Home Innovation
RESEARCH LABS™

# 2021 IECC Residential Cost Effectiveness Analysis

***Prepared For***

## National Association of Home Builders

**June 2021**

Report No. CR1391_06112021

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# ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

| | |
|---|---|
| AC | Air Conditioner |
| AFUE | Annual Fuel Utilization Efficiency |
| c.i. | Continuous Insulation |
| COP | Coefficient of Performance |
| CZ | Climate Zone |
| EA | Each |
| EF | Energy Factor |
| ERI | Energy Rating Index |
| GF | Gas Furnace |
| HP | Heat Pump |
| HPWH | Heat Pump Water Heater |
| HSPF | Heating Seasonal Performance Factor |
| IECC | International Energy Conservation Code |
| IRC | International Residential Code |
| LF | Linear Feet |
| O&P | Overhead and Profit |
| SEER | Seasonal Energy Efficiency Ratio |
| SF | Square Feet |
| UEF | Uniform Energy Factor |
| WH | Water Heater |

## BACKGROUND

The 2021 International Energy Conservation Code (IECC) includes several changes which impact both energy savings and construction costs for residential construction.

The objective of this analysis is to quantify the incremental construction cost and energy use cost savings associated with constructing a house compliant with the 2021 IECC relative to a 2018 IECC baseline and to evaluate the cost-effectiveness of the code changes.

## METHODOLOGY

To evaluate the cost effectiveness of the 2021 IECC changes, Home Innovation Research Labs (Home Innovation) determined incremental construction costs and energy use costs using a Standard Reference House with multiple configurations and in multiple locations, constructed in accordance with the prescriptive compliance requirements of the 2018 IECC and 2021 IECC Residential Provisions ("Sections R401 through R404" in the 2018 IECC; "Prescriptive Compliance Option" in the 2021 IECC). The results provided a basis for estimating energy use savings and simple paybacks.

The analysis for this study is based on a methodology[1] developed by Home Innovation (formerly NAHB Research Center) to calculate energy savings. This methodology defined a Standard Reference House, including the building configuration and energy performance parameters, that was originally used to report an analysis of the 2012 IECC code changes[2].

For analysis in this report, annual energy use costs were developed using BEopt[3] 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency[4]. The energy prices are national average annual 2019 residential prices: $0.1301/kWh for electricity; $1.051/therm for natural gas.

Construction costs were developed based on RSMeans[5] 2021 Residential Cost Data. Costs for mechanical equipment were sourced from distributor web sites. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of fees on rater web sites. Cost details are provided for individual code changes in Appendix A and by climate zone in Appendix B.

Appendix A costs are reported as both total to the builder and total to consumer. The total cost to builder includes overhead and profit (designated in the tables as "w/O&P") applied to individual component costs (materials and labor) to represent the cost charged by the sub-contractor. The total cost to consumer is based on applying a builder's gross profit margin of 19.0% to the builder's total cost[6]. These represent national average costs. For specific locations, the Appendix A costs could be

[1] Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012.
[2] 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012.
[3] BEopt (Building Energy Optimization Tool) software: https://beopt.nrel.gov/home
[4] Energy Information Agency: https://www.eia.gov/
[5] RSMeans, https://www.rsmeans.com/
[6] Industry average gross profit margin for 2017, as reported in NAHB's Builder's Cost of Doing Business Study, 2019 Edition. https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/?_ga=2.73913042.1310550892.1620653840-1896975365.1593698293

modified by applying the appropriate location adjustment factor from RSMeans; selected location adjustment factors from RSMeans are listed in Appendix C.

## Standard Reference House

The building geometry (Figure 1) used in this analysis is documented in the methodology paper and was originally developed using Home Innovation's 2009 Annual Builder Practices Survey (ABPS) for a representative single-family detached home. The parameters represent the average values from the ABPS for building areas and features not dictated by the IECC. The geometry has been updated based on Home Innovation's 2019 ABPS. Table 1 shows the floor, attic, wall, and window areas used in the Standard Reference House for this study.

**Table 1. Average Wall and Floor Areas of the Reference House**

| Reference House Component | Area (SF) |
|---|---|
| 1st floor conditioned floor area (CFA) | 1,875 |
| 2nd floor CFA | 625 |
| Total CFA without conditioned basement | 2,500 |
| Foundation perimeter, linear feet (LF) | 200 LF |
| Slab/basement/crawl floor area | 1,875 |
| Total CFA with conditioned basement | 4,375 |
| Ceiling area adjacent to vented attic | 1,875 |
| 1st floor gross wall area (9' height) | 1,800 |
| 2nd floor gross wall area (8.75' height) | 875 |
| Total above grade wall area (excludes rim areas) | 2,675 |
| Basement wall area (8' height; 2' above grade) | 1,600 |
| Crawlspace wall area (4' height; 2' above grade) | 800 |
| Window area (15% of CFA above grade) | 375 |

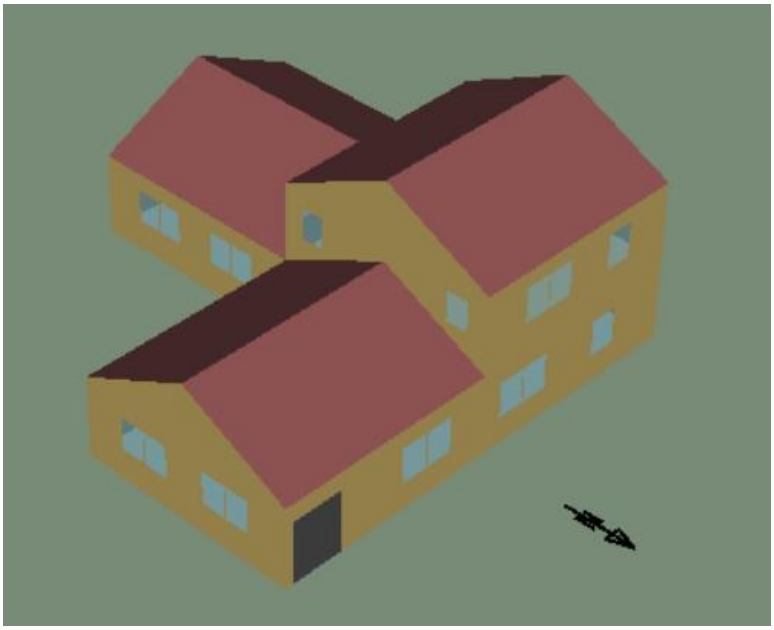


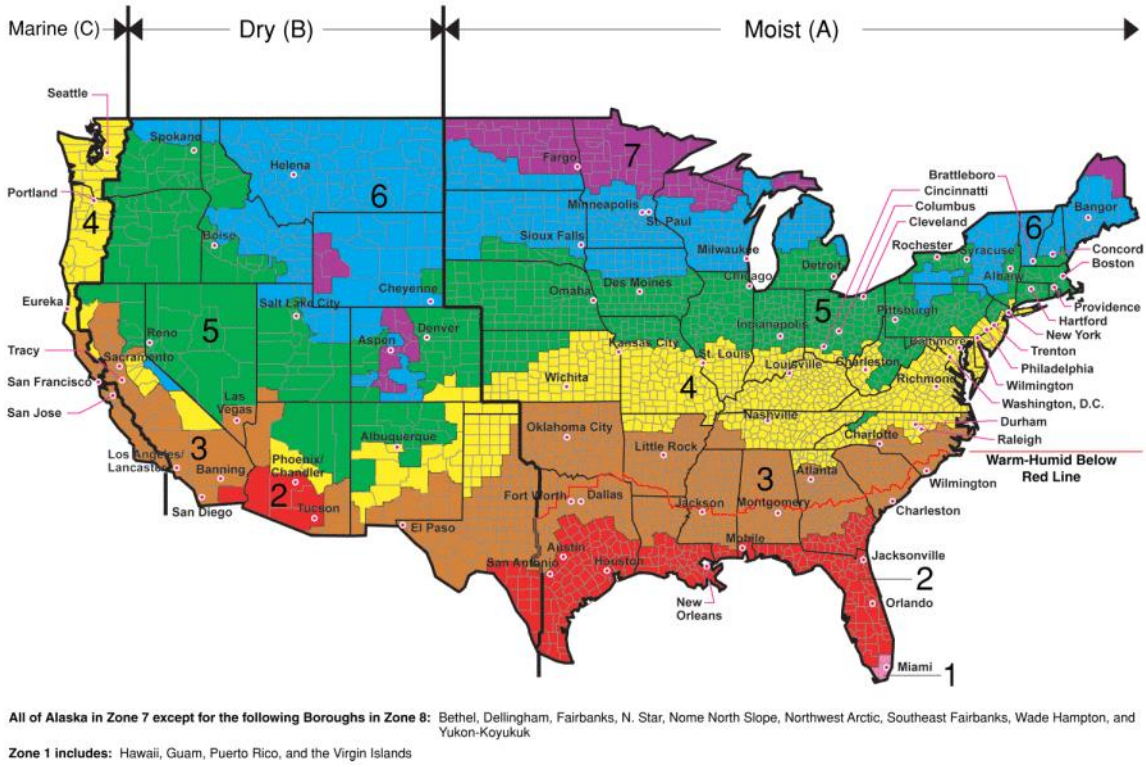
**Figure 1. Simulation Model of Standard Reference House**

## Representative Locations

Six cities (Table 2) representing DOE Climate Zones 2 through 7 (Figure 2) were selected to quantify energy savings for their respective climates.

**Table 2. Representative Locations**

| Climate Zone | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| **City** | Phoenix | Memphis | Baltimore | Chicago | Helena | Duluth |
| **State** | Arizona | Tennessee | Maryland | Illinois | Montana | Minnesota |
| **Moisture Region** | Dry | Moist | Moist | Moist | Dry | N/A |
| **HDD65*** | 1,050 | 2,960 | 4,600 | 6,330 | 7,660 | 9,570 |
| **CDD65*** | 4,640 | 2,110 | 1,233 | 842 | 317 | 162 |
| *Daily Average Weather Data (TMY). Source: Residential Energy Dynamics, redcalc.com | | | | | | |




**All of Alaska in Zone 7 except for the following Boroughs in Zone 8:** Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

**Zone 1 includes:** Hawaii, Guam, Puerto Rico, and the Virgin Islands

**Figure 2. DOE Climate Zone Map**

## Configurations and Weighted Averaging

Weighted averaging was applied both within and across climate zones based on market statistics for new single-family detached homes as reported by the 2019 ABPS. Within climate zones, weight factors were applied for wall types (light-framed and mass walls) and foundation types (slab, basement, and crawlspace).

The heating fuel used for this analysis, either natural gas or electric, was selected based on the predominant heating fuel in each climate. The predominant fuel for heating is also used for domestic hot water. All other appliances are electric.

Once the costs within a climate zone were determined, a weighted calculation according to housing starts for each climate zone was performed to obtain a national average across climate zones. Weighting averages used for this analysis are shown in Table 3.

**Table 3. Construction Data. Source: adapted from Home Innovation's 2019 ABPS**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Component** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| Primary heating fuel | Electric | Electric | Nat Gas | Nat Gas | Nat Gas | Nat Gas |
| Mass Wall | 30% | 10% | | | | |
| Frame Wall | 70% | 90% | 100% | 100% | 100% | 100% |
| Slab Foundation | 100% | 75% | 20% | 15% | 5% | 30% |
| Basement Foundation, finished | | 10% | 60% | 70% | 90% | 5% |
| Crawlspace, vented | | 15% | 20% | | | |
| Crawlspace, conditioned | | | | 15% | 5% | 65% |
| Housing Starts | 28% | 28% | 21% | 17% | 5% | 1% |

## HVAC and Water Heating Equipment

The Reference Houses utilize federal minimum efficiency HVAC systems and water heaters as shown in Table 4, except where the 2021 IECC houses are evaluated separately with higher efficiency equipment options suitable for the climate as shown in Table 5.

High efficiency HVAC systems for electric houses consist of air-source heat pump systems (i.e., not ground source or geothermal systems) with variable speed compressors ("inverter" drive compressors that provide variable refrigerant flow). The inverter systems are generally required to meet the minimum HSPF requirement for the heat pump efficiency option for 2021 (10 HSPF/16 SEER; see next section for description of 2021 efficiency package options). In addition to higher efficiencies, inverter systems are considered more suitable for colder climates because these can ramp up to provide higher heating capacities at lower outdoor temperatures compared to typical single-stage or two-stage equipment.

High efficiency water heaters for electric houses consist of heat pump water heater, 50 gallon capacity, 2.0 EF[7]

**Table 4. Standard Efficiency Equipment**

| Reference House | Equipment |
|---|---|
| Gas | 80 AFUE gas furnace + 13 SEER air conditioner (CZ 5-7) or 14 SEER (CZ 4) |
| | 40 gallon gas natural draft water heater, 0.58 UEF |
| Electric | 14 SEER/8.2 HSPF air source heat pump |
| | 50 gallon electric water heater, 0.92 UEF |

**Table 5. High Efficiency Equipment Options**

| Reference House | Equipment |
|---|---|
| Gas | 95 AFUE gas furnace + 16 SEER air conditioner |
| | Tankless gas direct vent water heater, 0.82 UEF |
| Electric | 16 SEER/10 HSPF inverter heat pump, rated to 7°F (CZ 2-3) or -13°F (CZ 5) |
| | Heat pump water heater, 50 gal, 2.0 EF |

[7] UEF (Uniform Energy Factor) is the current measure of water heater overall efficiency; the higher the UEF value, the more efficient the water heater; UEF is determined by the Department of Energy's test method outlined in 10 CFR Part 430, Subpart B, Appendix E.

## Changes for 2021

There are significant changes in the 2021 IECC compared to the 2018 IECC that impact construction cost and energy use cost. Changes to the prescriptive insulation and fenestration requirements include increased ceiling insulation (CZ 2-8), increased continuous insulation on frame walls (CZ 4-5), increased slab insulation (CZ 3-5), and lower window U-factor (CZ 3-4); these changes are shown in Appendix D.

Additional requirements include changes for lighting efficiency and controls; additional air sealing; duct testing even if ducts are entirely inside conditioned space; increased fan efficacy and testing for whole-dwelling ventilation fans; installing an HRV or ERV in CZ 7-8.

The 2021 IECC also has a new section that establishes additional requirements appliable to all compliance approaches to achieve additional energy efficiency (R401.2.5 Additional energy efficiency). The prescriptive approach requires installing one of the five prescribed additional efficiency package options:

- Enhanced envelope performance (5% improvement of UA and SHGC)
- More efficient HVAC equipment performance (minimum 95 AFUE natural gas furnace and 16 SEER air conditioner, 10 HSPF/16 SEER air source heat pump, or 3.5 COP ground source heat pump)
- Reduced energy use in service water-heating (minimum 0.82 EF fossil fuel water heater, 2.0 EF electric water heater, or 0.4 solar fraction solar water heating system)
- More efficient duct thermal distribution system (100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless systems, or 100% duct system located in conditioned space as defined by Section R403.3.2)
- Improved air sealing (max 3.0 ACH50) and efficient ventilation (ERV or HRV: min 75% SRE; max 1.1 CFM/Watt; shall not use recirculation as a defrost strategy; min 50% LRMT for ERV). For this study, when evaluating this option, the ERV (CZ 2-4) or HRV (CZ 5-7) was modeled in accordance with the 2021 IRC that provides for a ventilation rate credit of 30% where certain criteria are met; houses in CZ 2 were also modeled with a tighter building enclosure (3 ACH50 instead of 5 ACH50).

For houses that already meet the requirements for the efficient duct option (e.g., ducts and air handlers located entirely inside conditioned space) or efficient ventilation/improved air sealing option (e.g., HRV or ERV is now required in CZ 7), no additional efficiency package is required; otherwise, one of the efficiency packages must be selected at additional cost. For this study, the methodology defines houses with basement and conditioned crawlspace foundations as having ducts and air handlers inside conditioned space, and houses with slab and vented crawlspace foundatons as having some ducts outside of conditioned space. Therefore, only houses with slab and vented crawlspace foundations were evaluated for the efficient duct option.

The enhanced envelope option was not evaluted for this study due to it is not considered a reasonably viable option for builders at this time.

For the 2021 IECC, 10 code changes were identified that are considered to have a direct impact on energy use in residential buildings, for a sufficient number of new homes, and which can be reasonably

quantified in estimating energy impact. Those 10 changes were included in the energy modeling and are identified in Table 6 with an asterisk.

