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Energy Impact Study of the 2003 IECC and 2009 IECC Energy Codes for Nebraska

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Executive Summary

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

- Nebraska's current residential energy code, the 2003 International Energy Conservation Code (IECC), and
- The 2006 International Energy Conservation Code (IECC), and
- The 2009 International Energy Conservation Code (IECC), with Energy Star heating equipment. Both Energy Star air-source heat pumps and Energy Star forced air furnaces were investigated.

2009 IECC performs best in most cases

Homes constructed according to the requirements of the 2009 IECC consumed less energy annually for heating and cooling in cities representing Nebraska's three climate zones: Omaha, Chadron, and Norfolk. The reduction in whole-house energy consumption ranged from 3 to 12%. Utility bills were also lower in all cases, except when a heat pump was used in the Chadron climate.

The energy savings were greatest in the Omaha climate zone and were much smaller in Chadron. Most of the energy savings are due to new requirements for duct sealing and high-efficacy lighting. In the colder climate zones, the 2009 IECC actually requires less insulation than the 2003 IECC, which offsets a portion of the savings due to these new measures.

The study also shows that additional savings would be achieved through the adoption of a requirement for Energy Star heating equipment. For homes using gas furnaces, this requirement coupled with the 2009 IECC produces 13-15 percent energy savings. When energy star heat pumps are present, homes use significantly less site energy, but this produces operating cost savings only in Omaha and Norfolk.

Key differences between 2003 and 2009 codes

There are several important differences between the 2003 and 2009 IECC codes. Several of these differences were also present in a former study that we conducted to compare the 2003 and 2006 IECC codes. These are:

1. Under the 2003 code, Nebraska consisted of three separate climate zones with different insulation requirements for each. The 2009 code combines the entire state into a single climate zone with uniform requirements. The 2009 component insulation requirements are most similar to the 2003 requirements for Omaha, which has one of the state's warmer climates. This is why the savings for the 2009 code are largest in Omaha.
2. The 2003 IECC requires more insulation to be used when houses have a larger percentage of windows. This acts both as an incentive for builders to limit the percentage of windows and to partially offset the increased energy consumption that occurs as the amount of window area increases. The 2009 IECC drops this requirement: there is no limit on the window area that can be installed, and there is no longer a requirement to offset the energy consumed by the larger window area with increased insulation elsewhere in the house. This is why the savings for the 2009 IECC are smaller for homes with 18% window to wall ratio.
3. The 2009 code allows builders to use less insulation in floors and up to 500 sf (or 20%) of ceilings if the insulation fills the framing cavity. This potentially allows houses to be

constructed with much less insulation than the 2003 code would allow. These lower insulation values were not used in this study.

There are also several changes that were made between 2006 and 2009 that impact homes constructed in the state. These are:

1. All homes with furnaces must have an installed programmable thermostat that is initially programmed for 70ºF in the heating season and 78ºF in the cooling season.
2. Ducts must be air sealed and tested. If any portion of the ducts or air handler are located outside of conditioned space, duct sealing must be verified by one of three test methods: leakage to the outdoors tested less than 8% of conditioned floor area upon completion of the home, total duct leakage of less than 6% of conditioned floor area tested at rough-in with the air handler installed, or less than 4% of the conditioned floor area tested at rough-in if the air handler is not installed.
3. At least 50% of installed lamps must be high-efficacy. This includes compact fluorescent, fluorescent, and other lamps of similar efficacy (for example, LED).
4. Air sealing of the building thermal envelope must be performed and verified via either visual inspection of certain items or by performing a blower door test on a completed home.

About the Study

The study considers the annual energy consumption of houses constructed according to the 2003 and 2009 IECC energy codes. Energy use was modeled for three cities selected to represent climate zones 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] and a 2006 follow-up study that was based on the 2006 IECC[3]. 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 second 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.

One key change in methodology has been made relative to the previous studies: the adoption of a new software tool. The primary reasons for this are: the widespread acceptance of the RESNET standard by government agencies and the housing industry, the availability of software tools to easily model buildings according the standard, and the expansion of the standard in 2009 to include categories of home energy use that were not included in previous standards (for example, lighting and duct sealing). This makes 2009 an ideal time to switch to a software tool such as REM/Rate that has been specifically designed to model whole-house energy consumption according to the RESNET standard.

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.

Disclaimer

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Introduction

The objective of this study was to compare the energy impact for Nebraska homeowners under the 2003 International Energy Conservation Code (IECC), the 2009 IECC, and the 2009 IECC with 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]. 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 determined that the average Nebraska home built that year was 1,870 square feet (sf) in size. Unfortunately, data on floor area were not available for Omaha, where many of the state's larger homes are likely built. The average new home in Lincoln was approximately 2,200 sf, which supports this assumption. Also, U.S. census data[4] for 2001 report that the median new home in the area defined as "Midwest" was 1,965 sf, and the average new "Midwest" home was 2,209 sf (very large homes skew the average higher).

