target. To achieve this result reliably for every home, we recommend statewide builder education and a pre-drywall verification checklist to prevent failures from commonly occurring. If 3 ACH50 is not achieved, it can be very difficult to seal a home to this level after drywall is installed. If implementing the new code, the state may wish to consider a transitional phase-in period, during which any home that is tested but fails to reach 3 ACH50 would not result in a home failing to obtain a certificate of occupancy.

Key differences between 2009 and 2015 codes

There are several important differences between the 2009 and 2015 IECC codes. These are:

1. Maximum glazing U-factor has been decreased to 0.32. This change impacts both opaque doors and windows.
2. Minimum ceiling R-value has increased from R-38 to R-49.
3. Minimum basement wall insulation has increased from R-10 to R-15 for continuous insulation, and from R-13 to R-19 for frame cavity insulation.
4. The minimum percentage of high-efficacy lighting has increased from 50% to 75%. This includes compact fluorescent, fluorescent, and other lamps of similar efficacy (for example, LED).
5. Both codes require duct testing if any portion of the ducts or air handler are located outside of conditioned space. Three test methods are allowed, each method having its own airtightness requirement:

   a. Duct leakage to the outdoors tested post-construction: maximum of 4% of the conditioned floor area (reduced from 8% under the 2009 IECC)
   b. Total duct leakage tested at rough-in with air handler installed: maximum of 4% of the conditioned floor area (reduced from 6% under the 2009 IECC)
   c. Total duct leakage tested at rough-in without air handler installed: maximum of 3% of the conditioned floor area (reduced from 4% under the 2009 IECC)
6. Both codes require that air sealing of the building thermal envelope be performed. The 2009 IECC required that air sealing be verified either by visual inspection of certain items or by performing a blower door test on a completed home and achieving a result of 7 ACH50 or less. The 2015 IECC requires that a blower door test be performed, with a result of 3 ACH50 or less.
7. By reference to the IRC or IMC, the 2015 IECC requires a whole-house ventilation using rates specified by ASHRAE Standard 62.2-2010.

About the Study

The study considers the annual energy consumption of houses constructed according to the 2009 and 2015 IECC energy codes. Energy use was modeled for three cities selected to represent climate variability in the state: Chadron, Norfolk, and Omaha. Energy modeling was performed using REM/Rate, a commercially available software tool that conforms to RESNET standards[1] for home energy ratings. The RESNET standard is used as the basis for energy-efficient mortgages and is also a primary means used by EPA to determine compliance for the Energy Star® new homes program. It is the most widely accepted means of assessing and comparing home energy performance currently being used in the US.

Four houses were modeled for the study. These include a small ranch style house with 1,453 square feet (sf), a medium ranch style house with 1,852 sf, a medium two story house with 2,103 sf, and a large two story house at 2,932 sf. Each house was modeled with both 12% and 18% window to wall area ratio. Occupancy and usage patterns were based on national data for average use.

The modeling approach and houses used in this analysis were based on those used for a 2003 study of Nebraska energy codes[2], and follow-up studies performed in 2006, 2009, and 2012 based on updated versions of the IECC[3,4,5]. The first study investigated the life cycle cost impacts of upgrading Nebraska's state energy code from the 1983 Model Energy Code to the 2000 IECC. That study concluded that the new energy code would save buyers of new homes between $50 and $295 per year, depending on the size of the house and where they lived. Statewide, the new code was projected to save homeowners $254,000 the first year, and $59.6 million dollars over the life of houses built before 2015. The 2006 study showed that adoption of the 2006 IECC would not save energy compared with the 2003 IECC for the majority of new homes in Nebraska. The 2009 study showed that the 2009 IECC would provide savings, despite some reductions in required envelope insulation. The 2009 IECC was subsequently adopted by the state. The 2012 IECC included most of the changes that are in the 2015 IECC, and produced energy savings in heating and lighting, but was not subsequently adopted by the state.

About Energy Codes

Energy codes establish minimum insulation requirements for both commercial and residential buildings. Residential codes benefit homeowners by ensuring that newly constructed homes make use of modern techniques and products that make houses energy-efficient. This results in lower energy bills and often improved thermal comfort for the homeowner, and optimal utilization of fossil fuels and nonrenewable resources for communities. Codes also level the playing field for builders by requiring a basic level of quality in areas that homeowners might not see when they are buying a house (for example, the insulation in the walls).

About the Author

Amy Musser holds a Ph.D. degree in Architectural Engineering and an M.S. degree in Mechanical Engineering. She is also a registered professional engineer in the state of Nebraska, and has been conducting research in the fields of building energy and indoor air quality for approximately 20 years. She completed the original Nebraska codes study that investigated the life cycle cost impact of the 2000 IECC for Nebraska while she was a faculty member in the Architectural Engineering Program at the University of Nebraska-Lincoln. She currently holds the position of Principal at Vandemusser Design, LLC, a building energy and air quality consulting firm that she co-founded.

Disclaimer

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Introduction

The objective of this study was to compare the energy impact for Nebraska homeowners under the 2009 International Energy Conservation Code (IECC) and the 2015 IECC. Both comparisons were performed with code-minimum and Energy Star heating equipment. The study compares the modeled energy use of four houses in three Nebraska climates: Omaha, Norfolk, and Chadron. The four houses are based on those used for previous studies of Nebraska energy codes[2,3,4,5]. The houses include a ranch style house at the 20th percentile size being constructed in Nebraska, a ranch style house and a two story house at the median home size, and a two story house at the 80th percentile size. Each house is investigated with both 12% and 18% window to wall area ratio. Occupancy and appliance loads were modeled based on the RESNET standard[1].