# RESULTS

## Construction Costs

The incremental construction costs for the individual code changes that were selected to be evaluated for this study are summarized in Table 6. The cost details are provided in Appendix A for individual changes; Appendix B shows costs by climate zone. The weighted averages of construction costs are shown in Table 7. Changes that represent potential additional construction costs that may or may not affect the Reference House are shown separately in Table 8.

**Table 6. Incremental Construction Cost of Individual Code Change for the Reference House**

| Proposal | Description | Affected CZ | Reference House |
|---|---|---|---|
| RE7* | Lighting: revised definition of high-efficacy | All | $0 |
| RE18/20/21 | Certificate: additional info | All | $99 |
| RE29* | Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6) | 4-5 | $4,970 |
| RE32* | Slab edge: NR to R10/2 (CZ3) | 3 | $1,988 |
| “ | Slab edge: R10/2 to R10/4 (CZ4-5) | 4-5 | $993 |
| RE33* | Ceiling insulation R38 to R49 | 2-3 | $1,366 |
| RE36* | Ceiling insulation R49 to R60 | 4-7 | $1,366 |
| RE34 | Floors, removes exception for min R19 if fills cavity | 5-8 | NA |
| RE35* | Windows: reduces U-value from 0.32 to 0.30 | 3-4 | $76 |
| RE37 | Windows: changes SHGC form NR to 0.40 | 5 & 4C | $0 |
| RE105 | Windows: reduces max SHGC tradeoff from 0.50 to 0.40 | 2-3 | $0 |
| RE46 | Attic access hatch: no direct cost; cost of additional insulation | All | $13 |
| RE49 | Baffles at attic access | All | $12 |
| RE72 | Air seal narrow framing cavities | All | $156 |
| RE82 | Air seal rim (basement; unvented crawlspace) | All | $1,252 |
| " | Air seal rim (slab, vented crawlspace) | All | $417 |
| RE96 | House tightness, allows trade-off for performance path | All | $0 |
| RE103 | Air seal electrical & communication outlet boxes | All | $369 |
| RE106 | Thermostat: requires 7-day programming | All | $0 |
| RE112 | Removes exception for duct test (basement, unvented crawl) | All | $247 |
| RE130 | Adds requirement to test whole-dwelling ventilation | All | $62 |
| RE133* | Updates ventilation fan efficacy (affects bath EF) | All | $66 |
| RE139* | Requires ERV/HRV in CZ 7-8 (includes RE134 reqs.) | 7 | $3,206 |
| RE145* | Lighting: 100% high-efficacy; controls (slab) | All | $49 |
| " | Lighting: 100% high-efficacy; controls (basement, crawl) | All | $60 |
| RE148 | Lighting, commercial | All | NA |
| RE149 | Lighting: exterior controls | All | $25 |
| RE151 | Performance path backstop: 2009 IECC | All | NA |
| RE178 | Performance path ventilation type to match proposed | All | NA |
| CE40.2 | Insulation certificate if no manufacturer mark (i.e., blown) | All | $15 |
| CE151.2 | Defines duct TDE; adds requirements for underground ducts | All | NA |

| | | | |
|---|---|---|---|
| RE209* | Additional efficiency package options: | All | |
| | HVAC, gas house, 95 AFUE/16 SEER for 13 SEER baseline | 5-7 | $1,494 |
| | HVAC, gas house, 95 AFUE/16 SEER for 14 SEER baseline | 4 | $1,317 |
| | HVAC, electric house, 10 HSPF/18 SEER heat pump rated to 7F | 2-3 | $5,721 |
| | HVAC, electric house, 10 HSPF/16 SEER (10/18, rated -13F) | 5 | $8,196 |
| | Water Heater, gas house, tankless direct-vent, 0.82 UEF | All | $740 |
| | Heat Pump Water Heater, electric house, 50 gal, 2.0 EF | 2-3 | $1,331 |
| | Ventilation, gas house | 4-7 | $3,206 |
| | Ventilation, electric house | 3-5 | $3,109 |
| | Ventilation, electric house with improved air tightness | 2 | $4,591 |
| | Duct, slab house, buried ducts in attic | 2-3 | $4,125 |
| | Duct, slab house, buried ducts in attic | 4-7 | $1,736 |
| | Duct, vented crawlspace house | 3 | ($852) |
| | Duct, vented crawlspace house | 4 | ($193) |
| *Indicates a code change that was included in the energy modeling analysis for this study (10 total) | | | |

**Table 7. Incremental Construction Cost for 2021 Reference House, weighted averages**

| Configuration | National Average | CZ 2 Phoenix | CZ 3 Memphis | CZ 4 Baltimore | CZ 5 Chicago | CZ 6 Helena | CZ 7 Duluth |
|---|---|---|---|---|---|---|---|
| Total without additional efficiency package options | $5,477 | $2,648 | $4,326 | $8,550 | $8,695 | $3,685 | $6,618 |
| Total with HVAC option | $9,301 | $8,369 | $10,047 | $9,867 | $10,188 | $5,179 | $8,112 |
| Total with Water Heater option | $6,548 | $3,979 | $5,657 | $9,290 | $9,435 | $4,426 | $7,358 |
| Total with Ventilation option | $9,011 | $7,238 | $7,435 | $11,755 | $11,900 | $6,891 | $6,618 |
| Total with Duct option, slab house | $8,550 | $6,773 | $8,451 | $10,286 | $10,431 | $5,421 | $8,354 |
| Total with Duct option, vented crawlspace house | | | $3,474 | $8,356 | | | |

**Table 8. Potential Additional Cost of Individual Code Change for the Reference House**

| Proposal | Description | Affected CZ | Reference House |
|---|---|---|---|
| RE47 | Attic pull-down stair: adds exception to insulation requirements | 2-3 | ($90) |
| | Same | 4 | ($119) |
| RE49 | Baffles at tray ceiling (example) | 2-3 | $183 |
| | Same | 4-7 | $231 |
| RE52 | Walls: removes exception for reduced c.i. at WSP | 3-7 | $640-$2,652 |
| RE55 | Adds requirements for unconditioned basements | 4-5 | $59 |
| RE109 | Floor insulation for ducts in conditioned space: min R19 | 2 | $87 |
| RE134 | Adds min efficacy for air handlers if integrated w/ventilation | All | $1,222 |

## Energy Use Costs and Savings

The modeling results for annual energy use costs are shown in Table 9. The estimated energy savings, as a percentage of energy use costs, are shown in Table 10. The values shown in Table 9 and Table 10 are weighted averages; energy use details are provided in Appendix E.

## Cost Effectiveness

The construction costs (Table 7) and annual energy use costs (Table 9) provide the basis to calculate simple paybacks, shown in Table 11.

**Table 9. Annual Energy Use Cost for Reference House, weighted averages**

| | National | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|---|
| **Configuration** | **Average** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| 2018 baseline, all houses | $2,129 | $2,224 | $2,027 | $1,934 | $2,280 | $2,388 | $2,599 |
| slab houses only | $2,074 | $2,224 | $2,024 | $1,807 | $2,156 | $2,221 | $2,735 |
| vented crawl houses only | | | $1,959 | $1,826 | | | |
| 2021 without additional efficiency package options | $2,016 | $2,163 | $1,890 | $1,797 | $2,137 | $2,310 | $2,514 |
| 2021 with HVAC option | $1,882 | $2,045 | $1,768 | $1,680 | $1,959 | $2,113 | $2,266 |
| 2021 with Water Heater option | $1,922 | $2,028 | $1,741 | $1,761 | $2,106 | $2,283 | $2,505 |
| 2021 with Ventilation option | $1,994 | $2,144 | $1,876 | $1,778 | $2,104 | $2,251 | $2,495 |
| 2021 with Duct option, slab house | $1,851 | $2,046 | $1,789 | $1,585 | $1,889 | $1,985 | $2,418 |
| 2021 with Duct option, vented crawlspace house | | | $1,845 | $1,644 | | | |

**Table 10. Energy Cost Savings relative to 2018 Baseline Reference House**

| | National | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|---|
| **Configuration** | **Average** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| 2021 without additional efficiency package options | 5.3% | 2.7% | 6.8% | 7.1% | 6.3% | 3.3% | 3.3% |
| 2021 with HVAC option | 11.6% | 8.0% | 12.8% | 13.1% | 14.1% | 11.5% | 12.8% |
| 2021 with Water Heater option | 9.7% | 8.8% | 14.1% | 8.9% | 7.7% | 4.4% | 3.6% |
| 2021 with Ventilation option | 6.4% | 3.6% | 7.5% | 8.1% | 7.7% | 5.7% | na |
| 2021 with Duct option, slab house | 10.7% | 8.0% | 11.6% | 12.3% | 12.4% | 10.6% | 11.6% |
| 2021 with Duct option, vented crawlspace house | | | 5.8% | 10.0% | | | |
| | | | | | | | |

Table 11. Simple Payback relative to 2018 Baseline Reference House, years

| Configuration | National Average | CZ 2 Phoenix | CZ 3 Memphis | CZ 4 Baltimore | CZ 5 Chicago | CZ 6 Helena | CZ 7 Duluth |
|---|---|---|---|---|---|---|---|
| 2021 without additional efficiency package options | 48 | 43 | 31 | 62 | 61 | 47 | 78 |
| 2021 with HVAC option | 38 | 47 | 39 | 39 | 32 | 19 | 24 |
| 2021 with Water Heater option | 32 | 20 | 20 | 54 | 54 | 42 | 79 |
| 2021 with Ventilation option | 67 | 90 | 49 | 75 | 68 | 50 | 63 |
| 2021 with Duct option, slab house | 38 | 38 | 36 | 46 | 39 | 23 | 26 |
| 2021 with Duct option, vented crawlspace house | | | 30 | 46 | | | |

As mentioned in the Methodology section, houses were evaluated based on using either natural gas or electricity as the fuel for heating and hot water: electric in CZ 2-3; gas in CZ 4-7. To illustrate the difference in energy savings for comparison purposes by way of an example, houses in CZ 3 were also modeled using gas, and sample results are shown in Table 12. For houses with the water heater option, the energy savings decreased from 14.1% for electric houses (from Table 10) to 9.9% for gas houses, with a weighted average of 12.2%; the national average energy savings decreased from 9.7% (from Table 10) to 9.3%.

Table 12. Example Comparison of Gas vs. Electric Energy Cost Savings relative to 2018 baseline

| Configuration | CZ 3 Memphis | | | National Average |
|---|---|---|---|---|
| | Electric | Gas | Weighted Ave* | |
| 2021 without additional efficiency package options | 6.8% | 7.6% | 7.1% | 5.5% |
| 2021 with Water Heater option | 14.1% | 9.9% | 12.2% | 9.3% |
| *Weighted average based on 55% electric houses and 45% gas houses, adapted from ABPS | | | | |

## Cost Effectiveness of Selected Code Changes

Individual code changes were selected for evaluation. The results are shown by applicable climate zone for thermal envelope changes in Tables 13 through 16, the required HRV in CZ 7 in Table 17, and the additional efficiency package options in Tables 18 through 21.

**Table 13. Incremental Construction Cost of Thermal Envelope Changes**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Component** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| Ceiling insulation | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 |
| Slab insulation | | $1,988 | $993 | $993 | | |
| Wall continuous insulation | | | $4,970 | $4,970 | | |
| Window U-factor | | $76 | $76 | | | |

**Table 14. Annual Energy Use Cost of Thermal Envelope Changes**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Configuration** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| 2018 baseline, all houses | $2,224 | $2,027 | $1,934 | $2,280 | $2,388 | $2,599 |
| 2018 baseline, slab houses only | | $2,024 | $1,807 | $2,156 | | |
| 2018 + 2021 ceiling insulation | $2,216 | $2,016 | $1,925 | $2,268 | $2,376 | $2,584 |
| 2018 + 2021 slab insulation, slab houses only | | $1,936 | $1,772 | $2,120 | | |
| 2018 + 2021 wall continuous insulation | | | $1,886 | $2,217 | | |
| 2018 + 2021 window U-factor | | $2,020 | $1,924 | | | |

**Table 15. Energy Cost Savings of Thermal Envelope Changes relative to 2018 Baseline Reference House**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Configuration** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| 2018 + 2021 ceiling insulation | 0.3% | 0.6% | 0.5% | 0.5% | 0.5% | 0.6% |
| 2018 + 2021 slab insulation, slab houses only | | 4.3% | 1.9% | 1.7% | | |
| 2018 + 2021 wall continuous insulation | | | 2.5% | 2.8% | | |
| 2018 + 2021 window U-factor | | 0.3% | 0.5% | | | |

**Table 16. Simple Payback relative to 2018 Baseline Reference House for Thermal Envelope Changes, years**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Configuration** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| 2018 + 2021 ceiling insulation | 177 | 122 | 152 | 118 | 105 | 90 |
| 2018 + 2021 slab insulation, slab houses only | | 23 | 28 | 28 | | |
| 2018 + 2021 wall continuous insulation | | | 103 | 78 | | |
| 2018 + 2021 window U-factor | | 11 | 7 | | | |

**Table 17. Cost effectiveness of HRV in CZ 7**

| | CZ 7 |
|---|---|
| **Configuration** | **Duluth** |
| Incremental cost of HRV | $3,206 |
| Annual energy cost, 2021* without HRV | $2,538 |
| Annual energy cost, 2021* with HRV | $2,514 |
| Energy cost savings for HRV | 1.0% |
| Simple payback, years | 131 |
| *Without additional efficiency package options | |

**Table 18. Incremental Construction Cost of Additional Efficiency Package Options**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Component** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| HVAC option | $5,721 | $5,721 | $1,317 | $1,494 | $1,494 | $1,494 |
| Water heater option | $1,331 | $1,331 | $740 | $740 | $740 | $740 |
| Ventilation option | $4,591 | $3,109 | $3,206 | $3,206 | $3,206 | |
| Duct option, slab house | $4,125 | $4,125 | $1,736 | $1,736 | $1,736 | $1,736 |
| Duct option, vented crawlspace house | | ($852) | ($193) | | | |

**Table 19. Annual Energy Use Cost of Additional Efficiency Package Options**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Configuration** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| 2021 without additional efficiency package options, all houses | $2,163 | $1,890 | $1,797 | $2,137 | $2,310 | $2,514 |
| slab houses only | $2,163 | $1,867 | $1,655 | $1,999 | $2,165 | $2,639 |
| vented crawlspace houses only | | $1,890 | $1,711 | | | |
| 2021 with HVAC option | $2,045 | $1,768 | $1,680 | $1,959 | $2,113 | $2,266 |
| 2021 with Water Heater option | $2,028 | $1,741 | $1,761 | $2,106 | $2,283 | $2,505 |
| 2021 with Ventilation option | $2,144 | $1,876 | $1,778 | $2,104 | $2,251 | $2,495 |
| 2021 with Duct option, slab house | $2,046 | $1,789 | $1,585 | $1,889 | $1,985 | $2,418 |
| 2021 with Duct option, vented crawlspace | | $1,845 | $1,644 | | | |

**Table 20. Energy Cost Savings of Additional Efficiency Package Options relative to 2021 without packages**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Configuration** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| HVAC option | 5.4% | 6.4% | 6.5% | 8.3% | 8.5% | 9.9% |
| Water Heater option | 6.2% | 7.9% | 2.0% | 1.5% | 1.2% | 0.3% |
| Ventilation option | 0.9% | 0.7% | 1.1% | 1.5% | 2.6% | 0.8% |
| Duct option, slab house | 5.4% | 4.2% | 4.2% | 5.5% | 8.3% | 8.4% |
| Duct option, vented crawlspace house | | 2.4% | 3.9% | | | |

**Table 21. Simple payback of efficiency package options relative to 2021 house without packages, years**

| | CZ 2 | CZ 3 | CZ 4 | CZ 5 | CZ 6 | CZ 7 |
|---|---|---|---|---|---|---|
| **Configuration** | **Phoenix** | **Memphis** | **Baltimore** | **Chicago** | **Helena** | **Duluth** |
| HVAC option | 49 | 47 | 11 | 8 | 8 | 6 |
| Water Heater option | 10 | 9 | 21 | 24 | 27 | 89 |
| Ventilation option | 240 | 226 | 167 | 97 | 54 | 0 |
| Duct option, slab house | 35 | 53 | 25 | 16 | 10 | 8 |
| Duct option, vented crawlspace house | | 0 | 0 | | | |

## CONCLUSIONS

Home Innovation conducted a cost effectiveness analysis of the 2021 IECC code changes for residential construction based on incremental construction costs and energy use costs developed for a Standard Reference House with multiple configurations and in multiple locations.

