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Energy Impact Study of the 2009 IECC and 2012 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 2012 International Energy Conservation Code (IECC).

2012ECC performs best

The findings of this study indicate that the 2012 International Energy Conservation Code would result in less energy consumption for homes in all areas of the state. The benefit can be assigned to two major areas: lighting and heating. There is little change in cooling energy use. Lighting energy accounts for approximately 5% of the total reduction. The remainder of the savings is attributable to heating. The largest contribution to the savings in heating energy is achieved by increasing airtightness to 3 ACH50.

The average savings in whole-house energy cost was 11%. Depending on house size and location, the savings range from $171 to $553 per year, with an average annual savings of $311.

While there is a significant opportunity to save energy with the 2012 IECC, this savings does not come without challenges. 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 and insulation are installed. In implementing the new code, we recommend that the state consider a transitional phase-in period during which every home would be tested, but the failure to reach 3 ACH50 would not result in a home failing to obtain a certificate of occupancy.

Additionally, 3 ACH50 is a very tight building envelope, and our report raises concerns regarding an increase to this level of airtightness without also including a requirement for whole-house ventilation. We strongly recommend that the state include whole-house ventilation in compliance with the most current version of ASHRAE Standard 62.2 along with adoption of the 2012 IECC.

The state may want to consider phasing in code language that would limit the oversizing of heat pumps and air conditioners. This would allow homeowners to better realize financial savings of smaller equipment size related to improved building envelope, and would also allow systems to dehumidify more appropriately in the summer. More study is needed to determine how to define appropriate limits in a way that code officials can apply uniformly and appropriately and that is flexible enough to allow appropriate sizing for truly unusual conditions where a higher than usual cooling load is present.

Key differences between 2009 and 2012 codes

There are several important differences between the 2009 and 2012 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 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 2012 IECC requires that a blower door test be performed, with a result of 3 ACH50 or less.

About the Study

The study considers the annual energy consumption of houses constructed according to the 2009 and 2012 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 for 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], a 2006 follow-up study that was based on the 2006 IECC[3], and a 2009 follow-up study that was based on the 2009 IECC[4]. 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.

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 15 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.

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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 2012 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]. 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 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 2012 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 qualify for the Energy Star label and are a widely available upgrade.

Key changes in the 2012 IECC include:

7. Maximum glazing U-factor has been decreased to 0.32. This change impacts both opaque doors and windows.
8. Minimum ceiling R-value has increased from R-38 to R-49.
9. 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.
10. 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).
11. 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)

12. 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 2012 IECC requires that a blower door test be performed, with a result of 3 ACH50 or less.

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)	2012 IECC (case a)	2012 IECC (case b)
	80% AFUE furnace	Energy Star furnace	80% AFUE furnace	Energy Star 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
% CFL lighting	50	50	75	75
Duct leakage to outdoors	8%	8%	4%	4%

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 2012 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 climates with more than 3,500 degree days. 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 Energy Star heating equipment (a 90% AFUE furnace).

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 4 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, a 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. 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, the 2009 cases 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 2 by 10 inch joists. R-30 fiberglass batts were used in these locations. Table 6 summarizes the roof/ceiling insulation combinations that were used to meet the codes.

R-value ($^{o}Fft^{2}hr/Btu$)	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 2012 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 occur.

Whole-house ventilation

Neither code requires a whole-house ventilation system to be installed. In both cases, the minimum allowable ventilation system includes local intermittent fans (ie, in bathrooms). For this reason, this study did not include whole-house ventilation systems under either code condition. However, if the 2012 code is adopted we feel strongly that a whole-house ventilation system should be considered. ASHRAE Standard 62.2[6] is a consensus-based industry standard for residential whole-house ventilation.

While whole-house ventilation is important in any home, it becomes even more important in extremely tight homes. The purpose of whole-house ventilation systems is to dilute contaminants present indoor air. Because infiltration also dilutes indoor contaminants, very leaky homes may not need to have a system installed, and Standard 62.2 actually allows an exception for very leaky homes. Very tight homes will experience less infiltration, making a whole-house system more important. In heating dominated climates, water vapor generated by occupants and their activities can create problems in very tight homes. These homes tend to retain more indoor moisture, and we have seen this lead to problems with condensation on the interior surface of windows. Certain types of ventilation system (such as heat recovery ventilators or exhaust-only systems) can help to mitigate this effect.