The census data also include some information on the distribution of sizes. This was used to estimate the 20th and 80th percentile house sizes for the study. The 20th percentile Nebraska home is larger than 20 percent of new homes built in Nebraska. Likewise, the 80th percentile home is larger than 80 percent of new Nebraska homes. By interpolation of the census data, the 20th percentile home in the "Midwest" is approximately 1,450 sf, and the 80th percentile is about 2,900 sf.

The four selected house plans were: a ranch house at the 20th percentile, a ranch house at the mean size determined by the survey of Nebraska code officials, a two story house between the median and average sizes for Midwest homes according to the U.S. Census data, and a two story house at the 80th percentile. Plans and estimating kits were supplied by Design Basics, an Omaha building plan service that supplies plans for 15,000 houses per year. 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. An additional set of simulations were performed for homes with Energy Star electric heat pumps under the 2009 code.

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

Four combinations of energy code and heating system were modeled. These included the 2003 IECC (International Energy Conservation Code), the 2009 IECC, the 2009 IECC with an Energy Star gas furnace (90% AFUE), and the 2009 IECC with an Energy Star heat pump (14.5 SEER/8.5 HSPF).

The 2009 code contains several major changes. Three of these were first implemented in 2006:

1. The entire state of Nebraska has been included in a single climate zone with uniform requirements throughout the state. Under the 2003 code, Nebraska includes three climate regions with different requirements, with Omaha, Norfolk, and Chadron each falling in a different region.
2. Another major change is that the code requirements no longer change with window to wall area ratio. The 2003 IECC contains more stringent requirements for houses with window to wall ratio exceeding 15%. This means that the component requirements for that code are different for the cases with 12% and 18% window to wall ratio.
3. The new code also allows builders to use less insulation in floors and up to 500 sf (or 20%) of ceilings if the insulation fills the framing cavity. This potentially allows houses to be constructed with much less insulation than the 2003 code would allow. These lower insulation values were not used in this study when comparing the codes.

There were also four key changes that were adopted in 2009. These include:

1. All homes with furnaces must have an installed programmable thermostat that is initially programmed for 70ºF in the heating season and 78ºF in the cooling season.

2. Ducts must be air sealed and tested. If any portion of the ducts or air handler are located outside of conditioned space, duct sealing must be verified by one of three test methods: leakage to the outdoors tested less than 8% of conditioned floor area upon completion of the home, total duct leakage of less than 6% of conditioned floor area tested at rough-in with the air handler installed, or less than 4% of the conditioned floor area tested at rough-in if the air handler is not installed.
3. At least 50% of installed lamps must be high-efficacy. This includes compact fluorescent, fluorescent, and other lamps of similar efficacy (for example, LED).
4. Air sealing of the building thermal envelope must be performed and verified via either visual inspection of certain items or by performing a blower door test on a completed home.

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. An exception is the requirement for the 2003 18% window to wall ratio cases, for which the simplified prescriptive track cannot be used. A more detailed prescriptive track with similar tabular values taken from Chapter 5 of that code was used instead.

The 2009 IECC was modeled with three different HVAC system options, shown in Table 2. The first, (case a) is with an 80% AFUE gas furnace and a 13 SEER air conditioner. This is the minimum efficiency HVAC equipment that can be installed according to the code as written. The second, (case b) uses an Energy Star furnace with 90% AFUE and a 13 SEER air conditioner. The last, (case c) uses an Energy Star heat pump with 14.5 SEER and 8.5 HSPF.

Component	2003 IECC			2003 IECC			2009 IECC (case a)	2009 IECC (case b)	2009 IECC (case c)
	15% or less window to wall ratio			18% window to wall ratio			80% AFUE furnace	Energy Star furnace	Energy Star heat pump
	Omaha	Norfolk	Chadron	Omaha	Norfolk	Chadron	All cities	All cities	All cities
Glazing U-factor	0.35	0.35	0.35	0.34	0.33	0.33	0.35	0.35	0.35
Glazing SHGC	none	none	none	none	none	none	none	none	none
Opaque door U-factor	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Ceiling R-value (note a)	38	49	49	49	49	49	38	38	38
Wall R-value	18	21	21	22	22	25	20 or 13+5 (note b)	20 or 13+5 (note b)	20 or 13+5 (note b)
Floor R-value	21	21	21	19	25	30	30 (note c)	30 (note c)	30 (note c)
Basement wall R-value	10	11	11	10	11	15	10/13 (note d)	10/13 (note d)	10/13 (note d)
Forced air furnace (AFUE) (note e)	80%	80%	80%	80%	80%	80%	80%	90%	N/A
Central air conditioning (SEER) (note f)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	N/A
Air-source heat pump (SEER/HSPF)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14.5 /8.5
Programmable thermostat	No	No	No	No	No	No	Yes	Yes	No
% CFL lighting	0	0	0	0	0	0	50	50	50
Duct leakage	No testing requirement						Testing requirement		

Table 2. Component requirements by building code.

