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March 6, 2019

Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509

RE: 2018 International Energy Conservation Code Incremental Cost Report

Disclaimer: This report was prepared with the support of the U.S. Department of Energy (DOE) Grant #DE-EE-0007483. The findings, conclusions and recommendations herein are those of the author and do not necessarily reflect the views of DOE.

***Approach**:* This letter discusses cost impacts associated with upgrading the Nebraska State Energy Code from the current 2009 International Energy Conservation Code (IECC) to the 2018 IECC. It is based directly on our recently completed report: *Energy Impact Study of the 2009 IECC and 2018 IECC Energy Codes for Nebraska*. This report focused on the energy use impact of updating Nebraska's residential energy code.

The item-by-item differences between the 2009 and 2018 codes and the cost impact of each are discussed below.

Cost estimates were obtained from three sources:

- *Residential Costs with RS Means data– 2019*, 38th annual edition; Gordian. (Costs from Means are based on Omaha as a location. The cost factors for most other locations in the state are lower than Omaha. Unless noted otherwise, costs obtained from RS Means include materials, labor, equipment, overhead and profit to represent what an installing contractor will charge a customer.)
- *EPA report: "Cost & Savings estimates: Energy Star Certified Homes, Version 3 (Rev. 08)* October 1, 2016 available online at: https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/EstimatedCostandSavings.pdf. This report provides an estimate of the incremental cost to build an Energy Star version 3 certified home compared to the 2009 IECC code.
- *Home Depot web site* – provides online pricing available to customers nationwide. Online pricing often mirrors pricing available in national chain home improvement stores. Pricing for this report was obtained using "Central Omaha" as the store location, in March 2019.

Cost and savings examples are shown for the 1852 sf three bedroom home with 18% window to wall ratio and 95% AFUE furnace, located in Omaha. The savings example in the original energy report was for the smallest home plan in the study, but for this report, a median sized home plan was used. Because the REMrate software that was used in the

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energy study has been updated since the original report, the calculated energy costs and savings have changed slightly. The latest version of the software is showing $10 more in savings for this home than was calculated by the previous version of the software (a change of about 6%). The savings by line item for this house are as shown below:

Code based change	Energy cost $/yr	Change ($/year)
Begin with 2009 IECC	2281	
Increase foundation wall to R-19	2261	-20
Reduce window U-value to 0.30	2244	-17
Increase ceiling insulation to R-49	2233	-11
Reduce door U-value to 0.30	2231	-2
Decrease duct leakage to 2% to outside	2211	-20
Reduce infiltration to 3 ACH50	2159	-52
Increase to 90% high-efficacy lighting	2081	-78
Reduce size of air conditioner by ½ ton	2079	-2
Add R-3 hot water pipe insulation	2075	-4
Add whole house mechanical ventilation system	2116	+41
End with 2018 IECC	2116	-165 (total change)

Each line item above corresponds directly to a change in code requirements between the 2009 and 2018 IECC, except for the ½ ton reduction in air conditioner size. This is a result of many of the code upgrades, including insulation, windows, and airtightness. The installation cost savings associated with this reduction can be applied to the overall code upgrade. The 1852 sf home that is used for the cost examples in this report saw a reduction from a 3.5 ton to 3.0 ton air conditioner. RS means shows a cost reduction of $270 for the air handler and evaporator coil and $360 for the condenser unit, for a total of $630 in reduced construction cost.

Basement wall insulation:

The ***2009 IECC*** requires either R-10 continuous basement wall insulation or R-13 insulation in a framed cavity. R-10 continuous insulation can be achieved using a rigid board product on the interior or exterior of the wall. R-13 cavity insulation is most often obtained using R-13 fiberglass batts in a 2x4 cavity.

The ***2018 IECC*** requires either R-15 continuous basement wall insulation or R-19 insulation in a framed cavity. R-15 continuous insulation can be achieved using a rigid board product on the interior or exterior of the wall. R-19 cavity insulation is most often obtained using R-19 fiberglass batts in a 2x6 cavity.

Net change: If continuous rigid board insulation is used, a thicker board insulation would be required, but the installation cost would be the same. If framed cavity insulation is used, the 2018 IECC would require an increase from a 2x4 to a 2x6 wall and an increase in the R-value of batt insulation.

Cost example: The 1852 sf example home has 1600 sf of basement wall area.