Key findings are summarized here for the 2021 Reference House relative to the 2018 Baseline Reference House, based on weighted averages within climate zones (foundation type, wall type) and across climates for national averages (based on housing starts):

- The national average incremental construction cost ranges from $6,548 to $9,301 depending on the additional efficiency package option selected for compliance.
- Depending on climate zone, the weighted average incremental construction cost may range up to $11,900.
- The national average energy use cost savings ranges from 6.4% to 11.6% depending on the additional efficiency package option selected for compliance.
- The national average simple payback for complying with the 2021 IECC ranges from 32 years to 67 years.
- The average simple paybacks for selected individual envelope code changes within associated climate zones are 78-103 years for wall continuous insulation, 23-28 years for slab insulation, and 90-177 years for ceiling insulation.
- The average simple payback for the additional efficiency package options within associated climate zones is 6-11 years for natural gas heating and 47-49 years for heat pump heating, 9-10 years for a heat pump water heater in CZ 2-3 relative to a conventional resistance water heater and 21-27 years for a natural gas water heater (except 89 years for a gas water heater in CZ 7), 54-240 years for Ventilation option, 25-53 years for Duct option for slab houses in CZ 2-4 and 8-16 years for Duct option in CZ 5-8.

# APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

The estimated construction costs for the selected individual code changes are shown below. Construction costs were developed using RSMeans[8] 2021 Residential Data. Costs for mechanical equipment were sourced from distributor web sites[9]. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of rater web sites. See Appendix B for costs by climate zone.

## RE7

### Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

### Summary of the Code Change:

This code change revised the definition of HIGH EFFICACY LIGHT SOURCES. The new minimum efficacy is 65 lumens per watt for lamps and 45 lumens per watt for luminaires. Previously, the minimum efficacy was 60 lumens per watt for lamps over 40 watts, 50 for lamps over 15 watts to 40 watts, and 40 for lamps 15 watts or less (R202). The code change excludes kitchen appliance lighting fixtures from high efficacy requirements for permanently installed lighting fixtures. (R404.1).

### Cost Implication of the Code Change:

This code change should not increase the cost of construction as typical CFL and LED lamps meet or exceed the new efficacy requirements. (See RE 145 for lighting changes that do impact cost.)

[8] RSMeans, https://www.rsmeans.com/

[9] Mechanical equipment cost sources include: hvacdirect.com; supplyhouse.com; acwholesalers.com; menards.com

## RE18, RE20, RE21

### Reference Code Section

R401.3 Certificate

### Summary of the Code Change:

This code change requires additional information on the certificate for PV systems (RE18), code edition and compliance path (RE20), and area-weighted average insulation value (RE21).

### Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis is based on an estimate of the additional time required by a rater to collect and add this information to the certificate.

**Cost to add information to the certificate**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Incremental time for rater | HR | | | | 80.00 | 1 | 80 |
| **Total to Builder** | | | | | | | **80** |
| **Total to Consumer** | | | | | | | **99** |

## RE29

## Reference Code Section

Table R402.1.2; Table R402.1.3

## Summary of the Code Change:

This code change increases the prescriptive R-value of continuous insulation (c.i.) on frame walls in CZ 4-5 from "R20 or 13+5" to "R20+5 or 13+10 or 0+15".

## Cost Implication of the Code Change:

This code change will increase the cost of construction for frame walls in CZ 4-5. The analysis is based on the cost to increase c.i. from R5 to R10 for 2x4 walls and from none to R5 for 2x6 walls. The costs include associated additional trim at windows and doors and longer fasteners for cladding based on vinyl siding. A weighted average cost is then determined based on market data for walls (per the 2019 ABPS), as shown below.

**Weighted Average Cost to Increase Continuous Insulation (c.i.)**

| Component | Unit | Cost, from below | Weight | Cost, weighted |
|---|---|---|---|---|
| 2x4 wall, increase c.i. from R5 to R10 | $/house | 1,101 | 24.9% | 274 |
| 2x6 wall, increase c.i. from R0 to R5 | $/house | 6,504 | 72.2% | 4,696 |
| **Total to Consumer** | | | | **4,970** |

**Cost to increase c.i. from R5 to R10 for 2x4 wall**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1", R5 | SF | 0.68 | 0.45 | 1.13 | 1.49 | (2,675) | (3,986) |
| XPS, 15 psi, 2", R10 | SF | 0.83 | 0.49 | 1.32 | 1.72 | 2,675 | 4,601 |
| Window/door casing, PVC trim exterior | LF | 0.55 | | 0.55 | 0.61 | 415 | 251 |
| Siding attachment, 2.5" roofing nail galv | LB | 3.06 | | 3.06 | 3.37 | (21) | (71) |
| Siding attachment, 3.5" common nail galv | LB | 1.78 | | 1.78 | 1.96 | 49 | 96 |
| **Total to Builder** | | | | | | | **892** |
| **Total to Consumer** | | | | | | | **1,101** |

**Cost to increase c.i. from none to R5 for 2x6 wall**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1", R5 | SF | 0.68 | 0.45 | 1.13 | 1.49 | 2,675 | 3,986 |
| Door/window casing, PVC trim exterior | LF | 0.55 | 1.47 | 2.02 | 3.03 | 415 | 1,258 |
| Siding attachment, 1.5" roofing nail galv | LB | 2.78 | | 2.78 | 3.06 | (13.0) | (40) |
| Siding attachment, 2.5" roofing nail galv | LB | 2.78 | | 2.78 | 3.06 | 21.0 | 64 |
| **Total to Builder** | | | | | | | **5,268** |
| **Total to Consumer** | | | | | | | **6,504** |

## RE32

### Reference Code Section

Table R402.1.2, Table R402.1.3

### Summary of the Code Change:

This code change increases the slab edge insulation requirements in CZ 3 from none to R10/2 (R10, 2-feet deep) and in CZ 4-5 from 10/2 to 10/4 (R10, 4-feet deep).

### Cost Implication of the Code Change:

This code change will increase the cost of construction for slab homes in CZ 3-5. The analysis is based on the cost to install this insulation at the Reference House with a foundation perimeter of 200 linear feet, so the quantity of insulation 2-feet deep is 400 square feet. Note that the incremental quantity and cost of insulation is assumed to be the same for CZ 3 and CZ 4-5; however, for CZ 3, the cost of flashing at the top edge of the insulation is included.

**Cost of additional slab edge insulation, CZ 3**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 25 psi, 2" thick, R-10 | SF | 1.23 | 0.40 | 1.63 | 2.01 | 400 | 804 |
| Flashing, vinyl coated aluminum | SF | 1.92 | 1.17 | 3.09 | 4.03 | 200 | 806 |
| **Total to Builder** | | | | | | | **1,610** |
| **Total to Consumer** | | | | | | | **1,988** |

**Cost of additional slab edge insulation, CZ 4-5**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 25 psi, 2" thick, R-10 | SF | 1.23 | 0.40 | 1.63 | 2.01 | 400 | 804 |
| **Total to Builder** | | | | | | | **804** |
| **Total to Consumer** | | | | | | | **993** |

## RE33, RE36

### Reference Code Section

Table R402.1.2, Table R402.1.3, R402.2.1

### Summary of the Code Change:

These code changes increase ceiling insulation from R38 to R39 in CZ 2-3 (RE33) and from R49 to R60 in CZ 4-8 (RE36). The code change also updates the exception for ceiling insulation above wall top plates at eaves to include where R60 is now required.

### Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 2-8. The analysis is based on the incremental cost of blown fiberglass insulation in a vented attic. The incremental cost is assumed to be the same for both changes. The analysis does not address any potential costs associated with raised-heel trusses.

**Cost to Increase ceiling insulation from R-38 to R-49 or from R-49 to R-60**

| Component | Unit | Material | Labor | Equip | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|---|
| R-38 attic insulation, blown fg | SF | 0.69 | 0.61 | 0.36 | 1.66 | 2.14 | (1,875) | (4,013) |
| R-49 attic insulation, blown fg | SF | 0.91 | 0.76 | 0.45 | 2.12 | 2.73 | 1,875 | 5,119 |
| **Total to Builder** | | | | | | | | **1,106** |
| **Total to Consumer** | | | | | | | | **1,366** |

## RE34

### Reference Code Section

Table R402.1.3

### Summary of the Code Change:

This code change removed the footnote “g” exception for reduced insulation in floors for CZ 5 and Marine 4 through CZ 8. The deleted exception alternatively allowed insulation sufficient to fill the framing cavity providing not less than an R-value of R-19, instead of the prescribed values of R30 (CZ 5-6 and Marine 4) or R38 (CZ 7-8). Note that the prescribed floor insulation values did not change for 2021.

### Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases (e.g., installing spray foam insulation with a higher R-value per inch, or installing taller floor joists to accommodate sufficient insulation, may now be required to meet prescriptive floor insulation values), but there is no cost impact for the Reference House because the Reference House does not have floors above unconditioned space.

## RE35

### Reference Code Section

Table 402.1.2 and Table R402.1.3

### Summary of the Code Change:

This code change reduces the prescriptive maximum U-factor for windows in CZ 3-4 from 0.32 to 0.30. The change also adds a footnote that a maximum window U-factor of 0.32 shall apply in CZ 5/Marine 4 through CZ 8 for buildings located above 4,000 feet in elevation above sea level or in windborne debris regions where protection of openings is required.

### Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 3-4. The analysis is based on an incremental material cost of $0.15/SF for improving window U-factor from 0.32 to 0.30 as determined by the California Energy Commission[10].

The Department of Energy and EPA Energy Star along with those involved in the development of energy codes have traditionally had problems developing a clear incremental cost for changes in window thermal performance. An earlier report based on cost data collected by the U.S. Department of Energy indicated an incremental cost of $0.18/SF window area for improving U-value from 0.35 to 0.32[11]. In this analysis, prices used to develop the incremental cost associated with the code change are a best guess based on the available data.

**Cost to reduce the window U-factor from 0.32 to 0.30**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Incremental cost of window | SF | 0.15 | | 0.15 | 0.17 | 375 | 62 |
| **Total to Builder** | | | | | | | **62** |
| **Total to Consumer** | | | | | | | **76** |

[10] CEC report, see table 9: https://efiling.energy.ca.gov/GetDocument.aspx?tn=222199&DocumentContentId=27369

[11] https://www.energycodes.gov/sites/default/files/documents/iecc2018_R-2_analysis_final.pdf

## RE37

### Reference Code Section

Table 402.1.2 and Table R402.1.3

### Summary of the Code Change:

This code change changes the window SHGC in CZ 5 and CZ 4C Marine from “NR” to “0.40”.

### Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction because windows in these climate zones commonly meet the new requirement already. Energy Star criteria include maximum 0.40 SHGC in “North-Central” climates since 2015. Further, energy modeling typically assigns a value of 0.40 where SHGC is NR.

## RE105

### Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

### Summary of the Code Change:

This code change reduces the average maximum fenestration SHGC permitted using tradeoffs in CZ 0-3 from 0.50 to 0.40.

### Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction because windows in these climate zones commonly meet the new requirement already. Energy Star criteria include maximum 0.25 SHGC in “South-Central” and “Southern” climates since 2015.

## RE46

## Reference Code Section

R402.2.4 Access hatches and doors

## Summary of the Code Change:

This code change does not add new requirements; rather, it separates the prescriptive (required insulation levels) and mandatory (weatherstripping) provisions into separate sections.

## Cost Implication of the Code Change:

This code change does not directly impact the cost of construction. However, additional insulation is required due to increased prescriptive ceiling insulation requirements. The analysis is based on the cost to install an additional R-11 insulation above a 24” x 36” attic access hatch.

**Cost to increase the insulation above an attic access by R-11**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| EPS, 3" thick, R-11.5 | SF | 0.96 | 0.40 | 1.36 | 1.72 | 6 | 10 |
| **Total to Builder** | | | | | | | **10** |
| **Total to Consumer** | | | | | | | **13** |

## RE47

## Reference Code Section

R402.2.4 Access hatches and doors

## Summary of the Code Change:

This code change adds an exception to the attic access insulation requirement. Attic pull-down stairs in CZ 0-4 are not required to comply with the insulation level of the surrounding surfaces provided that the hatch meets all the following: average maximum U-0.10 insulation or average minimum R-10 insulation; at least 75% of the panel area shall be minimum R-13 insulation; maximum net area of the framed opening is 13.5 SF; the perimeter of the hatch shall be weatherstripped.

## Cost Implication of the Code Change:

This code change may decrease construction costs where pull-down attic stairs are utilized in CZ 0-4. The analysis is based on the cost savings of less insulation above the access: for this study, R13 versus R49 in CZ 2-3, and R13 versus R60 in CZ 4.

**Cost savings to reduce insulation above attic pull-down stair for CZ 2-3 (R49 ceiling)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1", R5 (one 1" layer) | SF | 0.68 | 0.45 | 1.13 | 1.49 | 13.5 | 20 |
| XPS, 15 psi, 2", R10 (one 2" layer) | SF | 0.83 | 0.49 | 1.32 | 1.72 | 13.5 | 23 |
| XPS, 15 psi, 2", R10 (five 2" layers) | SF | 0.83 | 0.49 | 1.32 | 1.72 | (67.5) | (116) |
| **Total to Builder** | | | | | | | **(73)** |
| **Total to Consumer** | | | | | | | **(90)** |

**Cost savings to reduce insulation above attic pull-down stair for CZ 4 (R60 ceiling)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1", R5 (one 1" layer) | SF | 0.68 | 0.45 | 1.13 | 1.49 | 13.5 | 20 |
| XPS, 15 psi, 2", R10 (one 2" layer) | SF | 0.83 | 0.49 | 1.32 | 1.72 | 13.5 | 23 |
| XPS, 15 psi, 2", R10 (six 2" layers) | SF | 0.83 | 0.49 | 1.32 | 1.72 | (81.0) | (139) |
| **Total to Builder** | | | | | | | **(96)** |
| **Total to Consumer** | | | | | | | **(119)** |

## RE49

## Reference Code Section

R402.2.4 Access hatches and doors

## Summary of the Code Change:

This code change adds a requirement for baffles to prevent loose-fill attic insulation from spilling into higher to lower sections of the attic, and from attics covering conditioned spaces to unconditioned spaces. Baffles at the attic access to prevent spilling into livings space are still required (although those must be taller now).

## Cost Implication of the Code Change:

This code change will increase the cost of construction for the attic access hatch. This code change may increase the cost of construction where ceiling height varies or attics above unconditioned spaces.

The analysis develops an incremental cost to construct a taller baffle (by 4") for a 24" x 36" attic access hatch for all CZs. The analysis also develops a cost to install baffles for a hypothetical tray ceiling (est. 48 LF): for blown fiberglass insulation at R-3.2/inch, the baffles would need to be 16" tall plus a 3" nailing surface for CZ 2-3 and 19" tall plus a 3" nailing surface for CZ 4-7.

**Cost to increase the height of insulation baffles at attic access hatch**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Plywood, 3/4" CDX | SF | 1.38 | 0.60 | 1.98 | 2.50 | 4 | 10 |
| **Total to Builder** | | | | | | | **10** |
| **Total to Consumer** | | | | | | | **12** |

**Cost to add baffles at tray ceiling (est. 48 LF) for CZ 2-3**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Plywood, 1/2" CDX | SF | 1.00 | 0.52 | 1.52 | 1.95 | 76 | 148 |
| **Total to Builder** | | | | | | | **148** |
| **Total to Consumer** | | | | | | | **183** |

**Cost to add baffles at tray ceiling (est. 48 LF) for CZ 4-8**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Plywood, 1/2" CDX | SF | 1.00 | 0.52 | 1.52 | 1.95 | 96 | 187 |
| **Total to Builder** | | | | | | | **187** |
| **Total to Consumer** | | | | | | | **231** |

## RE52

### Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

### Summary of the Code Change:

This code change deleted a section that allowed continuous insulation (c.i.) to be reduced, where c.i. is required and structural sheathing covers 40 percent or less of the gross wall area of all exterior walls, to result in a consistent total sheathing thickness on areas of the walls covered by structural sheathing.

### Cost Implication of the Code Change:

This code change would increase the cost of construction in CZ 3-8 where the exception was utilized. The analysis is based on the additional cost to increase the foam sheathing thickness to 1-1/2-inch where it was 1-inch before, and to 1-inch where it was ½-inch before over the structural sheathing. A second cost is developed separately based on the additional cost to install ½-inch structural sheathing over the entire wall area and 1-inch thick foam sheathing over the structural sheathing. Both costs are based on using XPS foam sheathing and the assumption that wood structural sheathing originally covered 40% of the wall area (1,070 SF) and the remaining 60% of the wall area (1,605 SF) was originally covered by foam only (i.e., not by wood structural sheathing).

