Cost Effectiveness of the Residential Provisions of the 2021 IECC

January 2022

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Background

The International Code Council (ICC) updates their model building codes on a 3-year cycle. The latest version of their International Energy Conservation Code (IECC) is the 2021 IECC[1] and contains multiple updates, or code changes, to the 2018 IECC as a result of a public process administered by the ICC.[2]

The code changes from the 2018 to the 2021 IECC result in both increased energy savings and construction costs, and this analysis quantifies the resulting cost-effectiveness.

Following U.S. Department of Energy cost effectiveness certification of the 2021 IECC, the National Association of Homebuilders (NAHB) commissioned the Home Innovation Research Labs (HIRL) to conduct an independent cost analysis of the 2021 IECC. The report, *2021 IECC Residential Cost Effectiveness Analysis*[3] (HIRL report), was published in June 2021, and asserted that the 2021 IECC imposed builder compliance costs of nearly $12,000 and homeowner payback periods of up to 79 years, depending on climate zone. This analysis is intended to "check the math" of the NAHB report using current cost data and widely accepted cost effectiveness metrics. To enable an easy comparison this report mirrors the HIRL Report structure, section by section and table by table, and is accompanied by a short comparison document titled Comparison of 2021 IECC Residential Cost Effectiveness Analyses, which also identifies concerns and issues identified in the HIRL report that were addressed.

Methodology

This analysis relies on existing data and new research. The primary source is the HIRL report mentioned above.

The energy savings for this analysis were sourced directly from the HIRL report and are documented in Appendix E. Below is how the HIRL report describes how energy savings were developed.

> "The analysis for this study is based on a methodology[4] 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.[5]
>
> For analysis in this report, annual energy use costs were developed using BEopt[6] 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency.[7] The energy prices are national average annual 2019 residential prices: $0.1301/kWh for electricity; $1.051/therm for natural gas."

The incremental costs of the code changes reported in the HIRL report were evaluated and updated. Material costs were generally updated to use publicly available sources from retailers and distributors, with sources shown in Appendix A. The majority of labor costs from the HIRL report were used and were developed using labor rates from RS Means.[8] Some code changes that contained a cost in the HIRL report were determined to result in no incremental cost after a review of the code change.

Cost-effectiveness was evaluated using the U.S. Department of Energy's *Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes* (DOE Methodology),[9] which is used when DOE conducts a determination analysis to evaluate whether the new edition of the IECC saves energy compared to its immediate predecessor. The HIRL report only considered simple payback, which is included in the DOE

1 https://codes.iccsafe.org/content/IECC2021P1
2 https://www.iccsafe.org/products-and-services/i-codes/code-development/
3 https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf
4 Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012.
5 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012.
6 BEopt (Building Energy Optimization Tool) software: https://beopt.nrel.gov/home
7 Energy Information Agency: https://www.eia.gov/
8 https://www.rsmeans.com/
9 https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

methodology along with Life-cycle cost, which was added for this analysis. A description of the two metrics used in this analysis are shown below, as described by the DOE methodology:

- Life-Cycle Cost (LCC) is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified time period. Any code change resulting in a net LCC less than or equal to zero (i.e., monetary benefits exceed costs) will be considered cost effective. LCC is the primary metric DOE uses to evaluate cost-effectiveness.
- Simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in fuel prices, tax effects, measure replacements, resale values, etc.

All costs and savings in this analysis are based on the model 2018 and 2021 IECC codes. When adopting codes many states and local jurisdictions implement amendments, often decreasing the stringency of codes. And as of January 2022, only 9 states (including Washington D.C.) have adopted a code equally stringent to the 2018 IECC.[10] Therefore for the remaining 42 states would realize greater energy savings, and likely be more cost-effective, than what is estimated in this analysis.

Standard Reference House

The building geometry in Table 1 utilized in this analysis is specified in the HIRL report and was originally for a representative single-family detached home using Home Innovation's 2009 Annual Builder Practices Survey (ABPS). The parameters are average values from the ABPS for non-IECC-mandated building areas and features. Based on Home Innovation's 2019 ABPS, the geometry was revised. The floor, attic, wall, and window areas used in the Standard Reference House for this study are shown in Table 1.