Selection and specification of houses modeled

House size and type

The four houses studied were based on those used for a previous study of the life cycle cost impact of adopting the 2000 IECC in Nebraska[2]. A 2002 survey of Nebraska building code officials conducted as part of that study was used as the basis for selecting four homes for modeling. Their square footages represent homes at the 20th percentile, mean, median, and 80th percentile of Nebraska homes. The actual houses modeled, their square footages, and other characteristics are shown in Table 1.

One difference from the original study is that the four houses were modeled with window to wall area ratios of both 12% and 18%. In the original study, the houses were modeled with the actual window area shown on the building plans. The 2006 study[3] was updated to model the homes with window to wall ratios of 12% and 18% due to the code change eliminating more stringent requirements for homes with larger than a 15% window to wall ratio.

House	Plan area	Style	Ceiling height (range, ft)	Above grade exterior wall area (sf)
20th percentile	1,453 sf	ranch	7.5-10.0	1,530
Surveyed mean	1,852 sf	ranch	7.5-10.0	2,070
Midwest mean	2,103 sf	2 story	7.5-9.0	2,620
80th percentile	2,932 sf	2 story	7.5-12.7	2,540

Table 1. Characteristics of houses modeled.

According to the survey, 92% of Nebraska houses have basements and 26% of these are finished basements. All four houses were modeled with conditioned basements. The survey also found that when records on the type of heating and cooling systems installed were available, 67% of new homes have gas-fired forced air furnaces and central air conditioning systems. All four homes were modeled using this type of heating/cooling system for both codes.

Occupant and appliance loads

Occupant behavior and heat gains associated with people and their activities influence the energy required for heating and cooling. The RESNET standard assumes a default lights and appliances load based on the square footage of the home, as well as typical occupant schedules that affect the consumption of this energy and the internal loads in the home. The number of people living in each home under the standard is the number of bedrooms plus one.

Codes

Two energy code conditions and two heating systems were modeled. The codes were the 2009 IECC (International Energy Conservation Code) and the 2015 IECC. The heating systems were forced air furnaces with efficiencies of 80% and 90% AFUE. Although the code minimum is 78% AFUE, 80% AFUE furnaces are widely available and so commonly installed that they can be considered the de facto minimum. 90% AFUE furnaces are a widely available upgrade.

Key changes in the 2015 IECC include:

1. Maximum glazing U-factor has been decreased to 0.32. This change impacts both opaque doors and windows.
2. Minimum ceiling R-value has increased from R-38 to R-49.
3. Minimum basement wall insulation has increased from R-10 to R-15 for continuous insulation, and from R-13 to R-19 for frame cavity insulation.
4. The minimum percentage of high-efficacy lighting has increased from 50% to 75%. This includes compact fluorescent, fluorescent, and other lamps of similar efficacy (for example, LED).
5. Both codes require that duct testing if any portion of the ducts or air handler are located outside of conditioned space. Three test methods are allowed, each method having its own airtightness requirement:
    a. Duct leakage to the outdoors tested post-construction: maximum of 4% of the conditioned floor area (reduced from 8% under the 2009 IECC)
    b. Total duct leakage tested at rough-in with air handler installed: maximum of 4% of the conditioned floor area (reduced from 6% under the 2009 IECC)
    c. Total duct leakage tested at rough-in without air handler installed: maximum of 3% of the conditioned floor area (reduced from 4% under the 2009 IECC)
6. Both codes require that air sealing of the building thermal envelope be performed. The 2009 IECC required that air sealing be verified either by visual inspection of certain items or by performing a blower door test on a completed home and achieving a result of 7 ACH50 or less. The 2015 IECC requires that a blower door test be performed, with a result of 3 ACH50 or less.
7. By reference to the IRC or IMC, the 2015 IECC requires a whole-house ventilation using rates specified by ASHRAE Standard 62.2-2010.

Table 2 summarizes the required component values for the code conditions modeled. The requirements shown below in Table 2 are associated with the "simplified prescriptive track" of each code, which is the easiest and most often used means of code compliance.

Component	2009 IECC (case a)	2009 IECC (case b)	2015 IECC (case a)	2015 IECC (case b)
	80% AFUE furnace	90% AFUE furnace	80% AFUE furnace	90% AFUE furnace
Glazing U-factor	0.35	0.35	0.32	0.32
Glazing SHGC	none	none	none	none
Opaque door U-factor	0.35	0.35	0.32	0.32
Ceiling R-value (note a)	38	38	49	49
Wall R-value (note b)	20 or 13+5	20 or 13+5	20 or 13+5	20 or 13+5
Floor R-value (note c)	30	30	30	30
Basement wall R-value (note d)	10/13	10/13	15/19	15/19
Forced air furnace (AFUE) (note e)	80%	90%	80%	90%
Central air conditioning (SEER)	13.0	13.0	13.0	13.0
Programmable thermostat	Yes	Yes	Yes	Yes
% high efficacy lighting	50	50	75	75
Duct leakage to outdoors	8%	8%	4%	4%
Whole house mechanical ventilation	No	No	Yes	Yes

Table 2. Component requirements by building code.

Note a: Both codes allow a lower R-value to be installed, where that R-value extends over the top plate at the eaves. This requirement is R-30 for the 2009 IECC and R-38 for the 2015 IECC. Both codes allow R-30 to be used for up to 500 ft (or 20%) of ceiling without attic when this fills the framing cavity.
Note b: 13+5 refers to R13 cavity insulation plus R5 insulated sheathing.
Note c: Less than R30 may be used if sufficient to fill the framing cavity; with a minimum of R19.
Note d: the first listed value may be used if insulation is continuous; the second must be used if insulation is placed in a framing cavity.
Note e: The “prevailing minimum federal efficiency of 78% is required, but 80% is widely installed and was used for the analysis.