For the rigid board insulation case, RSMeans shows the cost of Extruded polystyrene 2" thickness with an R-value of 10 to be $1.692/sf for a total of $2707 for this home, and it shows the cost of Extruded polystyrene 3" thickness with an R-value of 15 to be $2.178/sf for a total of $3485 for this home. The increased cost for the 2018 IECC is $778 when rigid board insulation is used.

For the framed cavity case, RSMeans shows $2.565/sf for 2x4 framing and R-13 insulation, for a total cost of $4104. The RSMeans cost for 2x6 framing and R-19 insulation is $$3.168, for a total cost of $5069. The increased cost for the 2018 IECC is $965 for the framed wall case.

Savings: The cost analysis shows energy savings of $20 per year when upgrading to the 2018 IECC.

Crawlspace wall insulation:

The ***2009*** and ***2018 IECC*** requirements for crawlspace walls are exactly the same as for basements. Most crawlspaces utilize rigid board insulation on the walls.

Cost example: None of the homes in our study had crawlspaces. If the 1852 sf ranch home were built on a 4 ft tall crawlspace instead of a basement, its wall area would be 800 sf. Using the RSMeans costs from the example above for rigid board insulation, the cost to upgrade to the 2018 IECC would be $389.

Savings: Since the energy study did not consider insulated crawlspaces, a calculated energy savings is not available. It is realistic to assume that if the wall area of a conditioned crawlspace is half of the equivalent basement wall area, the energy savings would also be approximately half, or $10 per year.

Ceiling insulation:

The ***2009 IECC*** requires R-38 insulation in ceilings. This can be accomplished using R-38 fiberglass batts (10" to 12" thick) or with blown-in insulation.

The ***2018 IECC*** requires R-49 insulation in most ceilings throughout the state. R-49 insulation can be accomplished with blown-in insulation or with a combination of batts and blown-in insulation.
Net change: The 2018 IECC will require an additional R-11 insulation to be installed in attics.
Cost example: The 1852 sf ranch home has 1852 sf ceiling area. Using RSMeans cost data for blown fiberglass attic insulation, the installed cost is $2.007/sf or $3717 total for R-38 insulation and $2.556/sf or $4734 total for R-49. This would be a $1017 construction cost increase with the 2018 IECC.
Savings: The cost analysis shows energy savings of $11 per year when upgrading to the 2018 IECC.

Windows, doors, and skylights:
The ***2009 IECC*** requires a minimum fenestration U-factor of 0.35 (for windows and doors) and a minimum skylight U-factor of 0.60.
The ***2018 IECC*** requires a minimum fenestration U-factor of 0.30 and a minimum skylight U-factor of 0.55.
Both codes allow one exterior door to be exempted from the minimum U-factor requirement.
Net change: The 2018 IECC requires a decrease of 0.05 in U-factor for windows, doors (one excepted), and skylights.
Cost example-windows: The energy study considered homes with both 12% and 18% window to wall ratio. The 1852 sf home used in that study has 240 sf of glazing for 12% window to wall ratio and 360 sf of glazing for 18% window to wall ratio. The Energy Star 2016 cost report analyzed the same level of improvement in windows and determined that the cost was $0.66 per square foot of window. This would produce a cost increase of $158.40 for the 12% window to wall ratio case and $237.60 for the 18% window to wall case.
Cost example – skylights: Skylights that meet the modestly lower U-value requirement of the ***2018 IECC*** are the norm in the marketplace. In performing a search of the Home Depot web site using central Omaha as the location, the top five selling skylights all had U-values between 0.43 and 0.49. Therefore in most cases, I expect there to be no additional cost associated with meeting the 2018 requirement.
Cost example – doors: The Energy Star report did not show costs associated with opaque doors, and RSMeans does not list opaque doors by R-value. The U-value of a typical wood door does not meet the requirements of either code, while the U-value of a typical steel insulated or fiberglass insulated door exceeds both codes. Therefore, it is reasonable to assume that there will be no anticipated cost impact for doors.
Savings: The energy study did not include skylights. For the 1852 sf case with 18% window to wall ratio, the energy savings due to windows and doors was $19 per year.