**Cost to install additional 1/2-inch thickness of continuous insulation**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1/2", R3 | SF | 0.60 | 0.43 | 1.03 | 1.37 | (1,070) | (1,465) |
| XPS, 15 psi, 1", R5 | SF | 0.68 | 0.45 | 1.13 | 1.49 | 1,070 | 1,594 |
| XPS, 15 psi, 1", R5 | SF | 0.68 | 0.45 | 1.13 | 1.49 | (1,605) | (2,391) |
| XPS, 15 psi, 1.5", R7.5 | SF | 0.76 | 0.49 | 1.25 | 1.64 | 1,605 | 2,639 |
| Window/door casing, add 1/2" | LF | 0.23 | | 0.28 | 0.31 | 415 | 128 |
| Siding attachment, 2" roofing nail galv | LB | 3.06 | | 3.06 | 3.37 | (17) | (57) |
| Siding attachment, 2.5" roofing nail galv | LB | 3.06 | | 3.06 | 3.37 | 21 | 71 |
| **Total to Builder** | | | | | | | **518** |
| **Total to Consumer** | | | | | | | **640** |

**Cost to install OSB over entire wall and cover with 1-inch XPS**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1/2", R3 | SF | 0.60 | 0.43 | 1.03 | 1.37 | (1,070) | (1,465) |
| XPS, 15 psi, 1", R5 | SF | 0.68 | 0.45 | 1.13 | 1.49 | 1,070 | 1,594 |
| OSB, wall, 1/2" | SF | 0.41 | 0.44 | 0.85 | 1.17 | 1,605 | 1,878 |
| Window/door casing, add 1/2" | LF | 0.23 | | 0.28 | 0.31 | 415 | 128 |
| Siding attachment, 2" roofing nail galv | LB | 3.06 | | 3.06 | 3.37 | (17) | (57) |
| Siding attachment, 2.5" roofing nail galv | LB | 3.06 | | 3.06 | 3.37 | 21 | 71 |
| **Total to Builder** | | | | | | | **2,148** |
| **Total to Consumer** | | | | | | | **2,652** |

## RE55

## Reference Code Section

R402.2.8 Basement walls

## Summary of the Code Change:

This code change adds requirements for how to insulate and seal unconditioned basements including at the floor overhead, walls surrounding the stairway, door leading to the basement from conditioned space; the requirements also include no uninsulated duct, domestic hot water or hydronic heating surfaces exposed to the basement, and no HVAC supply or return diffusers serving the basement.

## Cost Implication of the Code Change:

This code change will increase the cost of construction where insulation requirements are greater for 2021, i.e., increased continuous insulation (c.i.) for exterior walls in CZ 4-5 for this analysis. The analysis develops a cost to increase c.i. in the walls surrounding the stairway. This analysis assumes that builders were already constructing unconditioned basements as described by the code change.

**Cost to increase wall insulation in the stairway**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| XPS, 15 psi, 1", R5 | SF | 0.68 | 0.45 | 1.13 | 1.49 | (200) | (298) |
| XPS, 15 psi, 2", R10 | SF | 0.83 | 0.49 | 1.32 | 1.72 | 200 | 344 |
| Drywall screw, 2.5" | LB | 5.98 | | 5.98 | 6.58 | (1.3) | (9) |
| Drywall screw, 3.5" | LB | 5.98 | | 5.98 | 6.58 | 1.6 | 10 |
| **Total to Builder** | | | | | | | **48** |
| **Total to Consumer** | | | | | | | **59** |

## RE72

### Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

### Summary of the Code Change:

This code change adds a new requirement that “narrow cavities of an inch or less that are not able to be insulated shall be air sealed”.

### Cost Implication of the Code Change:

This code change may increase the cost of construction as applicable. The analysis is based on an estimated quantity of small cavities that would require the installation of sealant.

**Cost to install additional sealant for narrow framing cavities**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Sealant, latex acrylic, 3/4" x 1" bead | LF | 1.28 | 1.28 | 2.56 | 3.51 | 36 | 126 |
| **Total to Builder** | | | | | | | **126** |
| **Total to Consumer** | | | | | | | **156** |

## RE82

### Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

### Summary of the Code Change:

This code change adds a new requirement to air seal the rim board at the sill plate and subfloor. Rim areas in vented crawl spaces and attics are exempt.

### Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis is based on the linear feet of sealant required for the Reference House designs with a foundation perimeter of 200 LF and a second story perimeter of 100 LF. For basement and unvented crawlspace designs, the quantity of sealant is 600 LF (300 LF of rim area, multiplied by two to capture the sealant required at both the sill plate and subfloor). For slab and vented crawlspace designs, the quantity of sealant is 200 LF (100 LF of rim area for the second floor).

**Cost to install sealant at rim joists for basement or unvented crawlspace designs**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Sealant, latex acrylic, 1/4" x 1/4" bead | LF | 0.10 | 0.96 | 1.06 | 1.69 | 600 | 1,014 |
| **Total to Builder** | | | | | | | **1,014** |
| **Total to Consumer** | | | | | | | **1,252** |

**Cost to install sealant at rim joists for slab or vented crawlspace designs**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Sealant, latex acrylic, 1/4" x 1/4" bead | LF | 0.10 | 0.96 | 1.06 | 1.69 | 200 | 338 |
| **Total to Builder** | | | | | | | **338** |
| **Total to Consumer** | | | | | | | **417** |

## RE96

### Reference Code Section

R402.4.1.2 Testing

### Summary of the Code Change:

This code change makes house air tightness prescriptive and allows a trade-off option up to 5.0 ACH50 or 0.28 CFM/SF enclosure area (0.30 CFM/SF exception for attached dwellings and dwellings 1,500 SF or smaller). The prescriptive limits remain the same: 5.0 ACH50 in CZ 1-2; 3.0 ACH50 in CZ 3-8.

### Cost Implication of the Code Change:

This code change may decrease construction costs in some cases where a builder trades-off air leakage for other efficiency improvements for a house in CZ 3-8, but there is assumed to be no cost impact for the Reference House because there is not a straightforward approach to reasonably quantify such a change.

## RE103

### Reference Code Section

R402.4.6 Electrical and communication outlet boxes (air-sealed boxes)

### Summary of the Code Change:

This code change adds a new section that requires electrical and communication outlet boxes installed in the building thermal envelope (i.e., exterior walls and ceilings adjacent to vented attics) to be air sealed. These outlet boxes must be tested and labeled in accordance with NEMA OS 4.

### Cost Implication of the Code Change:

This code change will increase the cost of construction for all locations. The analysis is based on the cost to substitute a rated airtight box for a standard blue plastic new-work electrical box, using an estimated quantity of affected boxes for the Reference House.

**Cost of air sealed electrical and communication outlet boxes**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity* | Cost |
|---|---|---|---|---|---|---|---|
| Standard electric box, 1-gang | EA | 0.34 | | 0.34 | 0.37 | (42) | (16) |
| NEMA OS 4 Airtight box, 1-gang | EA | 5.52 | | 5.52 | 6.07 | 42 | 255 |
| Standard electric box, ceiling | EA | 1.19 | | 1.19 | 1.31 | (10) | (13) |
| NEMA OS 4 Airtight box, ceiling | EA | 6.60 | | 6.60 | 7.26 | 10 | 73 |
| **Total to Builder** | | | | | | | **299** |
| **Total to Consumer** | | | | | | | **369** |

***Estimated quantity of affected boxes**

| Box type | Quantity |
|---|---|
| Wall receptacle outlet (one every 10 LF of exterior wall) | 30 |
| Wall switch outlet | 6 |
| Wall communication outlet | 6 |
| Ceiling light fixture/smoke detector | 10 |

## RE106

### Reference Code Section

R403.1.1 Programmable thermostat

### Summary of the Code Change:

This code change modifies the required capabilities for programmable thermostats: in addition to being capable of controlling different set point temperatures at different times of the day, thermostats must now be capable of controlling this for different days of the week (i.e., a 7-day thermostat, versus a 5-2 day or 5-1-1 day).

### Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases, depending on the make and model of thermostat normally used, but a review of distributor websites indicated the lowest cost programmable thermostat by a leading national manufacturer already has 7-day capability for single-stage heat pump or gas furnace with air conditioner systems. Therefore, this code change is not anticipated to affect the cost of construction. There is not an energy use cost savings associated with this change because the energy modeling does utilize thermostat set-back settings.

## RE109

### Reference Code Section

R403.3.2 Ducts located in conditioned space

### Summary of the Code Change:

This code change adds requirements for ducts within floor or wall cavities to be considered ducts in conditioned space. The requirements include minimum R-19 insulation for floors above unconditioned space, e.g., above a garage, so there are implications for CZ 1-2 where the prescriptive minimum floor insulation is R-13.

### Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases although the Reference House does not have floors above unconditioned space and it is assumed there are no ducts within any wall cavities. The analysis is based on the incremental cost to install R-19 floor insulation instead of R-13 above a garage, assuming ducts occupy two joist bays (each 2' wide x 20' long), and to substitute oval duct for round duct so that the oval duct (typically 3") plus the R-19 insulation (typically 5.5") fits within the height of a 2x10 floor joist.

**Cost to increase floor insulation within joist bay from R-13 to R-19**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| **R-13 unfaced fiberglass batt** | SF | 0.49 | 0.42 | 0.91 | 1.22 | (80) | (98) |
| **R-19 unfaced fiberglass batt** | SF | 0.60 | 0.49 | 1.09 | 1.46 | 80 | 117 |
| **7" round metal duct** | LF | 2.00 | | 2.00 | 2.20 | (40) | (88) |
| **7" oval metal duct** | LF | 3.16 | | 3.16 | 3.48 | 40 | 139 |
| **Total to Builder** | | | | | | | **70** |
| **Total to Consumer** | | | | | | | **87** |

## RE112

### Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

### Summary of the Code Change:

This code change removes the exception for testing where ducts and air handlers are located entirely within the building thermal envelope (R403.3.5). The code change also increases the total leakage limit from 4.0 to 8.0 CFM25/100SFcfa where ducts and air handlers are located entirely within the building thermal envelope (R403.3.6).

### Cost Implication of the Code Change:

This code change will increase the cost of construction where ducts and air handlers are already installed in conditioned space but testing for duct leakage is now required. The analysis is based on a typical charge by a rater to conduct this test during the same visit as the house tightness test. Any cost of remediation for a failed test is not included. For the Reference Houses, it is assumed that this test will now be required for basement and unvented crawlspace designs.

**Estimated cost of the duct leakage test**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Charge by rater | EA | | | | 200.00 | 1 | 200 |
| **Total to Builder** | | | | | | | **200** |
| **Total to Consumer** | | | | | | | **247** |

## RE130

## Reference Code Section

R403.6.3 Testing (new)

## Summary of the Code Change:

This code change requires whole-dwelling mechanical ventilation systems to be tested and verified to provide the minimum required ventilation flow rates.

## Cost Implication of the Code Change:

This code change will increase the cost of construction for all houses. The analysis is based on a typical charge by a rater to conduct this test during the same visit as the house tightness test. Testing is in addition to duct leakage testing. Testing is now required for the ventilation system of record (e.g., bath exhaust fan, HRV/ERV, supply-type ducted to the return plenum of a central system). Any cost of remediation for a failed test is not included.

**Estimated cost of the mechanical ventilation test**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Charge by rater | EA | | | | 50.00 | 1 | 50 |
| **Total to Builder** | | | | | | | **50** |
| **Total to Consumer** | | | | | | | **62** |

## RE133

### Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

### Summary of the Code Change:

This code change updates the fan efficacy requirements for fans used to provide whole-dwelling mechanical ventilation (supply and exhaust fans now must meet the current EnergyStar requirements). The minimum efficacy for an exhaust fan increased from 1.4 to 2.8 CFM/watt for airflow rates less than 90 CFM and from 2.8 to 3.5 CFM/watt for airflow rates 90 CFM and above. The minimum efficacy for an ERV/HRV did not change.

### Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases depending on the make and model of fan already being installed. The Reference House uses a bath exhaust fan for whole-dwelling mechanical ventilation and requires a continuous ventilation rate of 63 CFM for slab and crawlspace designs or 82 CFM for basement designs. The analysis is based on the case where an exhaust fan with an efficacy of at least 1.4 CFM/watt but less than 2.8 CFM/watt must be replaced with unit with efficacy of at least 2.8 CFM/watt.

**Incremental cost of high efficacy bath exhaust fan**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Bath fan, 90 CFM, 1.8 CFM/W (Air King) | EA | 40.15 | | 40.15 | 44.17 | (1) | (44) |
| Bath fan, 90 CFM, EnergyStar (Air King) | EA | 88.43 | | 88.43 | 97.27 | 1 | 97 |
| **Total to Builder** | | | | | | | **53** |
| **Total to Consumer** | | | | | | | **66** |

## RE134

### Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

### Summary of the Code Change:

This code change adds efficacy requirements to air-handlers where integrated with whole-dwelling mechanical ventilation: minimum 1.2 cfm/watt, the "design outdoor airflow rate/watts of fan used".

### Cost Implication of the Code Change:

This code change may increase the cost of construction for integrated supply-type ventilation (ducted to the return plenum of the HVAC system) or balanced ventilation that is partially ducted (HRV or ERV ducting integrated with the HVAC system).

This change does not impact the Reference House that utilizes exhaust ventilation. However, a cost is developed for supply-type ventilation (this cost will also be a component of installing balanced ventilation where an HRV or ERV is integrated with the central duct system). The analysis is based on substituting a variable-speed furnace (constant-airflow ECM air drive) for a multi-speed furnace (constant-torque ECM air drive) to meet the efficacy requirement. During fan-only operation (no heating or cooling), the variable-speed furnace or air handler can be adjusted to operate at 25% of normal heating or cooling airflow, and at this lower airflow system will generally meet the efficacy requirement (although this value is typically not published in the manufacturer product data). Additionally, at this lower airflow, the differential pressure at the return plenum will not be sufficient to draw in the required amount of outdoor air, so an additional ventilation fan will normally be required. The analysis assumes the existing ventilation control is already accounted for.

**Incremental cost of variable-speed furnace**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Gas furnace, 80 AFUE, multi-speed | EA | 818.00 | | 818.00 | 899.80 | (1) | (900) |
| Gas furnace, 80 AFUE, variable-speed | EA | 1323.00 | | 1323.00 | 1455.30 | 1 | 1,455 |
| **Total to Builder** | | | | | | | **556** |
| **Total to Consumer** | | | | | | | **686** |

**Cost of both variable-speed furnace and ventilator fan**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Furnace, total to Builder from above | | | | | | | 556 |
| Ventilator fan with damper | EA | 293.04 | 39.90 | 332.94 | 388.18 | 1 | 388 |
| Ventilation damper | EA | 85.99 | | 85.99 | 94.59 | (1) | (95) |
| 15-amp circuit, duplex outlet, 20' 14/2 NM | EA | 7.30 | 23.50 | 30.80 | 46.00 | 1 | 46 |
| Wire, 14/2, add 20' | LF | 0.17 | 1.37 | 1.54 | 2.41 | 20 | 48 |
| GFCI 15-amp 1-pole breaker | EA | 41.99 | | 41.99 | 46.19 | 1 | 46 |
| **Total to Builder** | | | | | | | **989** |
| **Total to Consumer** | | | | | | | **1,222** |

## RE139

### Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

### Summary of the Code Change:

This code change requires an HRV or ERV system in CZ 7-8. The system shall be balanced with a minimum 65% SRE at 32°F at a flow greater than or equal to design airflow.

Note that in the 2021 IRC, Section M1505.4.3, there is a whole-dwelling ventilation rate credit of 30% available for a balanced ventilation system with a ducted supply to each bedroom and to one or more of the following rooms: living room; dining room; kitchen.

### Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 7-8. The analysis develops a cost to install an ERV that meets the efficiency requirements and substitutes a standard bath fan for a high efficacy fan that was used for exhaust-type whole-dwelling ventilation. The cost also includes substituting a variable-speed furnace (constant-airflow ECM air drive) for a multi-speed furnace (constant-torque ECM air drive) to meet the efficacy requirement for air handlers integrated with whole-dwelling mechanical ventilation (RE134); alternatively, the ERV would need to be ducted independently.