Note a: Both codes allow R30 to be substituted if the uncompressed R30 extends over the top plate at the eaves. In the 2009 Code, R30 may also be used for ceiling areas of up to 500 sf with no attic. The 2003 Code does not limit square feet.
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: R10 may be used if insulation is continuous; R13 must be used if insulation is placed in the framing cavity.
Note e: The “prevailing minimum federal efficiency of 78% is required, but 80% is widely installed and was used for the analysis.
Note f: The 2003 IECC required 10.0 SEER, but is no longer available since the minimum federal efficiency increased to 13.0 is 2006. 13.0 SEER is 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.

The 2009 codes are less stringent than the 2003 IECC in a number of areas related to building envelope. They do not require a lower glazing U-factor and higher R-values for other building components for larger window to wall ratios. The 2009 required ceiling R-value and wall R-value are lower than that required for all but the Omaha 12% case under the 2003 codes. Also, the 2009 codes allow R values that are significantly lower than the 2003 code 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, thus casting the 2009 code in its favorable light. The exception was allowed for a small section of vaulted ceiling (5% of the total roof area) in the largest of the home plans.

The R-value for framed floors over unconditioned spaces required by the 2009 code is larger than that required by the 2003 code. However, the houses in this study had only small areas of this type of floor, which was limited primarily to framed floors over garages. The 2009 codes also require more basement wall insulation than most of the 2003 cases. Modeling was performed with basement insulation in cavity walls, so R13 was used for the 2009 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. Likewise, the 2003 code did allow a 10.0 SEER air conditioning unit to be used, but these are no longer available due to an increase in the federal minimum efficiency requirement. Two additional cases were modeled with the 2009 IECC in which Energy Star heating equipment was used. The first of these used a 90% AFUE furnace with a 13 SEER air conditioner, while the second included a 14.5 SEER/8.5 HSPF air-source heat pump.

Climates

Three cities were chosen to represent the climate variation in Nebraska. These cities represent different heating degree day categories used in the 2003 IECC to specify required thermal performance of envelope components. 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 degree day categories, 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).

Degree day range (2003 IECC)	City	Annual heating degree days
6,000-6,499	Omaha	6,153
6,500-6,999	Norfolk	6,766
7,000-8,499	Chadron	7,021

Table 3. Selected Nebraska cities and climates.

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

Each code condition is 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-factor of 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

Wall insulation is typically available in specific increments of R-value, and was selected as such for this analysis. Table 4 summarizes the required insulation R-value, the framing required, and the insulation products used.

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. Rigid insulation is often used in place of exterior sheathing, with wood sheathing used at the corners for shear bracing. Because the 2009 codes allow this structural sheathing to cover up to 25% of the wall area without requiring an additional layer of insulation, a framing factor of 0.25 was also used for rigid insulation.

The 2009 IECC requires either cavity insulation of R-20 or cavity insulation of R-13 plus 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 both of these scenarios are very close to one another, the 2009 cases were modeled with an R-20 cavity insulation in a 2x6 wall.

Nominal R-value (ºFft^{2}hr/Btu)	Wall construction	Wall insulation type
18	2 x 4	3-½" R15 fiberglass batts plus R-3 isocyanurate rigid insulation
20 or 13+5	2 x 6	5-½" R20 cavity insulation (see discussion)
21	2 x 6	5-½" R21 fiberglass batts
22	2 x 6	5-½" R19 fiberglass batts plus R-

		3” isocyanurate rigid insulation
25	2 x 6	5-½” R21 fiberglass batts plus R-4 isocyanurate rigid insulation

Table 4. Wall insulation combinations used to meet code requirements.

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. Table 5 shows the basement wall insulation combinations used to meet the code requirements. All of the combinations result in the minimum required R-value except for the R10 requirement, which was met with R11 fiberglass batts.

R-value (°Fft^{2}hr/Btu)	Basement wall insulation type
10	3 ½” R11 fiberglass batts
11	3 ½” R11 fiberglass batts
13	3 ½” R13 fiberglass batts
15	3 ½” R15 fiberglass batts

Table 5. Basement wall insulation combinations used to meet code requirements.