There is no Solar Heat Gain Coefficient (SHGC) requirement for glazing in climate zones 5 and above. For modeling, a default SHGC of 0.66 was used for all cases modeled. This represents double glazed clear fenestration with operable metal frames or fixed nonmetal frames.

Neither of the codes modeled places a limit on window to wall ratio. Both codes also allow lower R values to be used for ceilings and floors if the insulation fills the framing cavity. In this analysis, we assumed that the builder did *not* make use of this exemption for floors. The exception was allowed for a small section of vaulted ceiling (5% of the total roof area) in the largest of the home plans. This vaulted ceiling was modeled as R-30 for both codes.

The houses in this study had only small areas of framed, insulated floor, which was limited primarily to framed floors over garages. Modeling was performed with basement insulation in cavity walls, with the listed cavity wall R-value used for each code.

The code minimum mechanical equipment efficiencies were modeled as 80% AFUE for forced air furnaces and 13.0 SEER for air conditioning. The codes do allow a 78% AFUE furnace to be installed, but 80% AFUE is widely used and comparable in cost. Additional cases were modeled with a 90% AFUE furnace.

The 2009 IECC does not require a whole-house ventilation system to be installed. The 2015 IECC refers to the 2015 IRC or IMC, which both require a system using the flow rates specified by ASHRAE Standard 62.2-2010[7]. Although whole-house ventilation is not an energy feature, it is highly desirable for codes that require very airtight homes to help avoid negative consequences for indoor air quality.

Climates

Three cities were chosen to represent the climate variation in Nebraska. The National Oceanic and Atmospheric Administration (NOAA) publishes a list of annual degree days that includes approximately 140 cities and towns in the state of Nebraska. The heating degree days (65°F base) in the state range from 5,552 to 7,862. Table 3 summarizes the selected cities and their actual numbers of degree days. Numbers of degree days for other code jurisdictions not shown can be found in Table A1 in the appendix to this report. Note that the state's second largest city, Lincoln, has nearly the same climate as Omaha (6,119 vs. 6,153 degree days).

City	Annual heating degree days
Omaha	6,153
Norfolk	6,766
Chadron	7,021

Table 3. Selected Nebraska cities and climates.

Both codes use the same climate zone map, which places the entire state of Nebraska in a single climate zone (5). Variations in actual heating degree days and cooling degree hours throughout the state will cause different cities to respond to code changes in slightly different ways.

Component Selection

Since variations in the way that some components are selected and installed can impact thermal performance, and because certain products are available only in discrete increments of R-value, it was necessary to specify some components in detail.

Windows

All code conditions are modeled with a window having exactly the prescribed U-factor and a default solar heat gain coefficient (SHGC) of 0.66. For reference, U-factors in the range of 0.32-0.35 can typically be achieved using a double glazed vinyl window with ½ inch argon fill and low-e coating.

Windows were modeled at 12% or 18% window to wall ratio, with 25% of the window area placed in each compass direction (N, S, E, and W) with no overhang.

Exterior wall insulation

In the model, the R-value of cavity insulation is adjusted to account for the effects of wood studs and other framing members. For this analysis, a framing factor of 0.23 was used; this means that the wood construction makes up 23% of the wall surface area.

Both codes require R-20 cavity insulation or R-13 cavity insulation with R-5 rigid insulation on the exterior. Typically, fiberglass batts are currently available in R-19 and R-21 increments. Cellulose insulation is typically R-21 when used in a 2x6 wall, and spray foams are now available that can be applied in various thicknesses to achieve R-values of 20 or more in a 2x6 cavity. Based on the code requirement for R-20, it is likely that most 2x6 walls will actually have installed R-21 cavity insulation. The overall U-value for this assembly is 0.58. The U-value for an assembly with exactly R-20 cavity insulation is 0.60. If the 13+5 method is used, a 2x4 stud wall with R-5 exterior insulation achieves a U-value of 0.58. However, accounting for sheathing on 25% of the exterior, the resulting U-value is 0.60. Because all of these scenarios are very close to one another, both codes were modeled with an R-20 cavity insulation in a 2x6 wall, with an overall U-value of 0.60.

Basement wall insulation

This analysis was performed with the assumption that the basements are conditioned, which requires that basement walls be insulated. For all of the code conditions, the insulation was placed in a framed cavity on the interior of the basement wall. Framing was modeled as 16" o.c. wood framing in both cases. Fiberglass batts, spray foams, cellulose, and other products are widely available in the R-13 and R-19 increments required by the two codes.

Ceiling insulation

Most of the ceiling area for the four house plans is beneath attics. Where attics are present, blown-in fiberglass insulation is used in the correct thickness to meet the R-value requirement. Framing is modeled with a 2x12 structural member at the attic floor and an 11% framing factor.

One floor plan also contains a small amount of cathedral ceiling (about 5% of the overall roof area) directly beneath a sloped roof supported by 2x10 joists. R-30 fiberglass batts were used in these locations. Table 4 summarizes the roof/ceiling insulation combinations that were used to meet the codes.

R-value (°Fft^{2}hr/Btu)	Insulation location	Insulation type
30	Cathedral ceiling	9" R30 fiberglass batts
38	Attic floor	15.2" blown-in fiberglass insulation (R2.5 per inch)
49	Attic floor	19.6" blown-in fiberglass insulation (R2.5 per inch)

Table 4. Roof and ceiling insulation combinations used to meet code requirements.

Floor insulation

Insulation requirements for framed floors over unconditioned space were met using an R-30 fiberglass batt in a minimum 2x10 floor cavity, with a framing factor of 13%. Note that when the depth of floor insulation is less than that of the framing cavity, the insulation must be installed next to the floor above in order to function properly.