**Cost to install an ERV**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Bath fan, 90 CFM, EnergyStar (AirKing) | EA | 88.43 | | 88.43 | 97.27 | (1) | (97) |
| Bath exhaust fan controller | EA | 56.60 | | 56.60 | 62.26 | (1) | (62) |
| Bath exhaust fan, standard | EA | 28.24 | | 28.24 | 31.06 | 1 | 31 |
| Gas furnace, 80 AFUE, multi-speed blower | EA | 818.00 | | 818.00 | 899.80 | (1) | (900) |
| Gas furnace, 80 AFUE, variable-speed blower | EA | 1323.00 | | 1323.00 | 1455.30 | 1 | 1,455 |
| ERV, 100 CFM | EA | 991.99 | | 991.99 | 1091.19 | 1 | 1,091 |
| HRV/ERV controller | EA | 82.99 | | 82.99 | 91.29 | 1 | 91 |
| Installation, labor | HR | | 39.90 | 39.90 | 65.84 | 2 | 132 |
| Installation, material | EA | 40.00 | | 40.00 | 44.00 | 1 | 44 |
| 15-amp circuit, duplex outlet, 20' 14/2 NM | EA | 7.30 | 23.50 | 30.80 | 46.00 | 1 | 46 |
| Wire, 14/2, add 20' | LF | 0.17 | 1.37 | 1.54 | 2.41 | 20 | 48 |
| GFCI 15-amp 1-pole breaker | EA | 41.99 | | 41.99 | 46.19 | 1 | 46 |
| Grille, exhaust (from house) | EA | 35.00 | 14.50 | 49.50 | 62.50 | 1 | 63 |
| Duct, flexible insulated, 6" dia | LF | 3.81 | 2.21 | 6.02 | 7.85 | 50 | 393 |
| Wall cap, 6" dia duct | EA | 54.50 | 29.00 | 83.50 | 108.00 | 2 | 216 |
| **Total to Builder** | | | | | | | **2,597** |
| **Total to Consumer** | | | | | | | **3,206** |

## RE145

### Reference Code Section

R404.1 Lighting equipment; R404.2 Interior lighting controls (new)

### Summary of the Code Change:

This code change mandates that all permanently installed lighting fixtures contain only high-efficacy lamps (previously 90%) and have built-in lighting controls (dimmer, occupant sensor, or other control) excluding bathrooms, hallways, exterior lighting fixtures, lighting designed for safety or security.

### Cost Implication of the Code Change:

This code change will increase the cost of construction for all houses. The analysis is based on an estimated quantity of high-efficacy lamps and dimmers required at the Reference Houses.

**Cost of high-efficacy lamps and dimmer switches (slab)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity* | Cost |
|---|---|---|---|---|---|---|---|
| CFL lamp | EA | 1.99 | | 1.99 | 2.19 | 4 | 9 |
| Incandescent lamp | EA | 1.02 | | 1.04 | 1.12 | (4) | (4) |
| Dimmer switch, toggle | EA | 9.99 | | 9.99 | 10.99 | 4 | 44 |
| Standard toggle switch | EA | 1.99 | | 1.99 | 2.19 | (4) | (9) |
| **Total to Builder** | | | | | | | **39** |
| **Total to Consumer** | | | | | | | **49** |

**Cost of high-efficacy lamps and dimmer switches (basement or crawl space)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity* | Cost |
|---|---|---|---|---|---|---|---|
| CFL lamp | EA | 1.99 | | 1.99 | 2.19 | 4 | 9 |
| Incandescent lamp | EA | 1.02 | | 1.99 | 1.12 | (4) | (4) |
| Dimmer switch, toggle | EA | 9.99 | | 9.99 | 10.99 | 5 | 55 |
| Standard toggle switch | EA | 1.99 | | 1.99 | 2.19 | (5) | (11) |
| **Total to Builder** | | | | | | | **48** |
| **Total to Consumer** | | | | | | | **60** |

***Quantities**

| Room | Lamps | Dimmer |
|---|---|---|
| Dining room | 6 | 1 |
| Kitchen | 6 | 1 |
| Breakfast | 4 | 1 |
| Family Room | 2 | 1 |
| Halls | 2 | 0 |
| Baths (3) | 10 | 0 |
| Bedrooms | 0 | 0 |
| Exterior | 2 | 0 |
| Basement or crawlspace | 4 | 1 |
| **Total, basement or crawl** | 36 | 5 |
| **Total, slab** | 32 | 4 |
| **Additional lamps required** | 4 | |

## RE148

### Reference Code Section

R404.1.1 Exterior lighting

### Summary of the Code Change:

This code change requires compliance with Section C405.4 of the IECC for connected exterior lighting for Group R-2, R-3, and R-4 buildings.

### Cost Implication of the Code Change:

This code change will not impact the cost of construction for homes constructed to the IRC.

## RE149

### Reference Code Section

R404.3 Exterior lighting controls (new)

### Summary of the Code Change:

This code change requires automatic controls where permanently installed exterior lighting power exceeds 30 watts.

### Cost Implication of the Code Change:

This code change may increase the cost of construction. The analysis assumes two 100-watt equivalent, 18-watt actual, exterior lamps and is based on installing two light-sensing devices.

**Cost of exterior lighting control with light sensor**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity* | Cost |
|---|---|---|---|---|---|---|---|
| **Control, 100-watt rated, screw-in type** | EA | 9.20 | | 9.20 | 10.12 | 2 | 20 |
| **Total to Builder** | | | | | | | **20** |
| **Total to Consumer** | | | | | | | **25** |

## RE151

### Reference Code Section

R405.2

### Summary of the Code Change:

This code change creates a backstop for the performance path that requires the building thermal envelope greater than or equal to levels of efficiency and solar heat gain coefficients in the 2009 IECC.

### Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction.

## RE178

### Reference Code Section

Table R405.4.2

### Summary of the Code Change:

This code change updates the mechanical ventilation system type for the standard reference design to match the proposed design when using the performance compliance option.

### Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction.

## RE209

### Reference Code Section

R401.2.5 Additional energy efficiency (new); R408 Additional efficiency package options (new)

### Summary of the Code Change:

This code change establishes additional requirements appliable to all compliance approaches to achieve additional energy efficiency. Compliance for the prescriptive approach requires installing at least one of the five prescribed efficiency package options:

- Enhanced envelope performance (5% UA and SHGC improvement)
- More efficient HVAC equipment performance (minimum 95 AFUE natural gas furnace and 16 SEER air conditioner, 10 HSPF/16 SEER airs source heat pump, or 3.5 COP ground source heat pump)
- Reduced energy use in service water-heating (minimum 0.82 EF fossil fuel water heater, 2.0 EF electric water heater, or 0.4 solar fraction solar water heating system)
- More efficient duct thermal distribution system (100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless systems, or 100% duct system located in conditioned space as defined by Section R403.3.2)
- Improved air sealing (max 3.0 ACH50) and efficient ventilation (ERV or HRV: min 75% SRE; max 1.1 CFM/Watt; shall not use recirculation as a defrost strategy; min 50% LRMT for ERV). [For this study, when evaluating this option, the ERV (CZ 2-4) or HRV (CZ 5-7) was modeled in accordance with the 2021 IRC that provides for a ventilation rate credit of 30% where certain criteria are met, and houses in CZ 2 were modeled with a tighter building enclosure (3 ACH50 instead of 5 ACH50)].

### Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis evaluates the costs associated with the additional efficiency package options except for the enhanced envelope option.

**HVAC equipment option for Gas House with baseline 13 SEER AC (CZ 5-7 for this study)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Gas furnace, 80kBtuh, AFUE 80% | EA | 761.00 | | 761.00 | 837.10 | (1) | (837) |
| Gas Chimney Vent, 4" dia. | LF | 9.65 | 8.45 | 18.10 | 24.50 | (25) | (613) |
| Gas Chimney Vent, 3" dia. (water heater) | LF | 7.95 | 8.00 | 15.95 | 22.00 | 25 | 550 |
| Gas furnace, 80kBtuh, AFUE 95% | EA | 1,295.00 | | 1,295.00 | 1,424.50 | 1 | 1,425 |
| Vent piping, PVC, 2" dia. | LF | 3.05 | 3.02 | 6.07 | 8.30 | 40 | 332 |
| 2" concentric vent kit | EA | 59.95 | | 59.95 | 65.95 | 1 | 66 |
| Condenser, 3 ton, 13 SEER | EA | 1,085.00 | | 1,085.00 | 1,193.50 | (1) | (1,194) |
| Condenser, 3 ton, 16 SEER | EA | 1,346.00 | | 1,346.00 | 1,480.60 | 1 | 1,481 |
| **Total to Builder** | | | | | | | **1,210** |
| **Total to Consumer** | | | | | | | **1,494** |

**HVAC equipment option for Gas House adjusted for baseline 14 SEER AC (CZ 2-4 for this study)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Total to Builder, from above | | | | | | | **1,210** |
| Condenser, 3-ton, 14 SEER | EA | 1,215.00 | | 1,215.00 | 1,336.50 | (1) | (1,337) |
| Condenser, 3-ton, 13 SEER | EA | 1,085.00 | | 1,085.00 | 1,193.50 | 1 | 1,194 |
| **Total to Builder** | | | | | | | **1,067** |
| **Total to Consumer** | | | | | | | **1,317** |

**HVAC option for Electric House: variable speed inverter heat pump, rated to 7F (CZ 2-4)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Heat Pump, 8.2 HSPF/14 SEER | EA | 1,629.00 | | 1,629.00 | 1,791.90 | (1) | (1,792) |
| Air Handler, matching | EA | 988.00 | | 988.00 | 1,086.80 | (1) | (1,087) |
| Heat Pump, inverter, minimum 10 HSPF/16 SEER, 7F rated | EA | 6,830.00 | | 6,830.00 | 7,513.00 | 1 | 7,513 |
| **Total to Builder** | | | | | | | **4,634** |
| **Total to Consumer** | | | | | | | **5,721** |

**HVAC option for Electric House: variable speed inverter heat pump, rated to -13F (CZ 5-7)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Heat Pump, 8.2 HSPF/14 SEER | EA | 1,629.00 | | 1,629.00 | 1,791.90 | (1) | (1,792) |
| Air Handler, matching | EA | 988.00 | | 988.00 | 1,086.80 | (1) | (1,087) |
| Heat Pump, inverter, minimum 10 HSPF/16 SEER, -13F rated | EA | 8,652.00 | | 8,652.00 | 9,517.20 | 1 | 9,517 |
| **Total to Builder** | | | | | | | **6,639** |
| **Total to Consumer** | | | | | | | **8,196** |

**Water Heater option for Gas House: Tankless Direct Vent Water Heater**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| 40 gal gas water heater, 0.58 UEF | EA | 559.00 | 165.00 | 724.00 | 883.52 | (1) | (884) |
| Tankless gas water heater, 0.82 UEF | EA | 799.00 | 174.00 | 973.00 | 1,162.17 | 1 | 1,162 |
| Concentric vent wall termination kit | EA | 90.00 | | 90.00 | 99.00 | 1 | 99 |
| Concentric vent 39" extension | EA | 37.59 | | 37.59 | 41.35 | 1 | 41 |
| Gas Chimney Vent, 3" dia. (WH connector) | LF | 7.95 | 8.00 | 15.95 | 22.00 | (4) | (88) |
| Gas piping, 1/2" | LF | 2.69 | 5.25 | 7.94 | 11.50 | (10) | (115) |
| Gas piping, 1" | LF | 3.73 | 6.25 | 9.98 | 14.25 | 10 | 143 |
| 15-amp circuit, toggle, 40' #14/2 NM | EA | 51.00 | 85.50 | 136.50 | 195.00 | 1 | 195 |
| GFCI 15-amp, 1-pole breaker | EA | 41.99 | | 41.99 | 46.19 | 1 | 46 |
| **Total to Builder** | | | | | | | **600** |
| **Total to Consumer** | | | | | | | **740** |

**Water Heater option for Electric House: 50 gal Heat Pump Water Heater (HPWH)**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| 50 gal electric water heater | EA | 419.00 | | 419.00 | 460.90 | (1) | (461) |
| HPWH, 50 gal, minimum 2.0 EF | EA | 1,199.00 | | 1,199.00 | 1,318.90 | 1 | 1,319 |
| Mixing valve | EA | 175.00 | 16.50 | 191.50 | 220 | 1 | 220 |
| **Total to Builder** | | | | | | | **1,078** |
| **Total to Consumer** | | | | | | | **1,331** |

**Ventilation Option Gas House**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Bath fan, 90 CFM, EnergyStar (AirKing) | EA | 88.43 | | 88.43 | 97.27 | (1) | (97) |
| Bath exhaust fan controller | EA | 56.60 | | 56.60 | 62.26 | (1) | (62) |
| Bath exhaust fan, standard | EA | 28.24 | | 28.24 | 31.06 | 1 | 31 |
| Gas furnace, 80 AFUE, multi-speed blower | EA | 818.00 | | 818.00 | 899.80 | (1) | (900) |
| Gas furnace, 80 AFUE, variable-speed blower | EA | 1323.00 | | 1323.00 | 1455.30 | 1 | 1,455 |
| ERV, 100 CFM | EA | 991.99 | | 991.99 | 1091.19 | 1 | 1,091 |
| HRV/ERV controller | EA | 82.99 | | 82.99 | 91.29 | 1 | 91 |
| Installation, labor | HR | | 39.90 | 39.90 | 65.84 | 2 | 132 |
| Installation, material | EA | 40.00 | | 40.00 | 44.00 | 1 | 44 |
| 15-amp circuit, duplex outlet, 20' 14/2 NM | EA | 7.30 | 23.50 | 30.80 | 46.00 | 1 | 46 |
| Wire, 14/2, add 20' | LF | 0.17 | 1.37 | 1.54 | 2.41 | 20 | 48 |
| GFCI 15-amp 1-pole breaker | EA | 41.99 | | 41.99 | 46.19 | 1 | 46 |
| Grille, exhaust (from house) | EA | 35.00 | 14.50 | 49.50 | 62.50 | 1 | 63 |
| Duct, flexible insulated, 6" dia | LF | 3.81 | 2.21 | 6.02 | 7.85 | 50 | 393 |
| Wall cap, 6" dia duct | EA | 54.50 | 29.00 | 83.50 | 108.00 | 2 | 216 |
| **Total to Builder** | | | | | | | **2,597** |
| **Total to Consumer** | | | | | | | **3,206** |

**Ventilation Option Electric House**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Bath fan, 90 CFM, EnergyStar (AirKing) | EA | 88.43 | | 88.43 | 97.27 | (1) | (97) |
| Bath exhaust fan controller | EA | 56.60 | | 56.60 | 62.26 | (1) | (62) |
| Bath exhaust fan, standard | EA | 28.24 | | 28.24 | 31.06 | 1 | 31 |
| Heat Pump system, multi-speed blower | EA | 2394.00 | | 2394.00 | 2633.40 | (1) | (2,633) |
| Heat Pump system, variable-speed | EA | 2828.00 | | 2828.00 | 3110.80 | 1 | 3,111 |
| ERV, 100 CFM | EA | 991.99 | | 991.99 | 1091.19 | 1 | 1,091 |
| HRV/ERV controller | EA | 82.99 | | 82.99 | 91.29 | 1 | 91 |
| Installation, labor | HR | | 39.90 | 39.90 | 65.84 | 2 | 132 |
| Installation, material | EA | 40.00 | | 40.00 | 44.00 | 1 | 44 |
| 15-amp circuit, duplex outlet, 20' 14/2 NM | EA | 7.30 | 23.50 | 30.80 | 46.00 | 1 | 46 |
| Wire, 14/2, add 20' | LF | 0.17 | 1.37 | 1.54 | 2.41 | 20 | 48 |
| GFCI 15-amp 1-pole breaker | EA | 41.99 | | 41.99 | 46.19 | 1 | 46 |
| Grille, exhaust (from house) | EA | 35.00 | 14.50 | 49.50 | 62.50 | 1 | 63 |
| Duct, flexible insulated, 6" dia | LF | 3.81 | 2.21 | 6.02 | 7.85 | 50 | 393 |
| Wall cap, 6" dia duct | EA | 54.50 | 29.00 | 83.50 | 108.00 | 2 | 216 |
| **Total to Builder** | | | | | | | **2,518** |
| **Total to Consumer** | | | | | | | **3,109** |

**Ventilation Option Electric House in CZ 2**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Associated ERV cost to builder from above | | | | | | | 2,518 |
| Improve ACH50 from 5 to 3, estimate | | | | | | | 1,200 |
| **Total to Builder** | | | | | | | **3,718** |
| **Total to Consumer** | | | | | | | **4,591** |