Thermal envelope air sealing and testing:

The ***2009 IECC*** provides two ways demonstrate air sealing: (1) testing – perform a blower door test and obtain results of less than 7 air changes per hour when tested at 50 Pa pressure (ACH50). Or (2) using a checklist to perform a visual inspection to verify air sealing and the presence of air barriers, performed by a code official or approved third party independent of the installer of the insulation. In practice, a recent evaluation performed by the Nebraska Energy Office indicated that 5 ACH50 is being widely achieved under the 2009 code.
The ***2018 IECC*** requires testing with a blower door, and homes must achieve an airtightness of less than 3 ACH50.
Net change: The 2018 IECC would require a blower door test to be performed, and homes would need to meet a more strict level of airtightness.
Cost example: RSMeans does not list costs for blower door testing or air sealing. However, the Energy Star 2016 Cost Estimate report lists costs to improve airtightness from 7 ACH50 to three different levels: 6 ACH50, 5 ACH50, and 4 ACH50. The cost data they provide have perfectly linear curve fit. Using this curve fit to extrapolate to 3 ACH50, the cost to improve airtightness to 3 ACH50 can be estimated to be $0.40/sf floor area. For the 1852 sf home, the total cost would be $741. This cost includes materials and labor to perform the air sealing, but does not include the cost of a blower door test. National cost data for blower door testing are not available, but based on a recent informal survey conducted in North Carolina, it was determined that even for very rural counties requiring a HERS rater to travel up to 2 hours to perform the test, testing could be performed for $100 or less if it were to become part of the code.
Savings: The cost analysis shows a savings of $52 per year when upgrading to the 2018 IECC.

Energy efficient lighting:
The ***2009 IECC*** requires that high-efficacy lighting be used for 50% of installed lamps (light bulbs). Today, this requirement is most frequently met using LED lamps.
The ***2018 IECC*** increases the requirement to 90% high-efficacy lamps.
Net change: The 2018 code would require that an additional 40% of the lighting be installed as high-efficacy.
Cost example: A home with eight rooms, having an average of three lamps installed per room would be delivered with 24 total lamps. RSMeans does not list cost data for lamps. The Home Depot web site lists a cost of $9.94 for a package of eight 60-Watt equivalent LED lamps ($1.24 each), and a cost of $34.99 for a package of twenty four 60-Watt incandescent lamps ($0.69 each). This is a cost difference of $0.55 each. To replace ten lamps, the total increased cost would be $5.50.
Savings: The cost analysis shows energy savings of $78 per year when upgrading to the 2018 IECC.

Duct sealing and testing:
The ***2009 IECC*** has requirements for duct leakage that can be met/demonstrated in one of four ways: (1) Postconstruction duct blaster testing demonstrating leakage to outdoors of

less than 8 cfm/100 sf of conditioned floor area; (2) Rough-in duct blaster testing demonstrating total duct leakage less than 6 cfm/100 sf of conditioned floor area performed with the air handler installed; (3) Rough-in duct blaster testing demonstrating total duct leakage less than 4 cfm/100 sf of conditioned floor area performed without the air handler installed; or (4) no testing is required if the air handler and all ducts are located inside conditioned space.

The ***2018 IECC*** has more stringent requirements for duct leakage that can be met/demonstrated in the same four ways: (1) Postconstruction duct blaster testing demonstrating leakage to outdoors of less than 4 cfm/100 sf of conditioned floor area; (2) Rough-in duct blaster testing demonstrating total duct leakage less than 4 cfm/100 sf of conditioned floor area performed with the air handler installed; (3) Rough-in duct blaster testing demonstrating total duct leakage less than 3 cfm/100 sf of conditioned floor area performed without the air handler installed; or (4) no testing is required if the air handler and all ducts are located inside conditioned space.

Net change: Many homes in Nebraska have all or part of the HVAC system located inside conditioned space. When this is the case, there is no cost increase associated with this requirement. For homes with systems installed outside conditioned space, there may be slight cost increases associated with more stringent air sealing of ductwork.

Cost example: RSMeans does not list costs for duct sealing and testing. The Energy Star report shows a cost of $109 to increase duct airtightness from 12 cfm/100 sf to 8 cfm/100 sf in a median-sized home with the test performed at completion of construction. Note that the result of a test performed at completion of construction is typically less airtight than one performed at rough-in, as the code allows.

For homes with all ductwork inside conditioned space, which is common in Nebraska, no test would be required, and there would be no cost. For the example of the 1852 sf home with ducts outside the conditioned space, a reasonable estimate would be to double the energy star cost, for a total of $218. Because the 2018 code would require tests only in the same circumstances as the 2009 code, the cost of testing does not need to be included.