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
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

[10] Source: https://www.energycodes.gov/status/residential

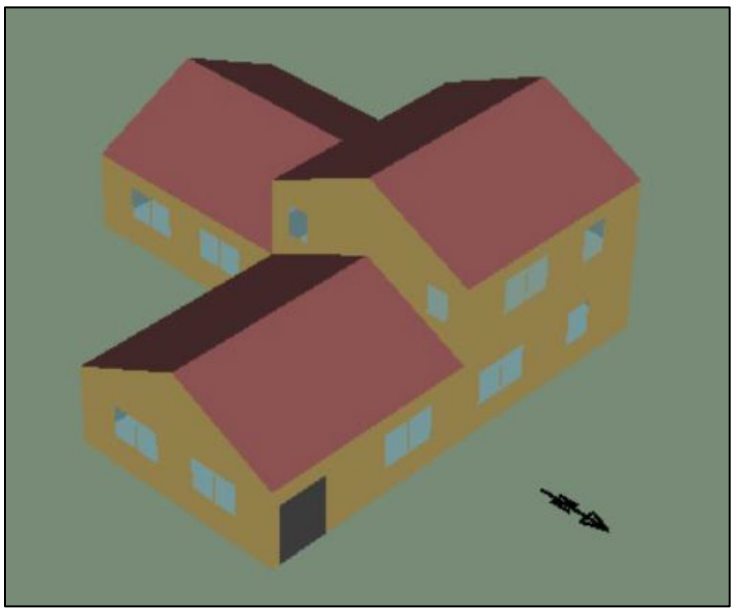


Figure 1 Simulation Model of Standard Reference House

Representative Locations

Energy savings were quantified using six representative locations in climate zones (CZs) 2 through 7, as shown in Table 2.

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*						

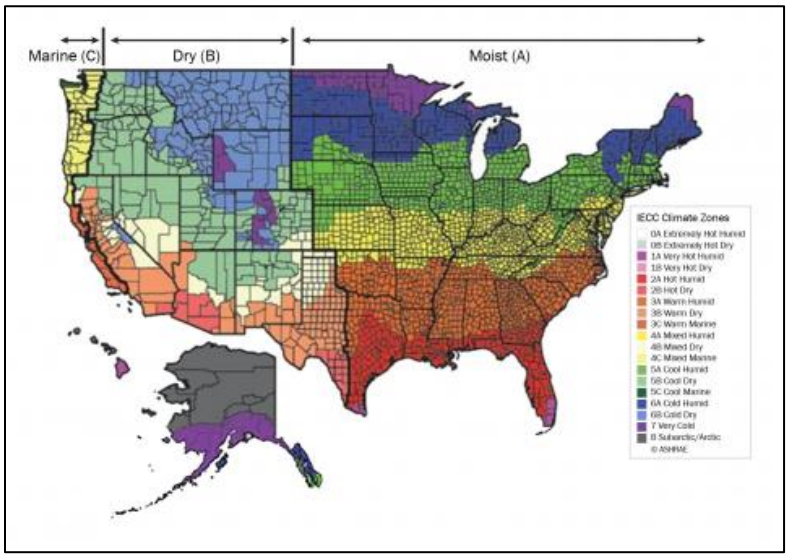


Figure 2 DOE Climate Zone Map

Configurations and Weighted Averaging

Results in this analysis (e.g., costs, savings, economic metrics) have been weighted by wall type, foundation type, for each climate zone, and by each location to result in a national weighted average. The data in Table 3 was used for these weightings and is based on the 2019 ABPS.

Only one heating fuel was used for each location based on the predominant fuel in the climate, and the heating and domestic hot water equipment use the same fuel.

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

Climate Zone	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Primary Heating Fuel	Electric	Electric	Gas	Gas	Gas	Gas
Mass Wall	30%	10%	n/a	n/a	n/a	n/a
Frame Wall	70%	90%	100%	100%	100%	100%
Slab	100%	75%	20%	15%	5%	30%
Cond. Basement	n/a	10%	60%	70%	90%	5%
Vented Crawlspace	n/a	15%	20%	n/a	n/a	n/a
Cond. Crawlspace	n/a	n/a	n/a	15%	5%	65%
Housing Starts	28%	28%	21%	17%	5%	1%

HVAC and Water Heating Equipment

The refence house is configured with equipment meeting the current DOE energy-efficiency standards as shown in Table 4. When an 'additional efficiency package option' from the 2021 IECC would require more efficient equipment the equipment in Table 5 was used.