**Duct Option: Slab House, Buried Ducts, CZ 2-3**

| Component | Unit | Material | Labor | Equip | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|---|
| R13 duct: add FSK min R5 over R8 duct | SF | 0.27 | 1.70 | | 1.97 | 3.14 | 680 | 2,135 |
| Add ceiling insulation, R49 f.g. blown | SF | 0.91 | 0.76 | 0.45 | 2.12 | 2.73 | 340 | 928 |
| Mechanical closet, 3'x4', partition wall | LF | 7.40 | 4.89 | | 12.29 | 16.15 | 10 | 162 |
| Mechanical closet, drywall, finished | SF | 0.38 | 0.61 | | 0.99 | 1.41 | 140 | 197 |
| Mechanical closet door | EA | 135.00 | 34.50 | | 169.50 | 205.00 | 1 | 205 |
| Delete attic platform decking, 3/4, 8'x8' | SF | 1.38 | 0.38 | | 1.76 | 2.14 | (64) | (137) |
| Delete attic platform joist framing, 2x12 | LF | 2.53 | 0.58 | | 3.11 | 3.73 | (40) | (149) |
| **Total to Builder** | | | | | | | | **3,341** |
| **Total to Consumer** | | | | | | | | **4,125** |

**Duct Option: Slab House, Buried Ducts, CZ 4-7**

| Component | Unit | Material | Labor | Equip | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|---|
| Add ceiling insulation, R60 f.g. blown | SF | 1.13 | 0.91 | 0.54 | 2.58 | 3.32 | 340 | 1,128 |
| Mechanical closet, 3'x4', partition wall | LF | 7.40 | 4.89 | | 12.29 | 16.15 | 10 | 162 |
| Mechanical closet, drywall, finished | SF | 0.38 | 0.61 | | 0.99 | 1.41 | 140 | 197 |
| Mechanical closet door | EA | 135.00 | 34.50 | | 169.50 | 205.00 | 1 | 205 |
| Delete attic platform decking, 3/4, 8'x8' | SF | 1.38 | 0.38 | | 1.76 | 2.14 | (64) | (137) |
| Delete attic platform joist framing, 2x12 | LF | 2.53 | 0.58 | | 3.11 | 3.73 | (40) | (149) |
| **Total to Builder** | | | | | | | | **1,406** |
| **Total to Consumer** | | | | | | | | **1,736** |

**Duct Option: Convert Crawlspace from Vented to Unvented, CZ 3**

| Component | Unit | Material | Labor | Equip | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|---|
| Floor insulation, R19 | SF | 0.60 | 0.49 | | 1.09 | 1.46 | (1,875) | (2,738) |
| Wall insulation, foil-faced polyiso, 1", R6 | SF | 0.81 | 0.37 | | 1.18 | 1.50 | 1000 | 1,502 |
| Foundation vents | EA | 7.98 | | | 7.98 | 8.78 | (6) | (53) |
| Class 1 vapor retarder on ground | SF | 0.08 | 0.08 | | 0.16 | 0.22 | 1875 | 413 |
| Supply duct, 38 cfm (1 cfm/50sf) | EA | | | | 125.00 | 137.50 | 1 | 138 |
| Transfer grille | EA | 24.00 | 13.30 | | 37.30 | 48.50 | 1 | 49 |
| **Total to Builder** | | | | | | | | **(690)** |
| **Total to Consumer** | | | | | | | | **(852)** |

**Duct Option: Convert Crawlspace from Vented to Unvented, CZ 4**

| Component | Unit | Material | Labor | Equip | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|---|
| Floor insulation, R19 | SF | 0.60 | 0.49 | | 1.09 | 1.46 | (1,875) | (2,738) |
| Wall insulation, foil-faced polyiso, 2", R12 | SF | 1.25 | 0.40 | | 1.65 | 2.04 | 1000 | 2,035 |
| Foundation vents | EA | 7.98 | | | 7.98 | 8.78 | (6) | (53) |
| Class 1 vapor retarder on ground | SF | 0.08 | 0.08 | | 0.16 | 0.22 | 1875 | 413 |
| Supply duct, 38 cfm (1 cfm/50sf) | EA | | | | 125.00 | 137.50 | 1 | 138 |
| Transfer grille | EA | 24.00 | 13.30 | | 37.30 | 48.50 | 1 | 49 |
| **Total to Builder** | | | | | | | | **(157)** |
| **Total to Consumer** | | | | | | | | **(193)** |

## CE40.2

### Reference Code Section

R303.1.2 Insulation mark installation

### Summary of the Code Change:

This code change adds a new requirement for an insulation certificate to certify the installed R-value of insulation products without an observable manufacturer's R-value mark such as blown-in attic insulation. The certificate must be left by the installer immediately after installation in a conspicuous location within the building.

### Cost Implication of the Code Change:

This code change may increase the cost of construction. The analysis is based on the estimated additional time for the installer to complete and post the certificate.

**Cost to provide insulation certificate**

| Component | Unit | Material | Labor | Total | w/O&P | Quantity | Cost |
|---|---|---|---|---|---|---|---|
| Insulation installer | HR | | 29.23 | 29.23 | 48.23 | 0.25 | 12 |
| **Total to Builder** | | | | | | | **12** |
| **Total to Consumer** | | | | | | | **15** |

## CE151.2

### Reference Code Section

R202 Defined terms (new); R403.3.1 Ducts located outside conditioned space

### Summary of the Code Change:

This code change adds a definition for Thermal Distribution Efficiency (TDE) and requirements for ducts buried underneath buildings.

### Cost Implication of the Code Change:

This code change may decrease the cost of construction in some cases, e.g., where ducts are buried beneath buildings, but this change does not impact cost for the Reference House.

# APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

| Incremental Construction Cost of Individual Code Chage for the Reference House | | | | CZ 2 Phoenix | |
|---|---|---|---|---|---|
| Proposal | Description | Affected CZ | Reference House | Mass (30%) Electric Slab 100% | Frame (70%) Electric Slab 100% |
| RE7 | Lighting: revised definition of high-efficacy | All | $0 | | |
| RE18/20/21 | Certificate: additional info | All | $99 | $99 | $99 |
| RE29 | Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6) | 4-5 | $4,970 | | |
| RE32 | Slab edge: NR to R10/2 (CZ3) | 3 | $1,988 | | |
| " | Slab edge: R10/2 to R10/4 (CZ4-5) | 4-5 | $993 | | |
| RE33 | Ceiling insulation R38 to R49 | 2-3 | $1,366 | $1,366 | $1,366 |
| RE36 | Ceiling insulation R49 to R60 | 4-7 | $1,366 | | |
| RE34 | Floors, removes exception for min R19 if fills cavity | 5-8 | NA | | |
| RE35 | Windows: reduces U-value from 0.32 to 0.30 | 3-4 | $76 | | |
| RE37 | Windows: changes SHGC form NR to 0.40 | 5 & 4C | $0 | | |
| RE105 | Windows: reduces max SHGC tradeoff from 0.50 to 0.40 | 2-3 | $0 | | |
| RE46 | Attic access hatch: no direct cost; cost of additional insulation | All | $13 | $13 | $13 |
| RE49 | Baffles at attic access | All | $12 | $12 | $12 |
| RE72 | Air seal narrow framing cavities | All | $156 | $156 | $156 |
| RE82 | Air seal rim (basement; unvented crawlspace) | All | $1,252 | | |
| " | Air seal rim (slab, vented crawlspace) | All | $417 | $417 | $417 |
| RE96 | House tightness, allows trade-off for performance path | All | $0 | | |
| RE103 | Air seal electrical & communication outlet boxes | All | $369 | $369 | $369 |
| RE106 | Thermostat: requires 7-day programming | All | $0 | | |
| RE112 | Removes exception for duct test (basement, unvented crawl) | All | $247 | | |
| RE130 | Adds requirement to test whole-dwelling ventilation | All | $62 | $62 | $62 |
| RE133 | Updates ventilation fan efficacy (affects bath EF) | All | $66 | $66 | $66 |
| RE139 | Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration) | 7 | $3,206 | | |
| RE145 | Lighting: 100% high-efficacy; controls (slab) | All | $49 | $49 | $49 |
| " | Lighting: 100% high-efficacy; controls (basement, crawl) | All | $60 | | |
| RE148 | Lighting, commercial | All | NA | | |
| RE149 | Lighting: exterior controls | All | $25 | $25 | $25 |
| RE151 | Performance path backstop: 2009 IECC | All | NA | | |
| RE178 | Performance path ventilation type to match proposed | All | NA | | |
| CE40.2 | Insulation certificate if no manufacturer mark (i.e., blown) | All | $15 | $15 | $15 |
| CE151.2 | Defines duct TDE; adds requirements for underground ducts | All | NA | | |
| | **Sub-total without additional efficiency package options** | | | $2,648 | $2,648 |
| | **Weighted average, foundations** | | | | $2,648 |
| | | | **Nat Ave** | **CZ 2** | |
| | **Weighted average without additional efficiency package options** | | 5,477 | 2,648 | |
| RE209 | HVAC option | | 3,824 | 5,721 | |
| RE209 | Water Heater option | | 1,071 | 1,331 | |
| RE209 | Ventilation option | | 3,570 | 4,591 | |
| RE209 | Duct option, slab houses | | 3,074 | 4,125 | |
| RE209 | Duct option, vented crawlspace houses | | na | | |
| | **Total with HVAC option** | | 9,301 | 8,369 | |
| | **Total with Water Heater option** | | 6,548 | 3,979 | |
| | **Total with Ventilation option** | | 9,047 | 7,238 | |
| | **Total with Duct option, slab houses** | | 8,550 | 6,773 | |
| | **Total with Duct option, vented crawlspace houses** | | na | | |

| Incremental Construction Cost of Individual Code Chage for the Reference House | | | | CZ 3 Memphis | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Mass Wall (10%) Electric | | | Frame Wall (90%) Electric | | |
| Proposal | Description | Affected CZ | Reference House | Slab 75% | Basement 10% | Crawl 15% | Slab 75% | Basement 10% | Crawl 15% |
| RE7 | Lighting: revised definition of high-efficacy | All | $0 | | | | | | |
| RE18/20/21 | Certificate: additional info | All | $99 | $99 | $99 | $99 | $99 | $99 | $99 |
| RE29 | Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6) | 4-5 | $4,970 | | | | | | |
| RE32 | Slab edge: NR to R10/2 (CZ3) | 3 | $1,988 | $1,988 | | | $1,988 | | |
| " | Slab edge: R10/2 to R10/4 (CZ4-5) | 4-5 | $993 | | | | | | |
| RE33 | Ceiling insulation R38 to R49 | 2-3 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 |
| RE36 | Ceiling insulation R49 to R60 | 4-7 | $1,366 | | | | | | |
| RE34 | Floors, removes exception for min R19 if fills cavity | 5-8 | NA | | | | | | |
| RE35 | Windows: reduces U-value from 0.32 to 0.30 | 3-4 | $76 | $76 | $76 | $76 | $76 | $76 | $76 |
| RE37 | Windows: changes SHGC form NR to 0.40 | 5 & 4C | $0 | | | | | | |
| RE105 | Windows: reduces max SHGC tradeoff from 0.50 to 0.40 | 2-3 | $0 | | | | | | |
| RE46 | Attic access hatch: no direct cost; cost of additional insulation | All | $13 | $13 | $13 | $13 | $13 | $13 | $13 |
| RE49 | Baffles at attic access | All | $12 | $12 | $12 | $12 | $12 | $12 | $12 |
| RE72 | Air seal narrow framing cavities | All | $156 | $156 | $156 | $156 | $156 | $156 | $156 |
| RE82 | Air seal rim (basement; unvented crawlspace) | All | $1,252 | | $1,252 | | | $1,252 | |
| " | Air seal rim (slab, vented crawlspace) | All | $417 | $417 | | $417 | $417 | | $417 |
| RE96 | House tightness, allows trade-off for performance path | All | $0 | | | | | | |
| RE103 | Air seal electrical & communication outlet boxes | All | $369 | $369 | $369 | $369 | $369 | $369 | $369 |
| RE106 | Thermostat: requires 7-day programming | All | $0 | | | | | | |
| RE112 | Removes exception for duct test (basement, unvented crawl) | All | $247 | | $247 | | | $247 | |
| RE130 | Adds requirement to test whole-dwelling ventilation | All | $62 | $62 | $62 | $62 | $62 | $62 | $62 |
| RE133 | Updates ventilation fan efficacy (affects bath EF) | All | $66 | $66 | $66 | $66 | $66 | $66 | $66 |
| RE139 | Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration) | 7 | $3,206 | | | | | | |
| RE145 | Lighting: 100% high-efficacy; controls (slab) | All | $49 | $49 | | | $49 | | |
| " | Lighting: 100% high-efficacy; controls (basement, crawl) | All | $60 | | $60 | $60 | | $60 | $60 |
| RE148 | Lighting, commercial | All | NA | | | | | | |
| RE149 | Lighting: exterior controls | All | $25 | $25 | $25 | $25 | $25 | $25 | $25 |
| RE151 | Performance path backstop: 2009 IECC | All | NA | | | | | | |
| RE178 | Performance path ventilation type to match proposed | All | NA | | | | | | |
| CE40.2 | Insulation certificate if no manufacturer mark (i.e., blown) | All | $15 | $15 | $15 | $15 | $15 | $15 | $15 |
| CE151.2 | Defines duct TDE; adds requirements for underground ducts | All | NA | | | | | | |
| | **Sub-total without additional efficiency package options** | | | $4,712 | $3,816 | $2,735 | $4,712 | $3,816 | $2,735 |
| | **Weighted average, foundations** | | | | | $4,326 | | | $4,326 |
| | | | **Nat Ave** | | | **CZ 3** | | | |
| | **Weighted average without additional efficiency package options** | | 5,477 | | | 4,326 | | | |
| RE209 | HVAC option | | 3,824 | | | 5,721 | | | |
| RE209 | Water Heater option | | 1,071 | | | 1,331 | | | |
| RE209 | Ventilation option | | 3,570 | | | 3,109 | | | |
| RE209 | Duct option, slab houses | | 3,074 | | | 4,125 | | | |
| RE209 | Duct option, vented crawlspace houses | | na | | | (852) | | | |
| | **Total with HVAC option** | | 9,301 | | | 10,047 | | | |
| | **Total with Water Heater option** | | 6,548 | | | 5,657 | | | |
| | **Total with Ventilation option** | | 9,047 | | | 7,435 | | | |
| | **Total with Duct option, slab houses** | | 8,550 | | | 8,451 | | | |
| | **Total with Duct option, vented crawlspace houses** | | na | | | 3,474 | | | |