Savings: The cost analysis shows a savings of $20 per year when upgrading to the 2018 IECC. Because so many systems in Nebraska are located at least partially inside conditioned space, the energy study was based on achieving 4 cfm/100 sf leakage to outside with the 2009 code and 2 cfm/100 sf leakage to outside with the 2018 code.

Fuel burning appliances:

The ***2018 IECC*** introduces a new requirement that fuel burning appliances, where open air ducts provide combustion air to the appliance, be located outside of the building envelope or enclosed in a room, isolated from inside the thermal envelope.

Net change: This places limitations on where atmospherically vented gas furnaces and water heaters can be located. Direct-vent gas models, electric water heaters, and heat pumps are not affected. In all of the examples for the energy study, the basement was considered part of the thermal envelope, so atmospherically vented equipment could no longer be located there.

Cost example - furnace: An atmospherically vented gas furnace can be moved to an unconditioned garage or attic, or replaced with a direct-vent model or heat pump. In most situations, there is a low to no cost alternative available for gas furnaces.

Cost example – water heater: Water heaters in Nebraska are not typically installed in garages or attics due to risk of freezing. One option would be to switch to an electric water heater. Electric water heaters are less expensive to install than gas water heaters. RSMeans shows an installed price of $1,440 for a 52 gallon electric water heater. Unfortunately, they do not show a cost for a same-size gas water heater, but a 30 gallon atmospherically vented gas water heater has a listed cost of $2,002.

For customers who prefer to stay with a gas water heater, the 2016 Energy Star cost report shows a cost increase of $150 to change from an atmospherically vented to a direct vent 40 gallon gas water heater.

Cost/savings is neutral: The inclusion of this requirement in the code is based on health and safety and not energy savings. As such, no savings was calculated in the energy study. In practice, switching from an atmospherically vented gas water heater to a direct-vented model would provide energy savings.

Use of building framing cavities as ducts or plenums:

The ***2009 IECC*** prohibited building framing cavities from being used as supply air ducts. The ***2018 IECC*** prohibits building framing cavities from being used as any (supply or return) duct or plenum.

Net change: The 2018 IECC no longer allows building framing cavities to be used as a return duct or plenum. "Panning" of floor joists is a common practice in which a return duct is formed using two floor joists as sides, the subfloor above as a top, and a piece of sheet metal or duct board as a bottom. This would no longer be acceptable.

Cost example: The cost of this change is difficult to estimate using RS Means, because that source does not provide data on panning, and it provides a minimal level of detail on ductwork. The RS Means estimate for an entire sheet metal return duct system for a 1200 sf home is $964. (A return system using flexible ductwork would cost less than this.) It is realistic to approximate that a median sized home would cost up to twice what RS Means shows for a 1200 sf home. Panning of ducts involves materials and labor, and installers often find that if they pan ductwork they don't pass their duct airtightness tests. I think it is reasonable to estimate that duct panning might cost half what it costs to install a full sheet metal return system. So, overall for a median sized home, this requirement could add up to $964 to the cost of a home.

Savings: The energy analysis did not include this as a separate line item because energy was analyzed using duct airtightness (discussed above). While this would contribute to duct airtightness, the impact depends on location and a number of other factors, and it does not guarantee tighter ductwork like the testing requirement does. I believe that this was included in the code primarily as a health and safety issue, since the panning of building cavities can cause unexpected pressure differences in homes and can in some cases lead to indoor air quality problems.

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Pipe insulation:
The ***2009 IECC*** required at least R-2 piping insulation for piping serving circulating hot water systems, and R-3 insulation for all mechanical system piping carrying fluids above 105°F or less than 55°F.
The ***2018 IECC*** requires at least R-3 insulation for hot water piping in a number of cases, including: (a) piping greater than ¾ inch diameter or larger, (b) piping serving more than one dwelling unit, (c) piping located outside conditioned space, (d) piping from the hot water to a distribution manifold, (e) piping located under a floor slab, (f) buried piping, and (g) piping in recirculation systems.
Net change: Of the 2018 changes, the requirement for pipe insulation on greater than ¾ inch diameter pipe will impact the most homes. The other requirements are all either similar to the 2009, do not occur frequently, or tend to involve very short lengths of pipe. ¾ inch diameter pipe is frequently used for hot water trunk piping in homes. As a note, only very large homes use 1" pipe for hot water trunk lines. So, increasing the size of pipe that requires insulation from ¾" to 1" would reduce the cost impact of this code change.
Cost example: A typical home could have hot water trunk piping equal to the long dimension of the home plus the floor to floor height. For the 1852 sf home, this could be 63 ft of trunk piping. For ½" rubber pipe wrap insulation on ¾" pipe, RS Means shows a cost of $6.03 per lineal foot, or $380.
Savings: The energy analysis showed an annual $4 in savings with the 2018 IECC.