Exterior doors

The U-factor requirement for opaque doors is equal to the U-factor requirement for windows under both codes, and the opaque portions of doors were modeled having this specified U-factor. For reference, a U-factor of 0.35 is met using a 2 ¼" wood solid core door. The requirement for a 0.32 or lower U-factor will likely require that a fiberglass or metal insulated door be used. These can achieve U-factors of 0.20 or better.

Infiltration

The 2009 IECC allows builders two options for meeting air sealing requirements. The first is to have the home tested using a blower door with a result of less than 7 air changes per hour at 50 Pa (ACH50). The second option is to have the home visually inspected and shown to be free of several common thermal bypasses and air sealing problems, most of which are taken from the current Energy Star thermal bypass checklist. While experience with the Energy Star program demonstrates that attention to these items can make homes tighter, the language in the code may not be clear enough to actually result in significantly improved airtightness. However, the testing requirement of less than 7 ACH50 is not a very stringent limit, and it is likely that many un-tested new homes would reach this level of airtightness.

The 2015 IECC requires testing with a blower door, and homes must achieve a much more stringent requirement of 3 ACH50 maximum. This is a significant increase in airtightness, and in our opinion, without good guidance on air sealing techniques, builder training, and pre-drywall visual inspection, a significant number of failures are likely to initially occur. However, with practice builders in above-code programs and states that have adopted this requirement can meet 3 ACH50.

Whole-house ventilation

The 2009 IECC does not require a whole-house ventilation system to be installed. The 2015 IECC refers to the 2015 IRC or IMC, which both require a system using the flow rates specified by ASHRAE Standard 62.2-2010[7].

The 2015 cases were modeled with whole-house ventilation systems. The rate is based on finished floor area and number of bedrooms. To calculate the rate for each of the modeled homes, 50% of the basement floor area was assumed to be finished, and there were no bedrooms in the basement. The whole-house mechanical ventilation systems were assumed to be continuous run exhaust-only, with a fan efficiency of 1.4 cfm/Watt. Table 5 shows the ventilation flow rates and fan Watts modeled for each home in the study.

Main floor area (sf)	# of bedrooms	Whole house ventilation airflow (cfm)	Fan power (W)
1453	3	52	37
1852	3	58	41
2103	4	69	49
2932	4	82	59

Table 5. Whole house ventilation inputs for 2015 IECC cases.

Thermostat settings

This study and previous studies assume a thermostat setpoint of 70°F in the winter and 76°F in the summer. These conditions are within the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)[8] comfort ranges for people seasonally dressed. Although both codes require an initial cooling setpoint of 78°F, it is likely that many homeowners will adjust the setting to a temperature that they find more comfortable. Since the ASHRAE comfort ranges are the most established method for determining that comfort range, the study continued to use a 76°F summer thermostat setpoint.

The RESNET standard was used to determine energy savings associated with the setback. This is based on a 2°F temperature offset from 11:00 PM to 6:00 AM in the heating season and from 9:00 AM to 3:00 PM in the cooling season. While many people will choose to use a larger temperature offset, some occupants will not use any offset, so this assumption seems appropriate for application to a large group of homeowners.

Ducts

Ducts for all cases were modeled with an R-value of 8 for supply ducts outside conditioned space and an R-value of 6 for all other ducts. The homes were modeled so that each has 50% of its ducts located in attics and/or floors over garages as appropriate to each home's design.

The 2009 cases were modeled with 4% duct leakage to outdoors. 4% was chosen because many homes in Nebraska have some or all of their duct systems located inside conditioned space. For this reason, we felt that even though the maximum duct leakage allowed by the code is 8% to the outdoors, many homes in the state will actually test better as a result of the requirement. We also felt that the requirement would create incentive for builders to place ducts inside conditioned space. Thus, 4% leakage to the outside is a better estimate of the actual condition likely to be present under the 2009 IECC.

Likewise, the 2015 IECC requirement of 4% duct leakage to the outdoors is likely to produce a lower typical leakage to the outdoors for these same reasons. The 2015 IECC homes were therefore modeled with 2% duct leakage to outdoors.

The 2015 IECC adds a requirement that building cavities not be used as ducts or plenums. This is good practice, and our experience is that it would be very difficult for an installer to achieve the tighter duct requirements of the 2015 IECC while using cavities as part of the duct system. Even when care is taken to seal edges with mastic and encapsulate the cavity, we have found that it is still very difficult to achieve acceptable airtightness and that with the shifting of the structure over time, these sealing efforts may not be durable. In addition, there are a number of potential indoor air quality benefits that result from prohibiting this practice that can also be used to justify its inclusion. Our study considers the energy impacts of this code change as part of the means a contractor would use to achieve the increased duct airtightness that was modeled.

HVAC system sizing

HVAC system sizing can affect the simulated energy consumption of a home, particularly as oversized cooling systems can be penalized for short-cycling inefficiencies. For each case, air conditioners were sized in ½ ton increments, and the smallest size that would meet the home's sensible load was installed.

The 2015 IECC requires that HVAC contractors utilize a Manual J calculation (or approved alternative) to size heating and cooling equipment. This ensures that the installed equipment will have enough capacity to meet the load, but it is also important to avoid oversizing because short cycling of space conditioning equipment can be inefficient and provides inadequate dehumidification in the summer. Another benefit of properly sizing equipment is that homeowners may see a cost savings if the increased insulation and airtightness requirements of the new code allow smaller equipment to be installed. For the cases in this study, most of the 2015 code cases required a ½ ton smaller air conditioner than the 2009 cases.