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 heat pump
	Heat pump water heater, 50 gal, 2.0 EF

Changes for 2021

The 2021 IECC contains changes relative to the 2018 IECC that will result in increased energy savings, and increased construction costs. Appendix A contains a complete list of code changes that were evaluated for this analysis, but the most significant changes include:

- Improved envelope requirements (See Appendix D)
    - Increased ceiling insulation in climate zones 2 through 8
    - Continuous insulation on above-grade walls in climate zones 4 and 5
    - Slab insulation in climate zones 3 through 5
    - Lower window U-factor in climate zones 3 and 4
- Higher efficacy lighting
- Increased fan efficacy, and testing requirements
- Balanced ventilation (ERV/HRV) in climate zones 7 and 8
- One of five 'additional efficiency package options' (See RE209 in Appendix A for details):
    - Enhanced envelope performance option[11]
    - More efficient HVAC equipment performance option
    - Reduced energy use in service water-heating option
    - More efficient duct thermal distribution system
    - Improved air sealing and efficient ventilation option

Some homes meet the requirements of the additional efficiency package options due to construction practices (i.e., ducts located in conditioned space for homes with basements and conditioned crawlspaces), or code requirements (i.e., ERV/HRV required in climate zones 7 and 8). For these homes, no changes are needed to meet this requirement, but for others a change will need to be made and it will result in additional costs and savings.

All code changes that were reflected in the energy models are noted in Table 6.

Results

Construction Costs

The incremental construction costs considered in this analysis are shown in Table 6, with details in Appendix A and B. The weighted average incremental construction cost is shown in Table 7.

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

Proposal	Description	Affected CZs	Reference House
RE7*	Lighting: revised definition of high-efficacy	All	$0
RE18/20/21	Certificate: additional info	All	$0
RE29*	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742
	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680
RE32*	Slab edge: NR to R10/2 (CZ3)	3	$709
	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709
RE33*	Ceiling insulation R38 to R49	2-3	$226
RE36*	Ceiling insulation R49 to R60	4-7	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	$0

[11] The enhanced envelope option was not evaluated for this study.

RE35*	Windows: reduces U-value from 0.32 to 0.30	3-4	$67
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	$6
RE72	Air seal narrow framing cavities	All	$0
RE82	Air seal rim (basement; unvented crawlspace)	All	$0
	Air seal rim (slab, vented crawlspace)	All	$0
RE96	House tightness, allows trade-off for performance path	All	$0
RE103	Air seal electrical & communication outlet boxes	All	$0
RE106	Thermostat: requires 7-day programming	All	$0
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31
RE133*	Updates ventilation fan efficacy (affects bath EF)	All	$0
RE139*	Requires ERV/HRV in CZ 7-8 (includes RE134 reqs.)	7	$1,742
RE145*	Lighting: 100% high-efficacy; controls (slab)	All	$33
	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$41
RE148	Lighting, commercial	All	$0
RE151	Performance path backstop: 2009 IECC	All	$0
RE178	Performance path ventilation type to match proposed	All	$0
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	$0
RE209*	Additional efficiency package options:	All	
	HVAC, gas house, 95 AFUE/16 SEER for 13 SEER baseline	5-7	$1,142
	HVAC, gas house, 95 AFUE/16 SEER for 14 SEER baseline	4	$952
	HVAC, electric house, 10 HSPF/18 SEER heat pump	All	$2,566
	Water Heater, gas house, tankless direct-vent, 0.82 UEF	All	$549
	Heat Pump Water Heater, electric house, 50 gal, 2.0 EF	2-3	$1,178
	Ventilation, gas house	4-7	$1,707
	Ventilation, electric house	3-5	$1,707
	Ventilation, electric house with improved air tightness	2	$2,057
	Duct, slab house, buried ducts in attic	2-3	$2,374
	Duct, slab house, buried ducts in attic	4-7	$658
	Duct, vented crawlspace house	3	($809)
	Duct, vented crawlspace house	4	($36)

***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

Total Incremental Cost	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Without additional efficiency package options	$1,373	$297	$902	$2,254	$3,102	$321	$2,050
With HVAC option	$3,273	$2,864	$3,469	$3,206	$4,245	$1,464	$3,192
With Water Heater option	$2,274	$1,475	$2,080	$2,803	$3,651	$870	$2,599
With Ventilation option	$3,161	$2,354	$2,609	$3,961	$4,809	$2,028	$2,050
With Duct option, slab house	$3,243	$2,672	$3,447	$3,444	$4,315	$926	$2,669
With Duct option, vented crawlspace house	n/a	n/a	-$437	$2,049	n/a	n/a	n/a

Table 8 contains code changes that were not included in this analysis either because they are unlikely to impact many homes or would result in some energy savings but their impacts were not modeled.