We urge the state to consider adopting the ventilation requirements of ASHRAE Standard 62.2 as part of its code in any case, but feel that this is especially critical if the airtightness requirements of the 2012 IECC are adopted.

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)[7] 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 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 2012 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 2012 IECC homes were therefore modeled with 2% duct leakage to outdoors.

The 2012 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 2012 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. My opinion is that this requirement’s primary purpose in the code is to prohibit a practice that would lead to frequent testing failures that would be very difficult to go back and bring into compliance. 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 2012 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 2012 code cases required a ½ ton smaller air conditioner than the 2009 cases.

The state may want to consider phasing limits on oversizing into the code. While rules of thumb are not an appropriate way to size equipment, they can be a reasonable way to identify the most egregious instances of oversizing. The code might, for instance, specify a minimum number of square feet per ton that would be allowed. An appropriate number to use would need to be investigated specific to the state. There would need to be a mechanism for allowing exceptions in the case of unusual conditions that justify a lower number of square feet per ton, but it would need to be carefully written to make cheating difficult. One way to accomplish this would be to require that the contractor provide a Manual J to the code official in these cases, and that a few basic checks be performed. These might include:

- conditioned square feet matches the permitted home within 10%
- Equipment Sensible Heat Ratio is 0.70 or higher (unless catalog data showing actual SHR less than 0.70 also provided)
- Window SHGC matches the permitted home within 0.10
- Window area matches the permitted home within 10%.
- Number of occupants equals bedrooms plus one
- Equipment sensible gains are limited to 1200 Btuh per kitchen. If additional equipment gains are used in the Manual J, manufacturer's literature showing the kWh or Btuh for the installed equipment are provided.
- Code officials have the authority to reject calculations at their discretion if an insulation R-value or surface area in the Manual J does not match the installed and inspected system.

Lighting

The 2009 code was modeled with 50% compact fluorescent lamps installed, and the 2012 IECC was modeled with 75% compact fluorescent lamps.

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 2012 IECC requires less overall energy for heating and cooling than the 2009 cases for all houses and climates. The 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 5 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. In most cases, the 2009 IECC actually uses slightly less energy.

This may be surprising because the 2012 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	2104	
Increase foundation wall to R-19	2135	+31
Reduce window U-value to 0.32	2149	+14
Increase ceiling insulation to R-49	2153	+4
Reduce door U-value to 0.32	2155	+2
Decrease duct leakage to 2% to outside	2108	-47
Reduce infiltration to 3 ACH50	2255	+147
Increase to 75% CFL lighting	2207	-48
Reduce size of air conditioner by ½ ton	2192	-15
End with 2012 IECC	2192	+88 (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 CFL lighting. However, these are more than offset in this climate by the increase in cooling energy related to the tighter building envelope. In this relatively mild climate, 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.

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%	2306	2893	3196	4147
2009 IECC (b)	Omaha	12%	2306	2893	3196	4147
2012 IECC (a)	Omaha	12%	2356	2916	3187	4144
2012 IECC (b)	Omaha	12%	2356	2916	3187	4144
2009 IECC (a)	Omaha	18%	2872	3582	4067	5253
2009 IECC (b)	Omaha	18%	2872	3582	4067	5253
2012 IECC (a)	Omaha	18%	2893	3580	4033	5207
2012 IECC (b)	Omaha	18%	2893	3580	4033	5207
2009 IECC (a)	Norfolk	12%	2066	2586	2893	3695
2009 IECC (b)	Norfolk	12%	2066	2586	2893	3695
2012 IECC (a)	Norfolk	12%	2098	2602	2857	3694
2012 IECC (b)	Norfolk	12%	2098	2602	2857	3694
2009 IECC (a)	Norfolk	18%	2592	3230	3703	4703
2009 IECC (b)	Norfolk	18%	2592	3230	3703	4703
2012 IECC (a)	Norfolk	18%	2597	3220	3645	4684
2012 IECC (b)	Norfolk	18%	2597	3220	3645	4684
2009 IECC (a)	Chadron	12%	1636	2054	2305	2934
2009 IECC (b)	Chadron	12%	1636	2054	2305	2934
2012 IECC (a)	Chadron	12%	1739	2157	2404	3060
2012 IECC (b)	Chadron	12%	1739	2157	2404	3060
2009 IECC (a)	Chadron	18%	2104	2632	3012	3819
2009 IECC (b)	Chadron	18%	2104	2632	3012	3819
2012 IECC (a)	Chadron	18%	2192	2715	3097	3926
2012 IECC (b)	Chadron	18%	2192	2715	3078	3926