Lighting

The 2009 code was modeled with 50% high efficacy lamps installed, and the 2015 IECC was modeled with 75% high efficacy lamps. In REMrate, this is accomplished by selecting compact fluorescent lamps. High-efficacy lamps include compact fluorescent, fluorescent, LED, and other lamps of similar efficacy (60 lumens per Watt for lamps greater than 40 Watts, 50 lumens per Watt for lamps between 15 and 40 Watts, and 40 lumens per Watt for lamps 15 Watts or less).

Water heating

Neither code addresses domestic water heating. However, an input is required for REM/Rate, and the whole-house energy consumption values in this report include domestic water heating. For all cases, a 50 gallon electric tank-style water heater with an efficiency factor of 0.86 was modeled. The water heater was located inside conditioned space.

Results

Annual energy simulations were performed for the four houses under the four code/furnace conditions to determine their annual energy consumption. Comparison of the results shows that the 2015 IECC requires less overall energy than the 2009 cases for all houses and climates. The overall percent savings are relatively uniform for homes in the various climates and with different window to wall ratios. In all cities, the largest home in the study did experience somewhat larger percent savings than the other homes.

Energy use

Table 6 shows the annual cooling-related electricity consumption of each house under each code condition. The furnace efficiency does not impact cooling energy, so the (a) and (b) cases of each code are identical. There is very little difference in cooling energy between the two codes, at most plus or minus 4%. In some cases, the 2009 IECC actually uses slightly less energy.

This may be surprising because the 2015 code has more stringent envelope requirements. However, particularly in the coolest climate studied, this can increase cooling energy. The Chadron 1453 sf home with 18% glass is used below to demonstrate. Note that the incremental change in energy use for each item is dependent on the order in which the items are added, but the process is a helpful way to demonstrate the effects of each change.

Code-based change	Cooling kWh	Change (kWh)
Begin with 2009 IECC	1950	
Increase foundation wall to R-19	1981	+31
Reduce window U-value to 0.32	1996	+15
Increase ceiling insulation to R-49	2000	+4
Reduce door U-value to 0.32	2001	+1
Decrease duct leakage to 2% to outside	1957	-44
Reduce infiltration to 3 ACH50	2105	+148
Add whole house mechanical ventilation system	2066	-39
Increase to 75% high-efficacy lighting	2012	-54
Reduce size of air conditioner by ½ ton	1999	-13
End with 2015 IECC	1999	+49 (total change)

It seems odd that more insulation can increase cooling energy. In the case of foundation wall insulation, this is because the ground is at less than ambient temperatures, and heat transfer with the ground helps in the cooling season. Decreasing above U-values (as with doors and windows) and increasing R-values (ceilings) should decrease cooling energy consumption at times of high outdoor temperature. However, a very small increase is predicted by the model. This is most likely because the additional R-value changes the way the home responds to temperature swings throughout the day. Changes in the cooling load and extent of oversizing of the air conditioner may also be involved. Overall, however, these effects are very small compared to other variables. The largest reductions in cooling energy are from duct leakage and high efficacy lighting. However, these are offset by the increase in cooling energy related to the tighter building envelope. The addition of whole-house ventilation mitigates the effect of envelope airtightness somewhat, but it appears that retaining more of the interior-generated heat and allowing less infiltration with outdoor air that may be cooler throughout much of the day results in a net higher energy use for the tighter home. It is helpful to keep in mind that these same parameters that increase cooling energy use will decrease heating energy use, which is a larger portion of energy bills in Nebraska.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC (a)	Omaha	12%	2114	2587	3019	3695
2009 IECC (b)	Omaha	12%	2114	2587	3019	3695
2015 IECC (a)	Omaha	12%	2110	2557	2948	3645
2015 IECC (b)	Omaha	12%	2110	2557	2948	3645
2009 IECC (a)	Omaha	18%	2683	3285	3894	4808
2009 IECC (b)	Omaha	18%	2683	3285	3894	4808
2015 IECC (a)	Omaha	18%	2652	3233	3809	4719
2015 IECC (b)	Omaha	18%	2652	3233	3809	4719
2009 IECC (a)	Norfolk	12%	1886	2299	2730	3270
2009 IECC (b)	Norfolk	12%	1886	2299	2730	3270
2015 IECC (a)	Norfolk	12%	1908	2260	2654	3229
2015 IECC (b)	Norfolk	12%	1908	2260	2654	3229
2009 IECC (a)	Norfolk	18%	2417	2952	3546	4291
2009 IECC (b)	Norfolk	18%	2417	2952	3546	4291
2015 IECC (a)	Norfolk	18%	2431	2891	3459	4233
2015 IECC (b)	Norfolk	18%	2431	2891	3459	4233
2009 IECC (a)	Chadron	12%	1479	1804	2163	2561
2009 IECC (b)	Chadron	12%	1479	1804	2163	2561
2015 IECC (a)	Chadron	12%	1542	1868	2214	2654
2015 IECC (b)	Chadron	12%	1542	1868	2214	2654
2009 IECC (a)	Chadron	18%	1950	2389	2875	3456
2009 IECC (b)	Chadron	18%	1950	2389	2875	3456
2015 IECC (a)	Chadron	18%	1999	2437	2918	3530
2015 IECC (b)	Chadron	18%	1999	2437	2918	3530

Table 6. Annual cooling electricity consumption (kWh).