Whole house ventilation system:
The ***2009 IECC*** did not require a whole-house ventilation system to be installed.
The ***2018 IECC*** refers to the 2018 IRC or IMC, which both require a system using the flow rates specified by ASHRAE Standard 62.2-2010.
Net change: This requirement is most commonly implemented by contractors using a quiet, continuous run bath fan.
Cost example: Installation costs are assumed to be the same for a traditional bathroom fan and a ventilation-capable fan, so only differences in material cost will be considered in this example. RS Means shows a materials-only cost of $48 for one 50 cfm bathroom exhaust fan. The Home Depot web site shows a low-sone bath fan rated up to 110 cfm with the appropriate control module for $205. Therefore the upgrade cost would be the difference between the two fans, or $157.
Energy Cost: This code change actually results in increased energy use costing $41 per year. The addition of whole-house ventilation is not an energy savings feature, but rather a health and safety issue. Many, likely most, homes in the Nebraska market are already achieving an airtightness level that would cause industry-consensus ventilation standards (like ASHRAE Standard 62.2) to require a whole-house ventilation system.

Summary:

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The table below summarizes expected construction costs for the 1,852 sf ranch-style house. Basement walls with rigid insulation and crawlspace walls were not included in the total because they are redundant, since a home can have only one foundation type.

Code Change	Construction Cost Change	Associated Annual Energy Impact	Notes
Basement walls – rigid insulation	+$778	-$20	
Basement walls – framed cavity insulation	+$965	-$20	This foundation type was used to calculate the total cost.
Crawlspace walls	+$389	-$10	
Ceiling	+$1017	-$11	
Windows, doors, and skylights	+$237.60	-$19	Costs and savings shown are for 18% window to wall area.
Air sealing and testing	+$841	-$52	Includes air sealing and testing cost
High efficacy lighting	+$5.50	-$78	
Duct sealing and testing	+$0 to 218	-$20	$0 cost if all ducts are inside conditioned space
Fuel burning appliances outside conditioned space	+$0 to $150*	Not applicable	Cost depends on strategy used. *Considered a health and safety upgrade.*
Non-use of building cavities as plenums	+$0 to $964*	Not applicable	Cost depends whether panning was being used. *Considered a health and safety upgrade.*
Pipe insulation	+$380	-$4	
Whole house mechanical ventilation	+$157*	+41	*Considered a health and safety upgrade.*
½ ton reduction in air conditioner size	-$630	-$2	Savings obtained when other measures are employed.
Estimated total	$2973-$4305	-$165 (savings)	
Estimated total with health and safety measures omitted	$2816-$3034	-$206 (savings)	

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**These costs can impact the future health and safety of the homeowners and is a factor in ownership cost, but this study does not quantify those related benefits.*

The table above provides cost estimates and savings for an example 1852 sf home constructed in Omaha that has 18% window to wall ratio and a conditioned basement. The data show:

- Total estimated increase in construction cost for the home ranging from $2973-$4305 if the 2018 IECC is adopted, in whole, as the Nebraska Energy Code, providing a simple payback in energy savings of 18 to 26 years (with no "payback" value assigned to the health and safety items).
- A total estimated increase in the construction cost for the home ranging from $2816-$3034 if the 2018 IECC is adopted and the increased costs related to health and safety are not included. Deleting the "additional" cost of work that does not provide energy savings provides simple payback of 13.7 to 14.7 years but ignores the long-term health and safety benefits for the homeowners.

Since most homes are financed on a 30 year mortgage and energy costs increase each year, a payback of this length is valuable to homeowners. With a 5% mortgage interest rate, the additional annual mortgage payment for $3000 in construction cost is $193. This means that the energy upgrades in the new code could pay for themselves starting in year 1 for homeowners with a mortgage. Inclusion of the health and safety upgrades would add approximately $74 in annual mortgage payments.

Sincerely,

Amy Musser
Vandemusser Design, LLC