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	($87)
	Same	4	($113)
RE49	Baffles at tray ceiling (example)	2-3	$125
	Same	4-7	$157
RE52	Walls: removes exception for reduced c.i. at WSP	3-7	$1,283 to $2,692
RE55	Adds requirements for unconditioned basements	4-5	$97
RE109	Floor insulation for ducts in conditioned space: min R19	2	$34
RE134	Adds min efficacy for air handlers if integrated w/ventilation	All	$1,115
RE149	Lighting: exterior controls	All	$22

Energy Use Costs and Savings

Modeled energy costs are shown in Table 9, and savings in Table 10, both as weighted averages. Complete energy use data for all homes modeled is in Appendix E.

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

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,129	$2,224	$2,028	$1,934	$2,279	$2,367	$2,599
slab houses only	$2,074	$2,224	$2,025	$1,807	$2,156	$2,222	$2,735
vented houses only			$1,960	$1,827			
2021 without additional efficiency package options	$2,015	$2,163	$1,890	$1,798	$2,137	$2,289	$2,514
2021 with HVAC option	$1,881	$2,045	$1,769	$1,680	$1,959	$2,093	$2,266
2021 with Water Heater option	$1,922	$2,029	$1,742	$1,761	$2,106	$2,261	$2,505
2021 with Ventilation option	$1,993	$2,144	$1,876	$1,778	$2,104	$2,231	$2,495
2021 with Duct option, slab house	$1,852	$2,047	$1,790	$1,586	$1,890	$1,985	$2,419
2021 with Duct option, vented crawlspace house			$1,845	$1,644			

Table 10 Energy Cost Savings relative to 2018 Baseline Reference House

	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	5.3%	2.8%	6.8%	7.1%	6.2%	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%	8.7%	14.1%	8.9%	7.6%	4.5%	3.6%
2021 with Ventilation option	6.4%	3.6%	7.5%	8.1%	7.7%	5.7%	n/a
2021 with Duct option, slab house	10.7%	8.0%	11.6%	12.3%	12.3%	10.6%	11.6%
2021 with Duct option, vented crawlspace house			5.8%	10.0%			

Cost Effectiveness

Cost effectiveness is calculated based on the data in Table 7 and Table 9 using the metrics described previously.

Table 11a summarizes the simple payback relative to the 2018 IECC, these results are informative, but Table 11b summarizes the weighted LCC cost for the various configurations of 2021 IECC compared to the 2018 IECC, which is more indicative of the cost-effectiveness of the 2021 IECC.

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

	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	11	5	6	16	22	4	25
2021 with HVAC option	14	16	13	13	13	5	10
2021 with Water Heater option	12	8	7	16	21	8	28
2021 with Ventilation option	24	29	18	26	28	15	20
2021 with Duct option, slab house	15	15	15	16	16	4	8
2021 with Duct option, vented crawlspace house			0	11			

In Table 11b, and for other LCC results, a negative LCC indicates a net savings, and a cost-effective code change. The packages which have a negative LCC have cells with blue text and show that in each location analyzed there are multiple cost-effective options with the structure of the 2021 IECC. Additionally, the cost-effectiveness of the 2021 IECC in practice is likely to be better for two reasons. First, as described in Appendix A, cost estimates are conservative because publicly available sources were used, and a builder is likely to purchase many products at a lower price due to their bulk purchasing power. And second, this analysis uses the Prescriptive Compliance Option (R401 through R404), and builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406) which have more flexibility in the measures a builder can use in their homes. The results show that construction based on the 2021 IECC is cost effective when compared to the 2018 IECC across all climate zones.