Table 7 shows annual heating electricity consumption. Since even with a forced air furnace, there is some energy required to operate the furnace fan, some electricity is required for heating even when a gas furnace is used. The fan energy for heating is in the range of 20-30% lower for the 2015 IECC than the 2009 IECC, with little variation between the cities. Heating electricity consumption is also lower in the homes with 90% AFUE furnaces, since more efficient furnaces typically have lower auxiliary electrical consumption.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC (a)	Omaha	12%	661	792	838	1146
2009 IECC (b)	Omaha	12%	505	635	672	992
2015 IECC (a)	Omaha	12%	503	592	630	861
2015 IECC (b)	Omaha	12%	384	475	505	690
2009 IECC (a)	Omaha	18%	690	826	873	1197
2009 IECC (b)	Omaha	18%	527	662	706	1036
2015 IECC (a)	Omaha	18%	529	623	668	901
2015 IECC (b)	Omaha	18%	404	499	535	731
2009 IECC (a)	Norfolk	12%	696	833	882	1206
2009 IECC (b)	Norfolk	12%	532	668	707	1044
2015 IECC (a)	Norfolk	12%	531	624	663	907
2015 IECC (b)	Norfolk	12%	405	500	532	727
2009 IECC (a)	Norfolk	18%	727	870	920	1261
2009 IECC (b)	Norfolk	18%	555	697	746	1091
2015 IECC (a)	Norfolk	18%	558	657	698	950
2015 IECC (b)	Norfolk	18%	426	526	566	771
2009 IECC (a)	Chadron	12%	728	871	914	1252
2009 IECC (b)	Chadron	12%	556	698	733	1084
2015 IECC (a)	Chadron	12%	550	648	685	939
2015 IECC (b)	Chadron	12%	420	519	549	753
2009 IECC (a)	Chadron	18%	759	909	909	1308
2009 IECC (b)	Chadron	18%	580	729	787	1133
2015 IECC (a)	Chadron	18%	579	682	727	984
2015 IECC (b)	Chadron	18%	442	546	583	798

Table 7. Annual heating electricity consumption (kWh).

Table 8 shows gas consumption for the various cases in therms per year. In all cases, the 2015 IECC has lower gas consumption. The reduction in gas consumed is also relatively uniform across cities, glazing percentage, and size of home, and ranges from 27% to 35%.

Most of the code changes in the 2015 IECC reduce heating energy use. One exception is the increase to 75% high efficacy lighting. Since high efficacy lighting reduces internal heat gains, the house requires slightly more heating. However, there is substantial energy savings to operate the lighting, as well as cooling energy savings. The whole house ventilation system increases heating energy modestly, but the increase is far smaller than the energy saved by reducing infiltration. This illustrates why, from an energy standpoint, it makes sense to “build tight and ventilate right”. Of the changes, the reduction in infiltration has by far the largest impact. Below is a summary of the effects of each item for the 1453 sf house located in Chadron with 18% glass and an 80% AFUE furnace: For this case, the decreased air infiltration accounts for the largest portion of the energy savings with the 2015 IECC.

Code based change	Heating therms	Change (therm)
Begin with 2009 IECC	851	
Increase foundation wall to R-19	809	-42
Reduce window U-value to 0.32	790	-19
Increase ceiling insulation to R-49	772	-18
Reduce door U-value to 0.32	771	-1
Decrease duct leakage to 2% to outside	752	-19
Reduce infiltration to 3 ACH50	571	-181
Add whole house mechanical ventilation system	602	+31
Increase to 75% high efficacy lighting	610	+8
End with 2015 IECC	610	-241 (total change)

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC (a)	Omaha	12%	715	892	916	1441
2009 IECC (b)	Omaha	12%	635	793	814	1281
2015 IECC (a)	Omaha	12%	510	619	644	944
2015 IECC (b)	Omaha	12%	453	550	573	839
2009 IECC (a)	Omaha	18%	728	907	940	1461
2009 IECC (b)	Omaha	18%	647	806	835	1299
2015 IECC (a)	Omaha	18%	526	639	677	974
2015 IECC (b)	Omaha	18%	468	568	602	866
2009 IECC (a)	Norfolk	12%	789	984	1012	1590
2009 IECC (b)	Norfolk	12%	702	875	900	1413
2015 IECC (a)	Norfolk	12%	567	687	716	1049
2015 IECC (b)	Norfolk	12%	504	611	637	932
2009 IECC (a)	Norfolk	18%	806	1004	1043	1616
2009 IECC (b)	Norfolk	18%	717	982	927	1437
2015 IECC (a)	Norfolk	18%	588	714	758	1087
2015 IECC (b)	Norfolk	18%	523	634	673	966
2009 IECC (a)	Chadron	12%	838	1045	1057	1669
2009 IECC (b)	Chadron	12%	745	929	940	1483
2015 IECC (a)	Chadron	12%	590	716	737	1087
2015 IECC (b)	Chadron	12%	524	636	655	966
2009 IECC (a)	Chadron	18%	851	1060	1084	1688
2009 IECC (b)	Chadron	18%	757	942	963	1500
2015 IECC (a)	Chadron	18%	610	740	779	1123
2015 IECC (b)	Chadron	18%	542	658	692	998

Table 8. Annual heating gas consumption (therm).

Table 9 shows the annual electricity consumption for lighting and appliances. Since this does not depend on city or glazing percentage, it is simply shown for each code and each house size. This value is influenced by the change to high-efficacy lamps and the addition of a mechanical ventilation fan. The additional high-efficacy lamps reduce the lighting and appliance energy use by approximately 5%.

However, once the energy use of the mechanical ventilation fan is included, the overall reduction in lighting/appliance energy is 1-2%.