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. 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 (°Fft^{2}hr/Btu)	Insulation location	Insulation type
30	Cathedral ceiling	9” R30 fiberglass batts
38	Cathedral ceiling	6 ¼” foamed in place urethane (approx. R6 per inch)
49	Cathedral ceiling	8” foamed in place urethane (approx. R6 per inch)
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 6. Roof and ceiling insulation combinations used to meet code requirements.

Floor insulation

Insulation requirements for framed floors over unconditioned space were met using the insulation combinations shown in Table 7. In each case, the exact minimum insulation requirement was used. 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.

R-value ($^oFft^2hr/Btu$)	Insulation type
19	5-½” R19 fiberglass batts
21	5-½” R21 fiberglass batts
25	9” R25 fiberglass batts
30	9” R30 fiberglass batts

Table 7. Floor insulation combinations used to meet code requirements.

Exterior doors

The U-factor requirement for opaque doors was 0.35 $Btu/hrft^{2o}F$ for all of the codes. The opaque portions of all doors were modeled with this U-factor.

Infiltration

The 2009 IECC adds requirements for air sealing. Builders are given two options for code compliance. 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 code officials to actually result in significantly improved airtightness. Furthermore, the testing requirement of less than 7 ACH50 is not a very stringent limit, and most likely not a significant improvement over the current average Nebraska home.

In our previous study, we modeled the homes with an air infiltration rate of 0.5 air changes per hour under normal weather conditions for the above ground portions of the home, and 0.2 air change per hour for basements. Air infiltration rates in U.S. houses vary by up to a factor of 10, and have been shown to vary by approximately 15% in identical houses constructed at the same time by the same contractor[5]. The rate of 0.5 air change per hour was selected for the model because it is the median annual infiltration value measured in a study of 312 U.S. houses of “newer, energy efficient construction”[6]. At the time, this was the best estimate of the air tightness of a typical home. Air change rate under normal weather conditions is also referred to as “ACH natural”. This measure of airtightness can only be approximately translated to ACH50. For a typical home constructed in Nebraska, ACH50 can be estimated by multiplying ACHnatural by 15. For the above grade portions of the home, our previous model would have had about 7.5 ACH50 in the previous study, and the basements would have had approximately 3 ACH50. With both combined, the overall home would have had less than 7 ACH50.

Since the code has set requirements for air infiltration for the first time in 2009 and has chosen to use the metric of ACH50, we have converted all of the energy models to this infiltration rate. It is expected that if future codes require a tighter building envelope, they will do so by reducing the allowable ACH50 test that a home can achieve. However, for the current study, since we do not expect the requirement to produce significantly tighter homes than are already being constructed, we have modeled all of the code cases with the identical infiltration rate of 7 ACH50.

Thermostat settings

Our previous studies of Nebraska codes did not include thermostat setbacks, which influence heating and cooling energy consumption. 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) comfort ranges for people seasonally dressed. Although the 2009 code requires 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.

Setback thermostats were not modeled for the 2003 code case or the 2009 case with a heat pump, but they were modeled for the 2009 cases that have gas furnaces. The 2009 IECC requires that programmable thermostats be installed for all homes having furnaces, but does not require them for homes with heat pumps. 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 IECC requirement for duct leakage requires that duct leakage, which was not included in the previous study, be included. The 2003 cases were modeled using the RESNET default distribution system efficiency of 80%. This includes both duct leakage and conduction heat loss through ducts located outside conditioned space. 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 feel 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. The requirement will also likely offer 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 if the code is adopted.

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. Heat pumps were also sized in ½ ton increments, but were sized ½ ton larger than the smallest size that would meet the home’s sensible cooling load. This allows the heat pump to meet more of the home’s heating load in winter.

Lighting

The 2009 code requires, for the first time that high-efficacy lighting be used for 50% of installed lamps. The 2003 code was modeled with no fluorescent lighting. The 2009 code was modeled with 50% compact fluorescent lamps installed.

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 three code conditions to determine their annual energy consumption. Comparison of the results shows that the 2009 IECC requires less energy for heating and cooling than the 2003 cases for all houses and climates. The savings are largest for homes in Omaha and homes with 12% window to wall ratio. The savings are smallest for the homes in Chadron with 18% window to wall ratio.

Energy use

Table 8 shows the annual cooling-related electricity consumption of each house under each code condition. In all cases, the 2003 IECC uses the most energy under cooling conditions. The two 2009 IECC cases with a 13 SEER air conditioner use between 11 and 15% less energy than their respective 2003 cases. The 2009 IECC with 14.5 SEER heat pump uses between 16 and 21% less energy than the homes built to 2003 code. The percent savings is similar regardless of window to wall ratio, though the actual savings is greater for larger window to wall ratio because the cooling load is larger.

This is somewhat surprising because the 2003 code has more stringent envelope requirements in most cases. However, most of the savings comes from two items: high efficacy lighting and reduced duct leakage. 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 (for example, programmable thermostat would show less savings if implemented after duct leakage and CFL lighting), but the process is a helpful way to demonstrate the effects of each change.