Table 5. Annual cooling electricity consumption (kWh).

Table 6 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 25-30% lower for the 2012 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%	663	793	839	1148
2009 IECC (b)	Omaha	12%	506	636	673	994

2012 IECC (a)	Omaha	12%	485	575	607	841
2012 IECC (b)	Omaha	12%	370	460	486	674
2009 IECC (a)	Omaha	18%	692	828	874	1199
2009 IECC (b)	Omaha	18%	528	663	707	1038
2012 IECC (a)	Omaha	18%	511	605	645	882
2012 IECC (b)	Omaha	18%	390	485	517	716
2009 IECC (a)	Norfolk	12%	698	835	884	1208
2009 IECC (b)	Norfolk	12%	533	669	708	1046
2012 IECC (a)	Norfolk	12%	511	606	640	888
2012 IECC (b)	Norfolk	12%	391	486	513	712
2009 IECC (a)	Norfolk	18%	728	871	921	1262
2009 IECC (b)	Norfolk	18%	556	698	747	1093
2012 IECC (a)	Norfolk	18%	539	639	675	931
2012 IECC (b)	Norfolk	18%	412	512	548	755
2009 IECC (a)	Chadron	12%	729	873	916	1254
2009 IECC (b)	Chadron	12%	557	699	734	1085
2012 IECC (a)	Chadron	12%	533	632	664	921
2012 IECC (b)	Chadron	12%	407	506	532	738
2009 IECC (a)	Chadron	18%	761	911	911	1310
2009 IECC (b)	Chadron	18%	581	730	788	1134
2012 IECC (a)	Chadron	18%	562	666	706	966
2012 IECC (b)	Chadron	18%	429	534	566	784

Table 6. Annual heating electricity consumption (kWh).

Table 7 shows gas consumption for the various cases in therms per year. In all cases, the 2012 IECC has lower gas consumption. The reduction in gas consumed is also relatively uniform across cities, glazing percentage, and size of home, with a typical reduction of approximately 35%.

All of the code changes in the 2012 IECC reduce heating energy use except for the increase to 75% CFL lighting. Since CFL lighting reduces internal heat gains, the house requires slightly more heating. However, there is savings when cooling and for lighting energy consumption. 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 approximately 65% of the energy savings with the 2012 IECC.

Code based change	Heating therms	Change (therm)
Begin with 2009 IECC	828	
Increase foundation wall to R-19	786	-42
Reduce window U-value to 0.32	767	-19
Increase ceiling insulation to R-49	749	-18
Reduce door U-value to 0.32	748	-1
Decrease duct leakage to 2% to outside	730	-18
Reduce infiltration to 3 ACH50	552	-178
Increase to 75% CFL lighting	558	+6
End with 2012 IECC	558	-270 (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%	692	854	894	1383
2009 IECC (b)	Omaha	12%	615	759	795	1229
2012 IECC (a)	Omaha	12%	452	549	581	852
2012 IECC (b)	Omaha	12%	402	488	517	757
2009 IECC (a)	Omaha	18%	706	872	920	1406
2009 IECC (b)	Omaha	18%	628	775	818	1250
2012 IECC (a)	Omaha	18%	475	577	622	891
2012 IECC (b)	Omaha	18%	422	513	553	792
2009 IECC (a)	Norfolk	12%	765	944	990	1528
2009 IECC (b)	Norfolk	12%	680	839	880	1358
2012 IECC (a)	Norfolk	12%	507	615	651	952
2012 IECC (b)	Norfolk	12%	451	546	579	846
2009 IECC (a)	Norfolk	18%	784	967	1022	1559
2009 IECC (b)	Norfolk	18%	697	859	909	1385
2012 IECC (a)	Norfolk	18%	535	649	699	1001
2012 IECC (b)	Norfolk	18%	476	577	621	890
2009 IECC (a)	Chadron	12%	813	1003	1034	1604
2009 IECC (b)	Chadron	12%	722	892	919	1425
2012 IECC (a)	Chadron	12%	532	644	674	990
2012 IECC (b)	Chadron	12%	473	572	599	880
2009 IECC (a)	Chadron	18%	828	1021	1062	1627
2009 IECC (b)	Chadron	18%	736	908	944	1446
2012 IECC (a)	Chadron	18%	558	677	723	1037
2012 IECC (b)	Chadron	18%	496	602	642	922