Code	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC	8242	9462	9102	12286
2015 IECC	8114	9268	9035	12040

Table 9. Annual electricity consumption for lights and appliances (kWh)

Table 10 shows annual whole-house energy consumption in MMBtu/year. This includes heating and cooling, domestic water heating, and lights and appliances. In all cases, the 2015 IECC used less total energy than the 2009 IECC. The percent savings are relatively uniform between the cities, glazing, and house sizes, but are slightly larger for the largest house. The savings range from 16% (the smallest house in Omaha) to 25% (the largest house in Chadron). The average overall energy savings was 19.5%.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC (a)	Omaha	12%	123.4	147.4	152.4	219.2
2009 IECC (b)	Omaha	12%	115.0	136.9	141.7	202.7
2015 IECC (a)	Omaha	12%	101.9	118.6	124.1	167.5
2015 IECC (b)	Omaha	12%	95.9	111.4	116.5	156.4
2009 IECC (a)	Omaha	18%	126.8	151.4	158.0	225.2
2009 IECC (b)	Omaha	18%	118.2	140.8	146.9	208.4
2015 IECC (a)	Omaha	18%	105.6	123.1	130.5	174.3
2015 IECC (b)	Omaha	18%	99.3	115.6	122.5	162.9
2009 IECC (a)	Norfolk	12%	130.6	156.1	161.7	233.3
2009 IECC (b)	Norfolk	12%	121.3	144.7	149.9	215.1
2015 IECC (a)	Norfolk	12%	107.5	125.0	130.9	177.2
2015 IECC (b)	Norfolk	12%	100.7	116.9	122.5	164.9
2009 IECC (a)	Norfolk	18%	134.2	160.5	167.7	239.6
2009 IECC (b)	Norfolk	18%	124.7	148.7	155.5	221.1
2015 IECC (a)	Norfolk	18%	111.5	129.9	137.9	184.6
2015 IECC (b)	Norfolk	18%	104.5	121.5	129.0	171.9
2009 IECC (a)	Chadron	12%	134.7	161.2	164.9	239.4
2009 IECC (b)	Chadron	12%	124.8	148.9	152.5	220.3
2015 IECC (a)	Chadron	12%	109.0	127.0	132.0	179.6
2015 IECC (b)	Chadron	12%	102.0	118.6	123.4	166.9
2009 IECC (a)	Chadron	18%	137.7	164.8	169.9	244.6
2009 IECC (b)	Chadron	18%	127.6	152.4	157.5	225.2
2015 IECC (a)	Chadron	18%	112.6	131.5	138.7	186.4
2015 IECC (b)	Chadron	18%	105.4	122.8	129.6	173.3

Table 10. Annual whole house energy consumption (MMBtu/year).

To understand the relative impact of each change on the overall energy use in Table 10, the Chadron 80% AFUE, 18% glass, 1453 sf home can also be used. This house design had a reduction of 18.2% in total energy use, which is close to the average of the various cases.

Code based change	Energy use MMBtu/yr	Change (MMBtu/year)
Begin with 2009 IECC	137.7	
Increase foundation wall to R-19	133.5	-4.2
Reduce window U-value to 0.32	131.6	-1.9
Increase ceiling insulation to R-49	129.8	-1.8
Reduce door U-value to 0.32	129.7	-0.1
Decrease duct leakage to 2% to outside	127.5	-2.2
Reduce infiltration to 3 ACH50	109.5	-18
Add whole house mechanical ventilation system	113.6	+4.1
Increase to 75% high efficacy lighting	112.7	-0.9
Reduce size of air conditioner by ½ ton	112.6	-0.1
End with 2015 IECC	112.6	-25.1 (total change)

The order in which the changes are implemented in the above analysis does slightly impact the magnitude of each change. However, it is clear that reducing the infiltration rate accounts for the lion's share of the savings. The energy penalty for adding a whole-house mechanical ventilation system is small compared to the savings achieved with more airtight construction. The next largest contributors to savings are foundation wall insulation, duct leakage, windows, ceiling insulation, and increased high efficacy lighting respectively.

Table 11 shows energy cost in dollars per year for each of the cases. Adopting the 2015 IECC saves consumers between 8% and 15% depending on the city. The average is 9.6% savings. The percent savings in energy cost and energy consumption are not exactly the same because different fuels (gas and electricity) have different costs and because each fuel has a fixed customer charge. Depending on house size and location, the savings range from $148 to $564 per year, with an average annual savings of $283.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC (a)	Omaha	12%	2329	2616	2708	3437
2009 IECC (b)	Omaha	12%	2263	2535	2625	3314
2015 IECC (a)	Omaha	12%	2163	2391	2489	3042
2015 IECC (b)	Omaha	12%	2115	2335	2431	2957
2009 IECC (a)	Omaha	18%	2402	2704	2822	3575
2009 IECC (b)	Omaha	18%	2334	2623	2737	3451
2015 IECC (a)	Omaha	18%	2236	2481	2609	3183
2015 IECC (b)	Omaha	18%	2186	2423	2547	3095
2009 IECC (a)	Norfolk	12%	2460	2792	2890	3767
2009 IECC (b)	Norfolk	12%	2366	2676	2771	3586
2015 IECC (a)	Norfolk	12%	2228	2474	2579	3203
2015 IECC (b)	Norfolk	12%	2159	2393	2494	3079
2009 IECC (a)	Norfolk	18%	2532	2879	3004	3898
2009 IECC (b)	Norfolk	18%	2435	2760	2881	3714
2015 IECC (a)	Norfolk	18%	2303	2565	2701	3343
2015 IECC (b)	Norfolk	18%	2232	2480	2612	3216
2009 IECC (a)	Chadron	12%	2388	2680	2755	3518
2009 IECC (b)	Chadron	12%	2307	2582	2655	3369
2015 IECC (a)	Chadron	12%	2187	2410	2500	3055
2015 IECC (b)	Chadron	12%	2130	2343	2431	2953
2009 IECC (a)	Chadron	18%	2448	2754	2848	3628
2009 IECC (b)	Chadron	18%	2366	2654	2750	3477
2015 IECC (a)	Chadron	18%	2251	2489	2607	3176
2015 IECC (b)	Chadron	18%	2192	2419	2533	3070

Table 11. Annual whole house energy cost ($/year).