Code-based change	Cooling kWh	Change (kWh)
Begin with 2003 IECC	2416	
Decrease foundation wall to R-13	2408	-8
Decrease rim joist and wall insulation to R-20	2406	-2
Increase window U-value to 0.35	2397	-9
Decrease ceiling insulation to R-38	2404	+7
Add programmable thermostat	2381	-23
Decrease duct leakage to 4% to outside	2203	-178
Add 50% CFL lighting	2105	-98
End with 2009 IECC	2105	-311 (total change)
Upgrade to 14.5 SEER heat pump	1951	-154 (additional)

It seems odd that less insulation can reduce 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 grade wall R-value should increase cooling energy consumption at times of high outdoor temperature. However, a very small decrease 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. Overall, however, wall R-values in this range have a very small effect on cooling energy compared to other variables. Window U-value and ceiling R-value also have a very small effect. The largest impacts are from duct leakage and CFL lighting. Upgrading to a 14.5 SEER heat pump also has a larger impact.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2003 IECC	Omaha	12%	2636	3275	3639	4859
2009 IECC/IRC (a)	Omaha	12%	2326	2895	3199	4185
2009 IECC/IRC (b)	Omaha	12%	2326	2895	3199	4185
2009 IECC/IRC (c)	Omaha	12%	2161	2685	2962	3861
2003 IECC	Omaha	18%	3266	4056	4617	6095
2009 IECC/IRC (a)	Omaha	18%	2874	3605	4069	5274
2009 IECC/IRC (b)	Omaha	18%	2874	3605	4069	5274
2009 IECC/IRC (c)	Omaha	18%	2665	3330	3754	4850
2003 IECC	Norfolk	12%	2314	2872	3263	4275
2009 IECC/IRC (a)	Norfolk	12%	2083	2588	2895	3714
2009 IECC/IRC (b)	Norfolk	12%	2083	2588	2895	3714
2009 IECC/IRC (c)	Norfolk	12%	1934	2400	2680	3433
2003 IECC	Norfolk	18%	2927	3634	4211	5462
2009 IECC/IRC (a)	Norfolk	18%	2594	3250	3705	4726
2009 IECC/IRC (b)	Norfolk	18%	2594	3250	3705	4726
2009 IECC/IRC (c)	Norfolk	18%	2405	3002	3417	4347
2003 IECC	Chadron	12%	1849	2309	2621	3398
2009 IECC/IRC (a)	Chadron	12%	1637	2056	2322	2936
2009 IECC/IRC (b)	Chadron	12%	1637	2056	2322	2936
2009 IECC/IRC (c)	Chadron	12%	1523	1910	2150	2716
2003 IECC	Chadron	18%	2416	2985	3474	4470
2009 IECC/IRC (a)	Chadron	18%	2105	2634	3014	3821
2009 IECC/IRC (b)	Chadron	18%	2105	2634	3014	3821
2009 IECC/IRC (c)	Chadron	18%	1951	2425	2784	3521

Table 8. Annual cooling electricity consumption (kWh).

Table 9 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 in those cases. When a heat pump is used, electricity is the primary heating fuel, so the consumption is much higher. There is a slight increase in heating kWh from the 2003 code to the 2009 code with 80% furnace, even though the overall heating energy (including gas consumption) decreases. We believe that this is an artifact of the way REMRate handles distribution system losses in the first case, where the system efficiency is modeled as 80% compared to how it models losses when actual duct leakage is specified. Thus this is simply a small modeling anomaly that does not affect the overall energy consumption prediction. Heating electricity consumption does decrease between the 2009 cases with 80% and 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
2003 IECC	Omaha	12%	623	737	772	1102
2009 IECC/IRC (a)	Omaha	12%	662	793	839	1147
2009 IECC/IRC (b)	Omaha	12%	506	636	673	993
2009 IECC/IRC (c)	Omaha	12%	10384	12914	13605	20927
2003 IECC	Omaha	18%	631	734	778	1116
2009 IECC/IRC (a)	Omaha	18%	691	827	882	1198
2009 IECC/IRC (b)	Omaha	18%	528	663	707	1037
2009 IECC/IRC (c)	Omaha	18%	10632	13110	13898	21212
2003 IECC	Norfolk	12%	631	746	785	1118
2009 IECC/IRC (a)	Norfolk	12%	697	834	883	1208
2009 IECC/IRC (b)	Norfolk	12%	533	669	708	1045
2009 IECC/IRC (c)	Norfolk	12%	11798	14660	15465	24463
2003 IECC	Norfolk	18%	652	771	815	1153
2009 IECC/IRC (a)	Norfolk	18%	728	871	921	1262
2009 IECC/IRC (b)	Norfolk	18%	556	698	747	1092
2009 IECC/IRC (c)	Norfolk	18%	12120	14923	15850	24344
2003 IECC	Chadron	12%	670	793	825	1177
2009 IECC/IRC (a)	Chadron	12%	729	872	916	1253
2009 IECC/IRC (b)	Chadron	12%	557	699	734	1085
2009 IECC/IRC (c)	Chadron	12%	12915	16124	16373	26087
2003 IECC	Chadron	18%	667	792	829	1178
2009 IECC/IRC (a)	Chadron	18%	761	911	963	1310
2009 IECC/IRC (b)	Chadron	18%	581	730	772	1134
2009 IECC/IRC (c)	Chadron	18%	12982	16565	16961	26163