Table 7. Annual heating gas consumption (therm).

Table 8 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. The reduction due to the additional high-efficacy lamps is approximately 5% in all cases.

Code	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2009 IECC	9104	11051	9969	15049
2012 IECC	8653	10498	9472	14286

Table 8. Annual electricity consumption for lights and appliances (kWh)

To put the lighting savings in context, the 451 kWh per year saved for the smallest house is accounts for 1.6 MBtu/year savings in energy consumed by that house. From Table 9 below, the typical total energy savings for the 2012 IECC is typically 25-30 MBtu/year for this house. This means that the increase to 75% CFL lighting accounts for about 5% of the total energy reduction.

Table 9 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 2012 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 20% (typical for the smallest house) to 29% (the largest house in the Omaha climate). The average overall energy savings was 22%.

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%	124.0	149.3	152.8	233.3
2009 IECC (b)	Omaha	12%	115.8	139.3	142.3	207.4
2012 IECC (a)	Omaha	12%	98.0	116.2	119.0	166.5
2012 IECC (b)	Omaha	12%	92.6	109.7	112.1	156.5
2009 IECC (a)	Omaha	18%	127.5	153.5	158.5	229.6
2009 IECC (b)	Omaha	18%	119.1	143.3	147.7	213.4
2012 IECC (a)	Omaha	18%	102.2	121.4	126.1	174.2
2012 IECC (b)	Omaha	18%	96.5	114.6	118.8	163.8
2009 IECC (a)	Norfolk	12%	131.0	157.8	161.9	237.0
2009 IECC (b)	Norfolk	12%	121.9	146.7	150.3	219.4
2012 IECC (a)	Norfolk	12%	103.1	122.2	125.4	175.6
2012 IECC (b)	Norfolk	12%	97.1	115.0	117.7	164.4
2009 IECC (a)	Norfolk	18%	134.8	162.4	168.1	243.6
2009 IECC (b)	Norfolk	18%	125.5	151.0	156.1	225.7
2012 IECC (a)	Norfolk	18%	107.7	127.9	133.0	184.1
2012 IECC (b)	Norfolk	18%	101.3	120.3	124.8	172.4
2009 IECC (a)	Chadron	12%	134.8	162.4	164.9	242.5
2009 IECC (b)	Chadron	12%	125.1	150.7	152.8	224.1
2012 IECC (a)	Chadron	12%	104.8	124.1	126.7	177.8
2012 IECC (b)	Chadron	12%	98.5	116.5	118.8	166.2
2009 IECC (a)	Chadron	18%	138.0	166.3	170.1	248.1
2009 IECC (b)	Chadron	18%	128.2	154.3	157.9	229.4
2012 IECC (a)	Chadron	18%	109.1	129.4	134.1	185.7
2012 IECC (b)	Chadron	18%	102.5	121.5	125.5	173.5

Table 9. Annual whole house energy consumption (MMBtu/year).

Table 10 shows energy cost in dollars per year for each of the cases. Adopting the 2012 IECC saves consumers between 8% and 15% depending on the city. The average is 11% savings. The percent savings in energy cost and energy consumption are not exactly the same because different fuels (gas and electricity) have different costs. Depending on house size and location, the savings range from $171 to $553 per year, with an average annual savings of $311.