Conclusions

The findings of this study indicate that the 2015 International Energy Conservation Code would result in less energy consumption for homes in all areas of the state. Most of the savings is related to heating. There is little change in cooling energy use, and a comparatively small savings in lighting energy. The largest contribution to the energy savings is achieved by increasing airtightness to 3 ACH50. The next largest contributors to savings are foundation wall insulation, duct leakage, windows, ceiling insulation, and increased high efficacy lighting respectively. Even when the increased airtightness is offset by the need for whole-house mechanical ventilation to maintain indoor air quality, the energy savings from the tighter homes is substantial.

The average energy savings was 19.5%, and ranged from 16% to 25% for the various house sizes and locations. The average savings in whole-house energy cost was 9.6%. Depending on house size and location, the savings range from $148 to $564 per year, with an average annual savings of $283.

While there is a significant opportunity to save energy with the 2015 IECC, this savings does not come without challenges. Our company's experience with the Energy Star® New Homes program has taught us that the 3 ACH50 target is a difficult but achievable target. However, to achieve this result reliably for every home, statewide builder education and pre-drywall verification with an air sealing checklist will be necessary to prevent failures from commonly occurring. Our experience with above-code programs also tells us that if an airtightness goal is not met, it can be very difficult to seal a home to 3 ACH50 after drywall is installed. If implementing the new code, the state may wish to consider a transitional phase-in period, during which any home that is tested but fails to reach 3 ACH50 would not result in a home failing to obtain a certificate of occupancy.

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Appendix A

Heating degree days by code jurisdiction

Jurisdiction	HDD	Modeled City	Jurisdiction	HDD	Modeled City
Albion	7087	Chadron	Louisville	6292	Omaha
Alliance	6823	Norfolk	McCook	5967	None
Alma	6203	Omaha	Mead	6570	Norfolk
Ashland	6379	Omaha	Milford	5779	None
Auburn	5765	None	Minden	6398	Omaha
Beatrice	6151	Omaha	Nebraska City	6023	Omaha
Bellevue	6153	Omaha	Norfolk	6766	Norfolk
Blair	6455	Omaha	North Platte	6766	Norfolk
Bloomfield	7057	Chadron	Ogallala	6672	Norfolk
Cass County	6292	Omaha	Omaha	6153	Omaha
Central City	5834	None	O'Neill	7246	Chadron
Ceresco	6613	Norfolk	Palmyra	6337	Omaha
Chadron	7021	Chadron	Papillion	6153	Omaha
Columbus	6411	Omaha	Plainview	6485	Omaha
Cozad	6303	Omaha	Plattsmouth	6153	Omaha
Crete	5811	None	Ralston	6153	Omaha
Dakota City	6600	Norfolk	Sarpy County	6153	Omaha
David City	6237	Omaha	Saunders County	6613	Norfolk
Douglas County	6153	Omaha	Scottsbluff	6742	Norfolk
Elkhorn	6153	Omaha	Seward	5779	None
Falls City	5795	None	Seward County	5779	None
Fremont	6444	Omaha	Sidney	7092	Chadron
Gering	6742	Norfolk	South Sioux City	6600	Norfolk
Grand Island	6385	Omaha	Superior	5552	None
Gretna	6379	Omaha	Sutton	6347	Omaha
Hall County	6385	Omaha	Tekamah	6564	Norfolk
Hastings	6211	Omaha	Valley	6570	Norfolk
Holdrege	6482	Omaha	Wahoo	6570	Norfolk
Kearney	6652	Norfolk	Washington Cty.	6455	Omaha
Keith County	6672	Norfolk	Waverly	6119	Omaha
LaVista	6153	Omaha	Wayne	7143	Chadron
Lancaster County	6119	Omaha	Wymore	6151	Omaha
Lexington	6303	Omaha	York	6338	Omaha
Lincoln	6119	Omaha	Yutan	6570	Norfolk

Table A1. Modeled city representing Nebraska code jurisdictions.

Appendix B

Glossary of Abbreviations used in this report

ACH50: Air changes per hour at 50 Pascals pressure difference. This is a tested measure of whole-house airtightness that is commonly used to benchmark whole-house airtightness.

AFUE: Annual fuel utilization efficiency. Used to quantify and compare the efficiency of gas furnaces. A higher value indicates better efficiency, with 100% being the theoretical maximum.

ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers, a global society dedicated to advancing the arts and sciences of HVAC.

cfm: cubic feet per minute, a measure of airflow

EPA: Environmental Protection Agency, an agency of the US federal government.

HVAC: Heating, Ventilating, and Air Conditioning

IECC: International Energy Conservation Code

NOAA: National Oceanic and Atmospheric Administration, an agency of the US federal government.

R-value: measures how well a product prevents heat from moving through the building exterior. A high R-value means that the material has a high resistance to heat flow and is considered a good insulator. R-value is the mathematical inverse of U-factor.

REMrate: A whole-house energy modeling tool used to perform this study.

RESNET: Residential Energy Services Network (www.resnet.us) This organization maintains the RESNET standards, a commonly used method of rating the energy performance of homes.

SEER: Seasonal energy efficiency ratio. Used to quantify and compare the efficiency of air conditioners (and heat pumps in cooling mode). A higher value indicates a more efficient unit. Currently available units range from 13 to approximately 20 SEER.

sf: square feet

SHGC: Solar heat gain coefficient. A number between 0 and 1 that expresses the portion of incident solar energy that passes through a window, including frame effects. The lower the value, the more solar heat is blocked from entering the home via the window.

U-factor: measures how well a product prevents heat from moving through the building exterior. A low U-factor means that the material has a high resistance to heat flow and is considered a good insulator. U-factor is the mathematical inverse of R-value.