Table 9. Annual heating electricity consumption (kWh).

Table 10 shows gas consumption for the various cases in therms per year. In all cases, the 2009 IECC has lower gas consumption. For heating, a tradeoff occurs between the superior envelope required by the 2003 IECC versus the improved duct system and programmable thermostat required by the 2009 IECC. For the homes located in Chadron with 18% window to wall ratio, the differences in thermal envelope components are the largest, and there is very little savings with the 2009 IECC. Below is a summary of the effects of each item for the 1453 sf house located in Chadron with 18% glass:

Code based change	Heating therms	Change (therm)
Begin with 2003 IECC	840	
Decrease foundation wall to R-13	852	+12
Decrease rim joist and wall insulation to R-20	889	+37
Increase window U-value to 0.35	904	+15

Decrease ceiling insulation to R-38	928	+24
Add programmable thermostat	911	-17
Decrease duct leakage to 4% to outside	812	-99
Add 50% CFL lighting	828	+16
End with 2009 IECC	828	-12 (total change)
Upgrade to 90% AFUE gas furnace	736	-92 (additional)

What the above summation shows is that a series of changes to envelope requirements in 2009 that erode the performance of the building envelope (foundation wall, wall, and ceiling insulation, as well as window U-value) are offset by a series of new requirements that improve overall building performance (thermostat and primarily duct leakage). High efficacy lighting actually adds to the heating consumption of a home, although when the energy to operate the lighting and its effect on cooling are considered, the overall effect is a net positive.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2003 IECC	Omaha	12%	795	976	1026	1606
2009 IECC/IRC (a)	Omaha	12%	692	854	894	1382
2009 IECC/IRC (b)	Omaha	12%	615	759	795	1229
2009 IECC/IRC (c)	Omaha	12%	n/a	n/a	n/a	n/a
2003 IECC	Omaha	18%	768	924	979	1548
2009 IECC/IRC (a)	Omaha	18%	706	872	920	1406
2009 IECC/IRC (b)	Omaha	18%	628	775	818	1250
2009 IECC/IRC (c)	Omaha	18%	n/a	n/a	n/a	n/a
2003 IECC	Norfolk	12%	831	1020	1077	1683
2009 IECC/IRC (a)	Norfolk	12%	765	944	990	1527
2009 IECC/IRC (b)	Norfolk	12%	680	839	880	1358
2009 IECC/IRC (c)	Norfolk	12%	n/a	n/a	n/a	n/a
2003 IECC	Norfolk	18%	828	1016	1074	1664
2009 IECC/IRC (a)	Norfolk	18%	784	967	1022	1558
2009 IECC/IRC (b)	Norfolk	18%	697	859	909	1385
2009 IECC/IRC (c)	Norfolk	18%	n/a	n/a	n/a	n/a
2003 IECC	Chadron	12%	891	1095	1135	1781
2009 IECC/IRC (a)	Chadron	12%	813	1003	1034	1603
2009 IECC/IRC (b)	Chadron	12%	722	892	919	1425
2009 IECC/IRC (c)	Chadron	12%	n/a	n/a	n/a	n/a
2003 IECC	Chadron	18%	840	1035	1079	1684
2009 IECC/IRC (a)	Chadron	18%	828	1021	1062	1626
2009 IECC/IRC (b)	Chadron	18%	736	908	944	1446
2009 IECC/IRC (c)	Chadron	18%	n/a	n/a	n/a	n/a

Table 10. Annual heating gas consumption (therm).

Table 11 shows the annual electricity consumption for lights 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 high-efficacy lamps is approximately 9% in all cases.

Code	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2003 IECC	10007	12158	10962	16574
2009 IECC (all cases)	9104	11051	9969	15049

Table 11. Annual electricity consumption for lights and appliances (kWh)

Table 12 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 2009 IECC used less total energy than the 2003 IECC. For the homes with 12% window to wall ratio, the reduction was 7 to 12% depending on city and house size. For the homes with 18% window to wall ratio, the reduction was 3 to 9% depending on city and house size. In Chadron, where the 2009 IECC most reduces envelope insulation requirements, the predicted savings for homes with 18% window to wall ratio averaged only 4%. When Energy Star heating equipment is added, the energy savings increases to an average of 13% in Chadron and 15% in Omaha.