Table 11b LCC* relative to 2018 Baseline Reference House ($ / house)

	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	(1,625.67)	(1,350.06)	(2,783.91)	(1,318.71)	(690.87)	(1,757.92)	1,411.09
2021 with HVAC option	(1,932.88)	(180.50)	(1,710.75)	(2,728.63)	(3,300.21)	(4,796.20)	(2,947.04)
2021 with Water Heater option	(2,590.72)	(2,963.03)	(4,790.45)	(1,295.80)	(550.40)	(1,507.53)	2,131.96
2021 with Ventilation option	1,102.13	1,892.34	(49.29)	1,388.91	1,679.62	(9.37)	933.64
2021 with Duct option, slab house	(2,670.47)	(2,199.57)	(2,958.79)	(2,324.45)	(2,612.12)	(5,121.73)	(3,784.46)
2021 with Duct option, vented crawlspace house	n/a	n/a	(3,688.02)	(2,759.88)	n/a	n/a	n/a

*Negative LCC indicates net savings

The HIRL report included an example of a comparison of savings for a gas and electric home in climate zone 3 in "Table 12. Example Comparison of Gas vs. Electric Energy Cost Savings relative to 2018 baseline." However, the report did not publish the energy use data for individual gas homes in climate zone 3, so that comparison and the relative cost-effectiveness could not be evaluated in this analysis.

Cost Effectiveness of Selected Code Changes

Individual code changes were evaluated to show their costs, savings, and cost-effectiveness against the 2018 IECC baseline. For thermal envelope changes, Table 13 shows the incremental costs, Table 14 shows the associated modeled energy cost, and Table 15 shows the energy savings.

Table 13 Incremental Construction Cost of Thermal Envelope Changes

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Ceiling insulation	$233	$233	$204	$204	$204	$204
Slab insulation	n/a	$709	$709	$709	n/a	n/a
Wall continuous insulation	n/a	n/a	$1,742	$2,680	n/a	n/a
Window U-factor	n/a	$67	$67	n/a	n/a	n/a

Table 14 Annual Energy Use Cost of Thermal Envelope Changes

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,224	$2,028	$1,934	$2,279	$2,367	$2,599
2018 baseline, slab houses only		$2,025	$1,807	$2,156		
2018 + 2021 ceiling insulation	$2,216	$2,017	$1,925	$2,269	$2,353	$2,584
2018 + 2021 slab insulation, slab houses only	n/a	$1,936	$1,773	$2,120	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	$1,886	$2,217	n/a	n/a
2018 + 2021 window U-factor	n/a	$2,021	$1,924	n/a	n/a	n/a

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

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	0.3%	0.6%	0.5%	0.5%	0.6%	0.6%
2018 + 2021 slab insulation, slab houses only	n/a	4.5%	1.9%	1.6%	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	2.5%	2.7%	n/a	n/a
2018 + 2021 window U-factor	n/a	0.4%	0.5%	n/a	n/a	n/a

Using the data above, the cost-effectiveness of the thermal envelope changes was evaluated with results in Table 16. Additionally, Table 17 contains data on the cost effectiveness of an HRV in climate zone 7. The data shows that some measures are cost-effective and some are not for the homes modeled. There are several key takeaways from these results.

- Individual code changes to the 2018 IECC may not be cost-effective by themselves, but the overall result for the 2021 IECC is that it is cost-effective (as shown in Table). These results will vary for each individual home with unique cost and savings resulting from different assembly areas.
- As mentioned before, costs may be less if a home complies using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406). With the information below a builder may choose to invest in more in measures that are cost-effective and less in those that are not without impacting the overall performance of the home.

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

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	31	20	22	19	15	14
2018 + 2021 slab insulation, slab houses only	n/a	8	20	20	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	36	43	n/a	n/a
2018 + 2021 window U-factor	n/a	9	6	n/a	n/a	n/a

Table 17 Cost effectiveness of HRV in CZ 7

	CZ 7 Duluth
Incremental cost of HRV	$1,742
Annual energy cost, 2021* without HRV	$2,539
Annual energy cost, 2021* with HRV	$2,514
Energy cost savings for HRV	1.0%
Simple payback years	12
*Without additional efficiency package options	

The 2021 IECC requires one of five 'additional efficiency package options' (See RE209 in Appendix A for details). The cost-effectiveness of these were evaluated based on data in Table 18 and Table 19, with results in Table 20, and Table 21.