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%	2200	2518	2539	3348
2009 IECC (b)	Omaha	12%	2142	2448	2466	3241

2012 IECC (a)	Omaha	12%	2008	2271	2287	2934
2012 IECC (b)	Omaha	12%	1969	2225	2239	2864
2009 IECC (a)	Omaha	18%	2268	2599	2644	3476
2009 IECC (b)	Omaha	18%	2208	2528	2569	3367
2012 IECC (a)	Omaha	18%	2077	2357	2400	3068
2012 IECC (b)	Omaha	18%	2037	2309	2348	2995
2009 IECC (a)	Norfolk	12%	2307	2650	2683	3575
2009 IECC (b)	Norfolk	12%	2231	2558	2587	3433
2012 IECC (a)	Norfolk	12%	2065	2340	2364	3050
2012 IECC (b)	Norfolk	12%	2014	2279	2300	2957
2009 IECC (a)	Norfolk	18%	2375	2732	2790	3701
2009 IECC (b)	Norfolk	18%	2297	2638	2691	3556
2012 IECC (a)	Norfolk	18%	2137	2429	2481	3188
2012 IECC (b)	Norfolk	18%	2083	2365	2413	3091
2009 IECC (a)	Chadron	12%	2415	2762	2780	3693
2009 IECC (b)	Chadron	12%	2332	2662	2678	3541
2012 IECC (a)	Chadron	12%	2155	2429	2450	3140
2012 IECC (b)	Chadron	12%	2100	2364	2383	3041
2009 IECC (a)	Chadron	18%	2476	2837	2875	3804
2009 IECC (b)	Chadron	18%	2391	2735	2773	3650
2012 IECC (a)	Chadron	18%	2224	2514	2562	3268
2012 IECC (b)	Chadron	18%	2166	2446	2487	3165

Table 10. Annual whole house energy cost ($/year).

Conclusion and recommendations

The findings of this study indicate that the 2012 International Energy Conservation Code would result in less energy consumption for homes in all areas of the state. The benefit can be assigned to two major areas: lighting and heating. There is little change in cooling energy use. Lighting energy accounts for approximately 5% of the total reduction. The remainder of the savings is attributable to heating. The largest contribution to the savings in heating energy is achieved by increasing airtightness to 3 ACH50.

The average savings in whole-house energy cost was 11%. Depending on house size and location, the savings range from $171 to $553 per year, with an average annual savings of $311.

While there is a significant opportunity to save energy with the 2012 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 a checklist such as Energy Star 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 and insulation are installed. In implementing the new code, the state may wish to consider a transitional phase-in period during which every home would be tested, but the failure to reach 3 ACH50 would not result in a home failing to obtain a certificate of occupancy.

Additionally, 3 ACH50 should be considered a very tight building envelope, and the state should give serious consideration to also adopting the whole-house ventilation requirements in the most recent version of ASHRAE Standard 62.2. In addition to diluting a wide variety of indoor contaminants that may be difficult to identify and quantify, this would have the effect of reducing indoor moisture levels. Our experience with above code programs in heating climates has shown that very tight homes can retain higher levels of indoor moisture, and windows with U-values similar to those required by this code can experience interior condensation during the winter. Problems of this type could undermine support for energy efficiency in the state, which would be counterproductive to the long-term goal of saving energy.

The state may want to consider phasing in code language that would limit the oversizing of heat pumps and air conditioners. This would allow homeowners to better realize financial savings of smaller equipment size related to improved building envelope, and would also allow systems to dehumidify more appropriately in the summer. More study is needed to determine how to define appropriate limits in a way that code officials can apply uniformly and appropriately and that is flexible enough to allow appropriate sizing for truly unusual conditions where a higher than usual cooling load is present.

REFERENCES

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[5]US Census Data http://www.census.gov/const/C25Ann/sftotalsqft.pdf

[6]ASHRAE Standard 62.2-2010. Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. Atlanta, GA, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

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Appendix

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. 2001 Residential Permits by Nebraska code jurisdiction.