| Incremental Construction Cost of Individual Code Chage for the Reference House | | | | | CZ 4 Baltimore Frame Wall Gas | |
|---|---|---|---|---|---|---|
| Proposal | Description | Affected CZ | Reference House | Slab 20% | Basement 60% | Crawl 20% |
| RE7 | Lighting: revised definition of high-efficacy | All | $0 | | | |
| RE18/20/21 | Certificate: additional info | All | $99 | $99 | $99 | $99 |
| RE29 | Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6) | 4-5 | $4,970 | $4,970 | $4,970 | $4,970 |
| RE32 | Slab edge: NR to R10/2 (CZ3) | 3 | $1,988 | | | |
| " | Slab edge: R10/2 to R10/4 (CZ4-5) | 4-5 | $993 | $993 | | |
| RE33 | Ceiling insulation R38 to R49 | 2-3 | $1,366 | | | |
| RE36 | Ceiling insulation R49 to R60 | 4-7 | $1,366 | $1,366 | $1,366 | $1,366 |
| RE34 | Floors, removes exception for min R19 if fills cavity | 5-8 | NA | | | |
| RE35 | Windows: reduces U-value from 0.32 to 0.30 | 3-4 | $76 | $76 | $76 | $76 |
| RE37 | Windows: changes SHGC form NR to 0.40 | 5 & 4C | $0 | | | |
| RE105 | Windows: reduces max SHGC tradeoff from 0.50 to 0.40 | 2-3 | $0 | | | |
| RE46 | Attic access hatch: no direct cost; cost of additional insulation | All | $13 | $13 | $13 | $13 |
| RE49 | Baffles at attic access | All | $12 | $12 | $12 | $12 |
| RE72 | Air seal narrow framing cavities | All | $156 | $156 | $156 | $156 |
| RE82 | Air seal rim (basement; unvented crawlspace) | All | $1,252 | | $1,252 | |
| " | Air seal rim (slab, vented crawlspace) | All | $417 | $417 | | $417 |
| RE96 | House tightness, allows trade-off for performance path | All | $0 | | | |
| RE103 | Air seal electrical & communication outlet boxes | All | $369 | $369 | $369 | $369 |
| RE106 | Thermostat: requires 7-day programming | All | $0 | | | |
| RE112 | Removes exception for duct test (basement, unvented crawl) | All | $247 | | $247 | |
| RE130 | Adds requirement to test whole-dwelling ventilation | All | $62 | $62 | $62 | $62 |
| RE133 | Updates ventilation fan efficacy (affects bath EF) | All | $66 | $66 | $66 | $66 |
| RE139 | Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration) | 7 | $3,206 | | | |
| RE145 | Lighting: 100% high-efficacy; controls (slab) | All | $49 | $49 | | |
| " | Lighting: 100% high-efficacy; controls (basement, crawl) | All | $60 | | $60 | $60 |
| RE148 | Lighting, commercial | All | NA | | | |
| RE149 | Lighting: exterior controls | All | $25 | $25 | $25 | $25 |
| RE151 | Performance path backstop: 2009 IECC | All | NA | | | |
| RE178 | Performance path ventilation type to match proposed | All | NA | | | |
| CE40.2 | Insulation certificate if no manufacturer mark (i.e., blown) | All | $15 | $15 | $15 | $15 |
| CE151.2 | Defines duct TDE; adds requirements for underground ducts | All | NA | | | |
| | **Sub-total without additional efficiency package options** | | | $8,686 | $8,786 | $7,705 |
| | **Weighted average, foundations** | | | | | $8,550 |
| | | | **Nat Ave** | | **CZ 4** | |
| | **Weighted average without additional efficiency package options** | | 5,477 | | 8,550 | |
| RE209 | HVAC option | | 3,824 | | 1,317 | |
| RE209 | Water Heater option | | 1,071 | | 740 | |
| RE209 | Ventilation option | | 3,570 | | 3,206 | |
| RE209 | Duct option, slab houses | | 3,074 | | 1,736 | |
| RE209 | Duct option, vented crawlspace houses | | na | | (193) | |
| | **Total with HVAC option** | | 9,301 | | 9,867 | |
| | **Total with Water Heater option** | | 6,548 | | 9,290 | |
| | **Total with Ventilation option** | | 9,047 | | 11,755 | |
| | **Total with Duct option, slab houses** | | 8,550 | | 10,286 | |
| | **Total with Duct option, vented crawlspace houses** | | na | | 8,356 | |

| Incremental Construction Cost of Individual Code Chage for the Reference House | | | | CZ 5 Chicago | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Frame Wall Gas (60%) | | | Frame Wall Electric (40%) | | |
| Proposal | Description | Affected CZ | Reference House | Slab 15% | Basement 70% | Crawl 15% | Slab 15% | Basement 70% | Crawl 15% |
| RE7 | Lighting: revised definition of high-efficacy | All | $0 | | | | | | |
| RE18/20/21 | Certificate: additional info | All | $99 | $99 | $99 | $99 | $99 | $99 | $99 |
| RE29 | Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6) | 4-5 | $4,970 | $4,970 | $4,970 | $4,970 | $4,970 | $4,970 | $4,970 |
| RE32 | Slab edge: NR to R10/2 (CZ3) | 3 | $1,988 | | | | | | |
| " | Slab edge: R10/2 to R10/4 (CZ4-5) | 4-5 | $993 | $993 | | | $993 | | |
| RE33 | Ceiling insulation R38 to R49 | 2-3 | $1,366 | | | | | | |
| RE36 | Ceiling insulation R49 to R60 | 4-7 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 |
| RE34 | Floors, removes exception for min R19 if fills cavity | 5-8 | NA | | | | | | |
| RE35 | Windows: reduces U-value from 0.32 to 0.30 | 3-4 | $76 | | | | | | |
| RE37 | Windows: changes SHGC form NR to 0.40 | 5 & 4C | $0 | | | | | | |
| RE105 | Windows: reduces max SHGC tradeoff from 0.50 to 0.40 | 2-3 | $0 | | | | | | |
| RE46 | Attic access hatch: no direct cost; cost of additional insulation | All | $13 | $13 | $13 | $13 | $13 | $13 | $13 |
| RE49 | Baffles at attic access | All | $12 | $12 | $12 | $12 | $12 | $12 | $12 |
| RE72 | Air seal narrow framing cavities | All | $156 | $156 | $156 | $156 | $156 | $156 | $156 |
| RE82 | Air seal rim (basement; unvented crawlspace) | All | $1,252 | | $1,252 | $1,252 | | $1,252 | $1,252 |
| " | Air seal rim (slab, vented crawlspace) | All | $417 | $417 | | | $417 | | |
| RE96 | House tightness, allows trade-off for performance path | All | $0 | | | | | | |
| RE103 | Air seal electrical & communication outlet boxes | All | $369 | $369 | $369 | $369 | $369 | $369 | $369 |
| RE106 | Thermostat: requires 7-day programming | All | $0 | | | | | | |
| RE112 | Removes exception for duct test (basement, unvented crawl) | All | $247 | | $247 | $247 | | $247 | $247 |
| RE130 | Adds requirement to test whole-dwelling ventilation | All | $62 | $62 | $62 | $62 | $62 | $62 | $62 |
| RE133 | Updates ventilation fan efficacy (affects bath EF) | All | $66 | $66 | $66 | $66 | $66 | $66 | $66 |
| RE139 | Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration) | 7 | $3,206 | | | | | | |
| RE145 | Lighting: 100% high-efficacy; controls (slab) | All | $49 | $49 | | | $49 | | |
| " | Lighting: 100% high-efficacy; controls (basement, crawl) | All | $60 | | $60 | $60 | | $60 | $60 |
| RE148 | Lighting, commercial | All | NA | | | | | | |
| RE149 | Lighting: exterior controls | All | $25 | $25 | $25 | $25 | $25 | $25 | $25 |
| RE151 | Performance path backstop: 2009 IECC | All | NA | | | | | | |
| RE178 | Performance path ventilation type to match proposed | All | NA | | | | | | |
| CE40.2 | Insulation certificate if no manufacturer mark (i.e., blown) | All | $15 | $15 | $15 | $15 | $15 | $15 | $15 |
| CE151.2 | Defines duct TDE; adds requirements for underground ducts | All | NA | | | | | | |
| | **Sub-total without additional efficiency package options** | | | $8,610 | $8,710 | $8,710 | $8,610 | $8,710 | $8,710 |
| | **Weighted average, foundations** | | | | | $8,695 | | | $8,695 |
| | | | **Nat Ave** | **CZ 5 Gas** | | | **CZ 5 Electric** | | |
| | **Weighted average without additional efficiency package options** | | 5,477 | 8,695 | | | 8,695 | | |
| RE209 | HVAC option | | 3,824 | 1,494 | | | 8,196 | | |
| RE209 | Water Heater option | | 1,071 | 740 | | | 2,503 | | |
| RE209 | Ventilation option | | 3,570 | 3,206 | | | 3,109 | | |
| RE209 | Duct option, slab houses | | 3,074 | 1,736 | | | 1,736 | | |
| RE209 | Duct option, vented crawlspace houses | | na | | | | | | |
| | **Total with HVAC option** | | 9,301 | 10,188 | | | 16,890 | | |
| | **Total with Water Heater option** | | 6,548 | 9,435 | | | 11,198 | | |
| | **Total with Ventilation option** | | 9,047 | 11,900 | | | 11,804 | | |
| | **Total with Duct option, slab houses** | | 8,550 | 10,431 | | | 10,431 | | |
| | **Total with Duct option, vented crawlspace houses** | | na | | | | | | |

| Incremental Construction Cost of Individual Code Chage for the Reference House | | | | CZ 6 Helena Frame Wall Gas | | | CZ 7 Duluth Frame Wall Gas | | |
|---|---|---|---|---|---|---|---|---|---|
| Proposal | Description | Affected CZ | Reference House | Slab 5% | Basement 90% | Crawl 5% | Slab 30% | Basement 5% | Crawl 65% |
| RE7 | Lighting: revised definition of high-efficacy | All | $0 | | | | | | |
| RE18/20/21 | Certificate: additional info | All | $99 | $99 | $99 | $99 | $99 | $99 | $99 |
| RE29 | Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6) | 4-5 | $4,970 | | | | | | |
| RE32 | Slab edge: NR to R10/2 (CZ3) | 3 | $1,988 | | | | | | |
| " | Slab edge: R10/2 to R10/4 (CZ4-5) | 4-5 | $993 | | | | | | |
| RE33 | Ceiling insulation R38 to R49 | 2-3 | $1,366 | | | | | | |
| RE36 | Ceiling insulation R49 to R60 | 4-7 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 | $1,366 |
| RE34 | Floors, removes exception for min R19 if fills cavity | 5-8 | NA | | | | | | |
| RE35 | Windows: reduces U-value from 0.32 to 0.30 | 3-4 | $76 | | | | | | |
| RE37 | Windows: changes SHGC form NR to 0.40 | 5 & 4C | $0 | | | | | | |
| RE105 | Windows: reduces max SHGC tradeoff from 0.50 to 0.40 | 2-3 | $0 | | | | | | |
| RE46 | Attic access hatch: no direct cost; cost of additional insulation | All | $13 | $13 | $13 | $13 | $13 | $13 | $13 |
| RE49 | Baffles at attic access | All | $12 | $12 | $12 | $12 | $12 | $12 | $12 |
| RE72 | Air seal narrow framing cavities | All | $156 | $156 | $156 | $156 | $156 | $156 | $156 |
| RE82 | Air seal rim (basement; unvented crawlspace) | All | $1,252 | | $1,252 | $1,252 | | $1,252 | $1,252 |
| " | Air seal rim (slab, vented crawlspace) | All | $417 | $417 | | | $417 | | |
| RE96 | House tightness, allows trade-off for performance path | All | $0 | | | | | | |
| RE103 | Air seal electrical & communication outlet boxes | All | $369 | $369 | $369 | $369 | $369 | $369 | $369 |
| RE106 | Thermostat: requires 7-day programming | All | $0 | | | | | | |
| RE112 | Removes exception for duct test (basement, unvented crawl) | All | $247 | | $247 | $247 | | $247 | $247 |
| RE130 | Adds requirement to test whole-dwelling ventilation | All | $62 | $62 | $62 | $62 | $62 | $62 | $62 |
| RE133 | Updates ventilation fan efficacy (affects bath EF) | All | $66 | $66 | $66 | $66 | $66 | $66 | $66 |
| RE139 | Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration) | 7 | $3,206 | | | | $3,206 | $3,206 | $3,206 |
| RE145 | Lighting: 100% high-efficacy; controls (slab) | All | $49 | $49 | | | $49 | | |
| " | Lighting: 100% high-efficacy; controls (basement, crawl) | All | $60 | | $60 | $60 | | $60 | $60 |
| RE148 | Lighting, commercial | All | NA | | | | | | |
| RE149 | Lighting: exterior controls | All | $25 | $25 | $25 | $25 | $25 | $25 | $25 |
| RE151 | Performance path backstop: 2009 IECC | All | NA | | | | | | |
| RE178 | Performance path ventilation type to match proposed | All | NA | | | | | | |
| CE40.2 | Insulation certificate if no manufacturer mark (i.e., blown) | All | $15 | $15 | $15 | $15 | $15 | $15 | $15 |
| CE151.2 | Defines duct TDE; adds requirements for underground ducts | All | NA | | | | | | |
| | **Sub-total without additional efficiency package options** | | | $2,648 | $3,740 | $3,740 | $5,853 | $6,946 | $6,946 |
| | **Weighted average, foundations** | | | | | $3,685 | | | $6,618 |
| | | | **Nat Ave** | **CZ 6** | | | **CZ 7** | | |
| | **Weighted average without additional efficiency package options** | | 5,477 | 3,685 | | | 6,618 | | |
| RE209 | HVAC option | | 3,824 | 1,494 | | | 1,494 | | |
| RE209 | Water Heater option | | 1,071 | 740 | | | 740 | | |
| RE209 | Ventilation option | | 3,570 | 3,206 | | | 0 | | |
| RE209 | Duct option, slab houses | | 3,074 | 1,736 | | | 1,736 | | |
| RE209 | Duct option, vented crawlspace houses | | na | | | | | | |
| | **Total with HVAC option** | | 9,301 | 5,179 | | | 8,112 | | |
| | **Total with Water Heater option** | | 6,548 | 4,426 | | | 7,358 | | |
| | **Total with Ventilation option** | | 9,047 | 6,891 | | | 6,618 | | |
| | **Total with Duct option, slab houses** | | 8,550 | 5,421 | | | 8,354 | | |
| | **Total with Duct option, vented crawlspace houses** | | na | | | | | | |

# APPENDIX C: LOCATION ADJUSTMENT FACTORS

| State | City | Cost Adjustment Factor | State | City | Cost Adjustment Factor |
|---|---|---|---|---|---|
| Alabama | Birmingham | 0.84 | Montana | Billings | 0.89 |
| Alabama | Mobile | 0.83 | Nebraska | Omaha | 0.90 |
| Alaska | Fairbanks | 1.21 | Nevada | Las Vegas | 1.03 |
| Arizona | Phoenix | 0.84 | New Hampshire | Portsmouth | 0.95 |
| Arizona | Tucson | 0.84 | New Jersey | Jersey City | 1.18 |
| Arkansas | Little Rock | 0.83 | New Mexico | Albuquerque | 0.86 |
| California | Alhambra | 1.15 | New York | Long Island City | 1.36 |
| California | Los Angeles | 1.15 | New York | Syracuse | 0.99 |
| California | Riverside | 1.13 | North Carolina | Charlotte | 0.99 |
| California | Stockton | 1.20 | North Carolina | Hickory | 0.93 |
| Colorado | Boulder | 0.90 | North Carolina | Raleigh | 0.94 |
| Colorado | Colorado Springs | 0.87 | North Dakota | Fargo | 0.87 |
| Colorado | Denver | 0.91 | Ohio | Columbus | 0.91 |
| Connecticut | New Haven | 1.10 | Oklahoma | Oklahoma City | 0.84 |
| Delaware | Dover | 1.02 | Oklahoma | Tulsa | 0.83 |
| District of Columbia | Washington, D.C. | 0.92 | Oregon | Bend | 1.02 |
| Florida | Fort Meyers | 0.79 | Pennsylvania | Norristown | 1.05 |
| Florida | Miami | 0.83 | Pennsylvania | State College | 0.94 |
| Florida | Orlando | 0.82 | Rhode Island | Providence | 1.09 |
| Florida | Tampa | 0.81 | South Carolina | Greenville | 0.97 |
| Georgia | Atlanta | 0.90 | South Dakota | Sioux Falls | 0.92 |
| Hawaii | Honolulu | 1.22 | Tennessee | Memphis | 0.87 |
| Idaho | Boise | 0.89 | Texas | Austin | 0.80 |
| Illinois | Chicago | 1.25 | Texas | Dallas | 0.84 |
| Indiana | Indianapolis | 0.92 | Texas | Houston | 0.84 |
| Iowa | Des Moines | 0.92 | Texas | San Antonio | 0.83 |
| Kansas | Wichita | 0.81 | Utah | Ogden | 0.84 |
| Kentucky | Louisville | 0.89 | Utah | Provo | 0.85 |
| Louisiana | Baton Rouge | 0.85 | Utah | Salt Lake City | 0.85 |
| Maine | Portland | 0.94 | Vermont | Burlington | 0.95 |
| Maryland | Baltimore | 0.93 | Virginia | Fairfax | 1.00 |
| Massachusetts | Boston | 1.18 | Virginia | Winchester | 0.99 |
| Michigan | Ann Arbor | 0.99 | Washington | Tacoma | 1.05 |
| Minnesota | Minneapolis | 1.09 | West Virginia | Charleston | 0.94 |
| Mississippi | Biloxi | 0.83 | Wisconsin | La Crosse | 0.95 |
| Missouri | Springfield | 0.86 | Wyoming | Casper | 0.85 |

*Source: RSMeans *Residential Cost Data 2021*. Sample cities are listed in this table; check RSMeans for additional locations.

# APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

The table below shows the insulation and fenestration requirements for the 2018 IECC and 2021 IECC. For comparison purposes, the 2021 IECC values are shown only where those have been changed from the 2018 values.