The cases with an electric heat pump show significantly less energy used overall. However, this will not necessarily translate into lower energy bills for the homeowner or improved environmental conditions. Electric heat pumps are extremely efficient in terms of site energy (energy used at the house), but are less efficient in terms of source energy (energy burned at the power plant to deliver electricity to the home).

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2003 IECC	Omaha	12%	138.4	166.3	170.7	253.1
2009 IECC/IRC (a)	Omaha	12%	124	149.3	152.9	223.4
2009 IECC/IRC (b)	Omaha	12%	115.8	139.3	142.3	207.5
2009 IECC/IRC (c)	Omaha	12%	87.5	104.5	106.2	151.6
2003 IECC	Omaha	18%	137.9	163.8	169.4	251.6
2009 IECC/IRC (a)	Omaha	18%	127.5	153.6	158.6	229.6
2009 IECC/IRC (b)	Omaha	18%	119.1	143.4	147.7	213.5
2009 IECC/IRC (c)	Omaha	18%	90	107.4	109.9	155.9
2003 IECC	Norfolk	12%	141.3	169.8	175	259.3
2009 IECC/IRC (a)	Norfolk	12%	131.1	157.8	161.9	237
2009 IECC/IRC (b)	Norfolk	12%	122	146.7	150.3	219.4
2009 IECC/IRC (c)	Norfolk	12%	91.9	109.9	112	162.6
2003 IECC	Norfolk	18%	143.1	172.1	178	261.6
2009 IECC/IRC (a)	Norfolk	18%	134.8	162.4	168.1	243.6
2009 IECC/IRC (b)	Norfolk	18%	125.5	151.1	156.1	225.8
2009 IECC/IRC (c)	Norfolk	18%	94.6	112.9	115.8	165.3
2003 IECC	Chadron	12%	146.2	175.9	179.2	266.8
2009 IECC/IRC (a)	Chadron	12%	134.8	162.4	164.9	242.4
2009 IECC/IRC (b)	Chadron	12%	125.1	150.7	152.8	224.1
2009 IECC/IRC (c)	Chadron	12%	94.7	113.6	113.7	166.2
2003 IECC	Chadron	18%	143	172.3	176.5	260.7

2009 IECC/IRC (a)	Chadron	18%	138	166.3	170.3	248
2009 IECC/IRC (b)	Chadron	18%	128.2	154.3	157.9	229.3
2009 IECC/IRC (c)	Chadron	18%	96.4	116.9	117.9	169.2

Table 12. Annual whole house energy consumption (MMBtu/year).

Table 13 shows energy cost in dollars per year for each of the cases. Adopting the 2009 IECC saves consumers an average of 5 to 8% depending on the city. The percent savings in energy cost and energy consumption are not exactly the same because different fuels (gas and electricity) have different costs. The addition of Energy Star heating equipment results in a 7 to 10% cost savings compared with the 2003 IECC. Costs with electric heat pumps depend both on electric rate and the number of hours at low temperatures, when heat pumps do not operate efficiently. For this reason, there are cost savings averaging 14% in Omaha and 12% in Norfolk, but in Chadron, the heat pump cases had an average of 8% higher energy costs.

Code	City	Window/ wall ratio	1,453 sf ranch	1,852 sf ranch	2,103 sf 2 story	2,932 sf 2 story
2003 IECC	Omaha	12%	1987	2274	2300	3079
2009 IECC/IRC (a)	Omaha	12%	1850	2110	2132	2806
2009 IECC/IRC (b)	Omaha	12%	1798	2046	2065	2708
2009 IECC/IRC (c)	Omaha	12%	1693	1953	1976	2647
2003 IECC	Omaha	18%	2021	2304	2350	3143
2009 IECC/IRC (a)	Omaha	18%	1904	2178	2218	2909
2009 IECC/IRC (b)	Omaha	18%	1850	2113	2150	2809
2009 IECC/IRC (c)	Omaha	18%	1743	2012	2051	2738
2003 IECC	Norfolk	12%	1951	2227	2261	3017
2009 IECC/IRC (a)	Norfolk	12%	1849	2105	2131	2803
2009 IECC/IRC (b)	Norfolk	12%	1791	2035	2058	2694
2009 IECC/IRC (c)	Norfolk	12%	1689	1947	1975	2676
2003 IECC	Norfolk	18%	1996	2282	2330	3095
2009 IECC/IRC (a)	Norfolk	18%	1899	2169	2212	2899
2009 IECC/IRC (b)	Norfolk	18%	1839	2097	2137	2787
2009 IECC/IRC (c)	Norfolk	18%	1737	2002	2046	2739
2003 IECC	Chadron	12%	1646	1849	1853	2375
2009 IECC/IRC (a)	Chadron	12%	1556	1753	1757	2221
2009 IECC/IRC (b)	Chadron	12%	1538	1720	1723	2174
2009 IECC/IRC (c)	Chadron	12%	1715	1982	1986	2704
2003 IECC	Chadron	18%	1678	1887	1905	2435
2009 IECC/IRC (a)	Chadron	18%	1607	1802	1819	2296
2009 IECC/IRC (b)	Chadron	18%	1578	1769	1784	2248
2009 IECC/IRC (c)	Chadron	18%	1751	2040	2059	2769

Table 13. Annual whole house energy cost ($/year).

Conclusion and recommendations

The findings of this study indicate that the 2009 International Energy Conservation Code would result in less energy consumption for homes in all areas of the state. It is unfortunate that the 2009 code rolls back envelope insulation requirements for homes with high percentages of glass, and for homes in colder regions. However, the added requirement of the 2009 code to test and reduce duct leakage is a very positive step that will provide savings. The savings will vary according to duct placement within the house, and may be less than predicted for homes with most of their ductwork inside conditioned space, but could be much larger than predicted for homes with poorly sealed ducts located in attics. The new requirement for high-efficacy lighting will also provide significant energy savings, particularly during summer peak periods.

It should also be mentioned that since the 2009 IECC does not place any limitation on window to wall ratio, some homes could be constructed with very large glazing percentages. These homes could be less efficient than would be allowed under the 2003 code.

The addition of a requirement for Energy Star heating equipment does result in significant additional savings, and should be considered. This requirement would allow homeowners in the colder parts of the state to also experience savings with the new code.

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Appendix

Number of permits and heating degree days by code jurisdiction

Jurisdiction	Permits	HDD	Modeled City	Jurisdiction	Permits	HDD	Modeled City
Albion	7	7087	Chadron	Louisville	3	6292	Omaha
Alliance	5	6823	Norfolk	McCook	7	5967	None
Alma	3	6203	Omaha	Mead	1	6570	Norfolk
Ashland	32	6379	Omaha	Milford	6	5779	None
Auburn	6	5765	None	Minden	3	6398	Omaha
Beatrice	35	6151	Omaha	Nebraska City	9	6023	Omaha
Bellevue	300	6153	Omaha	Norfolk	65	6766	Norfolk
Blair	56	6455	Omaha	North Platte	53	6766	Norfolk
Bloomfield	1	7057	Chadron	Ogallala	12	6672	Norfolk
Cass County	121	6292	Omaha	Omaha	2136	6153	Omaha
Central City	1	5834	None	O'Neill	4	7246	Chadron
Ceresco	1	6613	Norfolk	Palmyra	3	6337	Omaha
Chadron	9	7021	Chadron	Papillion	142	6153	Omaha
Columbus	60	6411	Omaha	Plainview	2	6485	Omaha
Cozad	7	6303	Omaha	Plattsmouth	20	6153	Omaha
Crete	10	5811	None	Ralston	2	6153	Omaha
Dakota City	7	6600	Norfolk	Sarpy County	281	6153	Omaha
David City	7	6237	Omaha	Saunders County	47	6613	Norfolk
Douglas County	42	6153	Omaha	Scottsbluff	19	6742	Norfolk
Elkhorn	64	6153	Omaha	Seward	24	5779	None
Falls City	1	5795	None	Seward County	22	5779	None
Fremont	40	6444	Omaha	Sidney	35	7092	Chadron
Gering	32	6742	Norfolk	South Sioux City	23	6600	Norfolk
Grand Island	101	6385	Omaha	Superior	1	5552	None
Gretna	166	6379	Omaha	Sutton	2	6347	Omaha
Hall County	24	6385	Omaha	Tekamah	4	6564	Norfolk
Hastings	59	6211	Omaha	Valley	4	6570	Norfolk
Holdrege	8	6482	Omaha	Wahoo	13	6570	Norfolk
Kearney	116	6652	Norfolk	Washington Cty.	79	6455	Omaha
Keith County	50	6672	Norfolk	Waverly	15	6119	Omaha
LaVista	115	6153	Omaha	Wayne	11	7143	Chadron
Lancaster County	34	6119	Omaha	Wymore	5	6151	Omaha
Lexington	7	6303	Omaha	York	19	6338	Omaha
Lincoln	1140	6119	Omaha	Yutan	4	6570	Norfolk

Table A1. 2001 Residential Permits by Nebraska code jurisdiction.