**Insulation and Fenestration Requirements. Source: adapted from the 2018 and 2021 IECC.**

| | CZ 2 | | CZ 3 | | CZ 4 except 4C | | CZ 5 and 4C | | CZ 6 | | CZ 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Phoenix | | Memphis | | Baltimore | | Chicago | | Helena | | Duluth | |
| **Component** | **2018** | **2021** | **2018** | **2021** | **2018** | **2021** | **2018** | **2021** | **2018** | **2021** | **2018** | **2021** |
| **Fenestration U-factor** | 0.40 | | 0.32 | 0.30 | 0.32 | 0.30 | 0.30 | | 0.30 | | 0.30 | |
| **Fenestration SHGC** | 0.25 | | 0.25 | | 0.4 | | NR | 0.40 | NR | | NR | |
| **Skylight U-factor** | 0.65 | | 0.55 | | 0.55 | | 0.55 | | 0.55 | | 0.55 | |
| **Ceiling R-value** | 38 | 49 | 38 | 49 | 49 | 60 | 49 | 60 | 49 | 60 | 49 | 60 |
| **Frame Wall R-value (selected for modeling)** | 13 | | 13+5 | | 13+5 | 13+10 | 13+5 | 13+10 | 13+10 | | 13+10 | |
| **Mass Wall R-value (<half/>half on interior** | 4/6 | | 8/13 | | 8/13 | | 13/17 | | 15/20 | | 19/21 | |
| **Floor R-value** | 13 | | 19 | | 19 | | 30 | | 30 | | 38 | |
| **Basement wall R-value, ci/cavity** | 0 | | 5/13 | | 10/13 | | 15/19 | | 15/19 | | 15/19 | |
| **Slab R-value/depth** | 0 | | 0 | 10/2 | 10/2 | 10/4 | 10/2 | 10/4 | 10/4 | | 10/4 | |
| **Crawl wall R-value, ci/cavity** | 0 | | 5/13 | | 10/13 | | 15/19 | | 15/19 | | 15/19 | |

# APPENDIX E: ENERGY USE BY CLIMATE ZONE

| Configuration | | Annual Energy Use CZ 2 Phoenix Mass Wall (30%) Electric kWh/yr | $/yr | Savings* | Frame Wall (70%) Electric kWh/yr | $/yr | Savings* |
|---|---|---|---|---|---|---|---|
| **2018 Baseline** | Slab | 17,107 | 2,225 | | 17,087 | 2,223 | |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2018 + 2021 ceiling insulation | Slab | 17,052 | 2,218 | 0.3% | 17,028 | 2,215 | 0.4% |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2018 + 2021 slab insulation | Slab | | | | | | |
| | Ave for CZ | | | | | | |
| | | | | | | | |
| 2018 + 2021 wall cont. insulation | Slab | | | | | | |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2018 + 2021 window U-Factor | Slab | | | | | | |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| **2021 without efficiency options** | Slab | 16,638 | 2,164 | 2.7% | 16,615 | 2,162 | 2.7% |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2021 + HVAC option | Slab | 15,727 | 2,046 | 8.0% | 15,715 | 2,045 | 8.0% |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2021 + Water Heater option | Slab | 15,618 | 2,030 | 8.8% | 15,589 | 2,027 | 8.8% |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2021 + Ventilation option | Slab | 16,506 | 2,147 | 3.5% | 16,465 | 2,142 | 3.6% |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2021 + Duct option | Slab | 15,768 | 2,051 | 7.8% | 15,715 | 2,044 | 8.1% |
| | Crawl** | | | | | | |
| *Cost savings ($/yr) relative to 2018 baseline | | | | | | | |
| **Crawl: vented CZ 3-4; conditioned CZ 5-7 | | | | | | | |

| Configuration | | Annual Energy Use CZ 3 Memphis Mass Wall (10%) Electric kWh/yr | $/yr | Savings* | Frame Wall (90%) Electric kWh/yr | $/yr | Savings* |
|---|---|---|---|---|---|---|---|
| **2018 Baseline** | Slab | 15618 | 2031 | | 15,557 | 2,023 | |
| | Basement | 16612 | 2161 | | 16547 | 2152 | |
| | Crawl** | 15144 | 1970 | | 15056 | 1958 | |
| | | | | | | | |
| 2018 + 2021 ceiling insulation | Slab | 15536 | 2021 | 0.5% | 15,472 | 2,012 | 0.5% |
| | Basement | 16521 | 2149 | 0.6% | 16,451 | 2,140 | 0.6% |
| | Crawl** | 15053 | 1958 | 0.6% | 14,959 | 1,946 | 0.6% |
| | | | | | | | |
| 2018 + 2021 slab insulation | Slab | 14938 | 1943 | 4.3% | 14,877 | 1,935 | 4.3% |
| | Ave for CZ | | | | | 1,936 | |
| | | | | | | | |
| 2018 + 2021 wall cont. insulation | Slab | | | | | | |
| | Basement | | | | | | |
| | Crawl** | | | | | | |
| | | | | | | | |
| 2018 + 2021 window U-Factor | Slab | 15566 | 2024 | 0.3% | 15,501 | 2,016 | 0.3% |
| | Basement | 16553 | 2154 | 0.3% | 16,489 | 2,145 | 0.3% |
| | Crawl** | 15091 | 1963 | 0.4% | 14,994 | 1,951 | 0.4% |
| | | | | | | | |
| **2021 without efficiency options** | Slab | 14,408 | 1,874 | 7.7% | 14,344 | 1,866 | 7.8% |
| | Basement | 15,903 | 2,068 | 4.3% | 15,832 | 2,059 | 4.3% |
| | Crawl** | 14,610 | 1,900 | 3.6% | 14,519 | 1,889 | 3.5% |
| | | | | | | | |
| 2021 + HVAC option | Slab | 13,485 | 1,754 | 13.6% | 13,450 | 1,749 | 13.5% |
| | Basement | 14,824 | 1,928 | 10.8% | 14,786 | 1,924 | 10.6% |
| | Crawl** | 13,561 | 1,765 | 10.4% | 13,502 | 1,756 | 10.3% |
| | | | | | | | |
| 2021 + Water Heater option | Slab | 13,277 | 1,726 | 15.0% | 13,212 | 1,718 | 15.1% |
| | Basement | 14,742 | 1,916 | 11.3% | 14,669 | 1,907 | 11.4% |
| | Crawl** | 13,470 | 1,752 | 11.1% | 13,382 | 1,740 | 11.1% |
| | | | | | | | |
| 2021 + Ventilation option | Slab | 14,326 | 1,864 | 8.2% | 14,259 | 1,855 | 8.3% |
| | Basement | 15,727 | 2,046 | 5.3% | 15,651 | 2,036 | 5.4% |
| | Crawl** | 14,446 | 1,879 | 4.6% | 14,346 | 1,867 | 4.6% |
| | | | | | | | |
| 2021 + Duct option | Slab | 13,816 | 1,797 | 11.5% | 13,749 | 1,788 | 11.6% |
| | Crawl** | 14,273 | 1,857 | 5.7% | 14,174 | 1,844 | 5.8% |
| *Cost savings ($/yr) relative to 2018 baseline | | | | | | | |
| **Crawl: vented CZ 3-4; conditioned CZ 5-7 | | | | | | | |

| Configuration | | Annual Energy Use CZ 4 Baltimore Frame Wall Natural Gas kWh/yr | thrm/yr | $/yr | Savings* |
|---|---|---|---|---|---|
| **2018 Baseline** | Slab | 8,262 | 697 | 1,807 | |
| | Basement | 9,848 | 696 | 2,012 | |
| | Crawl** | 8,669 | 665 | 1,826 | |
| | | | | | |
| 2018 + 2021 ceiling insulation | Slab | 8,244 | 690 | 1,797 | 0.6% |
| | Basement | 9,833 | 689 | 2,003 | 0.4% |
| | Crawl** | 8,652 | 659 | 1,818 | 0.4% |
| | | | | | |
| 2018 + 2021 slab insulation | Slab | 8,180 | 674 | 1,772 | 1.9% |
| | Ave for CZ | | | 1,772 | |
| | | | | | |
| 2018 + 2021 wall cont. insulation | Slab | 8,177 | 661 | 1,758 | 2.7% |
| | Basement | 9,763 | 660 | 1,964 | 2.4% |
| | Crawl** | 8,590 | 629 | 1,778 | 2.6% |
| | | | | | |
| 2018 + 2021 window U-Factor | Slab | 8,256 | 687 | 1,796 | 0.6% |
| | Basement | 9,848 | 686 | 2,002 | 0.5% |
| | Crawl** | 8,666 | 656 | 1,816 | 0.5% |
| | | | | | |
| **2021 without efficiency options** | Slab | 7,673 | 626 | 1,655 | 8.4% |
| | Basement | 9,159 | 649 | 1,873 | 6.9% |
| | Crawl** | 8,174 | 616 | 1,711 | 6.3% |
| | | | | | |
| 2021 + HVAC option | Slab | 7,348 | 565 | 1,550 | 14.2% |
| | Basement | 8,795 | 580 | 1,753 | 12.9% |
| | Crawl** | 7,761 | 552 | 1,590 | 12.9% |
| | | | | | |
| 2021 + Water Heater option | Slab | 7,670 | 604 | 1,624 | 10.1% |
| | Basement | 9,188 | 617 | 1,835 | 8.8% |
| | Crawl** | 8,171 | 594 | 1,678 | 8.1% |
| | | | | | |
| 2021 + Ventilation option | Slab | 7,931 | 586 | 1,648 | 8.8% |
| | Basement | 9,481 | 584 | 1,847 | 8.2% |
| | Crawl** | 8,420 | 575 | 1,700 | 6.9% |
| | | | | | |
| 2021 + Duct option | Slab | 7,495 | 581 | 1,585 | 12.3% |
| | Crawl** | 7,732 | 607 | 1,644 | 10.0% |
| *Cost savings ($/yr) relative to 2018 baseline | | | | | |
| **Crawl: vented CZ 3-4; conditioned CZ 5-7 | | | | | |

| Configuration | | Annual Energy Use CZ 5 Chicago Frame Wall Natural Gas (60%) kWh/yr | thrm/yr | $/yr | Savings* |
|---|---|---|---|---|---|
| **2018 Baseline** | Slab | 7635 | 1098 | 2156 | |
| | Basement | 9,297 | 1,089 | 2,355 | |
| | Crawl** | 7,720 | 999 | 2,054 | |
| | | | | | |
| 2018 + 2021 ceiling insulation | Slab | 7,691 | 1,090 | 2,146 | 0.5% |
| | Basement | 9,285 | 1,080 | 2,343 | 0.5% |
| | Crawl** | 7,702 | 991 | 2,043 | 0.5% |
| | | | | | |
| 2018 + 2021 slab insulation | Slab | 7,647 | 1,071 | 2,120 | 1.7% |
| | Ave for CZ | | | | |
| | | | | | |
| 2018 + 2021 wall cont. insulation | Slab | 7,617 | 1,049 | 2,093 | 2.9% |
| | Basement | 9,209 | 1,040 | 2,291 | 2.7% |
| | Crawl** | 7,635 | 952 | 1,993 | 3.0% |
| | | | | | |
| 2018 + 2021 window U-Factor | Slab | | | | |
| | Basement | | | | |
| | Crawl** | | | | |
| | | | | | |
| **2021 without efficiency options** | Slab | 7,142 | 1,018 | 1,999 | 7.3% |
| | Basement | 8,614 | 1,037 | 2,210 | 6.2% |
| | Crawl** | 7,216 | 947 | 1,934 | 5.8% |
| | | | | | |
| 2021 + HVAC option | Slab | 6,770 | 898 | 1,824 | 15.4% |
| | Basement | 8,209 | 914 | 2,029 | 13.8% |
| | Crawl** | 6,838 | 837 | 1,769 | 13.9% |
| | | | | | |
| 2021 + Water Heater option | Slab | 7,169 | 1,002 | 1,977 | 8.3% |
| | Basement | 8,655 | 1,007 | 2,175 | 7.6% |
| | Crawl** | 7,245 | 929 | 1,910 | 7.0% |
| | | | | | |
| 2021 + Ventilation option | Slab | 7,400 | 966 | 1,978 | 8.3% |
| | Basement | 8,927 | 960 | 2,170 | 7.9% |
| | Crawl** | 7,482 | 901 | 1,921 | 6.5% |
| | | | | | |
| 2021 + Duct option | Slab | 7,022 | 929 | 1,889 | 12.4% |
| | Crawl** | | | | |
| *Cost savings ($/yr) relative to 2018 baseline | | | | | |
| **Crawl: vented CZ 3-4; conditioned CZ 5-7 | | | | | |

| Configuration | | Annual Energy Use CZ 6 Helena Frame Wall Natural Gas kWh/yr | thrm/yr | $/yr | Savings* | Annual Energy Use CZ 7 Duluth*** Frame Wall Natural Gas kWh/yr | thrm/yr | $/yr | Savings* |
|---|---|---|---|---|---|---|---|---|---|
| **2018 Baseline** | Slab | 7,374 | 1,201 | 2,221 | | 7,178 | 1,676 | 2,735 | |
| | Basement | 8,962 | 1,166 | 2,391 | | 8,664 | 1,612 | 2,873 | |
| | Crawl** | 7,345 | 1,057 | 2,066 | | 7,119 | 1,473 | 2,515 | |
| | | | | | | | | | |
| 2018 + 2021 ceiling insulation | Slab | 7,359 | 1,192 | 2,210 | 0.5% | 7,116 | 1,665 | 2,722 | 0.5% |
| | Basement | 8,945 | 1,155 | 2,378 | 0.5% | 8,649 | 1,599 | 2,857 | 0.6% |
| | Crawl** | 7,333 | 1,047 | 2,054 | 0.6% | 7,105 | 1,460 | 2,499 | 0.6% |
| | | | | | | | | | |
| 2018 + 2021 slab insulation | Slab | | | | | | | | |
| | Ave for CZ | | | | | | | | |
| | | | | | | | | | |
| 2018 + 2021 wall cont. insulation | Slab | | | | | | | | |
| | Basement | | | | | | | | |
| | Crawl** | | | | | | | | |
| | | | | | | CZ 7 2021 no HRV, for reference: | | | |
| 2018 + 2021 window U-Factor | Slab | | | | | 7,087 | 1,671 | 2,678 | 2.1% |
| | Basement | | | | | 8,479 | 1,607 | 2,791 | 2.9% |
| | Crawl** | | | | | 7,028 | 1,466 | 2,454 | 2.4% |
| | | | | | | | | | |
| **2021 without efficiency options** | Slab | 6,970 | 1,198 | 2,165 | 2.5% | 7,321 | 1,605 | 2,639 | 3.5% |
| | Basement | 8,379 | 1,162 | 2,311 | 3.3% | 8,787 | 1,523 | 2,743 | 4.5% |
| | Crawl** | 6,937 | 1,052 | 2,008 | 2.8% | 7,283 | 1,419 | 2,438 | 3.1% |
| | | | | | | | | | |
| 2021 + HVAC option | Slab | 6,586 | 1,054 | 1,964 | 11.6% | 6,879 | 1,403 | 2,369 | 13.4% |
| | Basement | 7,984 | 1,024 | 2,115 | 11.5% | 8,344 | 1,333 | 2,486 | 13.5% |
| | Crawl** | 6,583 | 930 | 1,833 | 11.3% | 6,870 | 1,244 | 2,201 | 12.5% |
| | | | | | | | | | |
| 2021 + Water Heater option | Slab | 7,037 | 1,188 | 2,155 | 3.0% | 7,400 | 1,600 | 2,635 | 3.7% |
| | Basement | 8,441 | 1,135 | 2,282 | 4.6% | 8,854 | 1,499 | 2,718 | 5.4% |
| | Crawl** | 7,005 | 1,038 | 1,993 | 3.5% | 7,353 | 1,409 | 2,429 | 3.4% |
| | | | | | | CZ 7 2021 HRV .75 SRE v. .65: | | | |
| 2021 + Ventilation option | Slab | 7,198 | 1,126 | 2,120 | 4.5% | 7,307 | 1,588 | 2,619 | 4.2% |
| | Basement | 8,672 | 1,068 | 2,250 | 5.9% | 8,772 | 1,502 | 2,719 | 5.4% |
| | Crawl** | 7,189 | 995 | 1,980 | 4.2% | 7,271 | 1,403 | 2,420 | 3.8% |
| | | | | | | | | | |
| 2021 + Duct option | Slab | 6,832 | 1,043 | 1,985 | 10.6% | 7,210 | 1,409 | 2,418 | 11.6% |
| | Crawl** | | | | | | | | |
| *Cost savings ($/yr) relative to 2018 baseline | | | | | | | | | |
| **Crawl: vented CZ 3-4; conditioned CZ 5-7 | | | | | | | | | |
| ***For CZ 7 all 2021 results include an HRV | | | | | | | | | |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