Table 18 Incremental Construction Cost of Additional Efficiency Package Options

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	$1,900	$2,567	$2,567	$952	$1,143	$1,143
Water Heater option	$901	$1,178	$1,178	$549	$549	$549
Ventilation option	$1,788	$2,057	$1,707	$1,707	$1,707	$1,707
Duct option, slab house	$1,870	$2,374	$2,545	$1,190	$1,213	$605
Duct option, vented crawlspace house			($1,339)	($205)		

Table 19 Annual Energy Use Cost of Additional Efficiency Package Options

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options, all houses	$2,163	$1,890	$1,798	$2,137	$2,289	$2,514
slab houses only	$2,163	$1,867	$1,656	$1,999	$2,166	$2,639
vented houses only	n/a	$1,890	$1,711	n/a	n/a	n/a
2021 with HVAC option	$2,045	$1,769	$1,680	$1,959	$2,093	$2,266
2021 with Water Heater option	$2,029	$1,742	$1,761	$2,106	$2,261	$2,505
2021 with Ventilation option	$2,144	$1,876	$1,778	$2,104	$2,231	$2,495
2021 with Duct option, slab house	$2,047	$1,790	$1,586	$1,890	$1,985	$2,419
2021 with Duct option, vented crawlspace	n/a	$1,845	$1,644	n/a	n/a	n/a

Table 20 shows the savings of the additional efficiency package options relative to the base 2021 code. The packages were designed to achieve roughly 5% additional savings, and in this analysis the savings ranged from 0.4% to 9.9%, with an average of 4.4%.

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

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	5.4%	6.4%	6.5%	8.3%	8.5%	9.9%
Water Heater option	6.2%	7.8%	2.0%	1.5%	1.2%	0.4%
Ventilation option	0.9%	0.7%	1.1%	1.6%	2.5%	0.8%
Duct option, slab house	5.4%	4.1%	4.3%	5.5%	8.4%	8.4%
Duct option, vented crawlspace house	n/a	2.4%	3.9%	n/a	n/a	n/a

Table 21 shows the cost-effectiveness of each additional efficiency package option relative to the base 2021 IECC. This data by itself does not provide meaningful conclusion because it uses the 2021 1ECC as a baseline, and the efficiency package options along with all the other code changes collectively achieve savings beyond the 2018 IECC. However, it can be used to infer the relative cost-effectiveness of each of these options. Table 11 can be used to make the same comparison, and as mentioned previously builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406).

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

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	21.8	21.3	8.1	6.4	5.8	4.6
Water Heater option	8.8	8.0	15.3	17.9	21.2	75.3
Ventilation option	109.7	134.9	109.8	60.5	30.3	0.0
Duct option, slab house	20.5	30.7	9.3	6.0	3.6	3.0
Duct option, vented crawlspace house	n/a	0.0	0.0	n/a	n/a	n/a

Conclusions

The HIRL report was analyzed and updated with new costs for code changes based on publicly available sources, and cost-effectiveness was re-examined using metrics from the DOE Methodology that is used to evaluate the cost-effectiveness of code changes (i.e., Life-Cycle Cost). Key findings from this analysis are:

- The 2021 IECC is cost effective when compared to the 2018 IECC across all climate zones, and there are multiple cost-effective compliance options in each climate zone.
- The cost-effectiveness of the 2021 IECC in practice is likely to be better for two reasons. First, as described in Appendix A, cost estimates are conservative because publicly available sources were used, and a builder is likely to purchase many products at a lower price due to their bulk purchasing power. And second, this analysis uses the Prescriptive Compliance Option (R401 through R404), and builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406).
- There are significant savings relative to the 2018 IECC, ranging from a national average of 6.4% to 11.6%, depending on which additional efficiency package option is assumed.
- The weighted national average incremental cost of the code changes ranges from $2,695 to $3,694 depending on which additional efficiency package option is assumed.
- Individual code changes to the 2018 IECC have varying ranges of simple payback, but overall, the 2021 IECC is cost-effective as a package of measures that work together to achieve significant cost-effective savings (as shown in Table 11b). These results will vary for each individual home with unique cost and savings resulting from different assembly areas.
- As mentioned before, costs may be less if a home complies using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406). With the information below a builder may choose to invest in more in measures that are cost-effective and less in those that are not without impacting the overall performance of the home.

APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

Code changes are summarized below along with their estimated incremental costs. This analysis evaluated and updated the incremental costs of the code changes reported in the HIRL report. Material costs were generally updated to use publicly available sources from retailers and distributors in November 2021, with sources shown in footnotes. When the same product was available from multiple retailers, the least cost option was used as a source because a builder has higher purchasing power and like likely to purchase many products at a lower price due to their bulk purchasing power. Even with this approach the material costs used in this report are likely to be higher than what a builder would pay, therefore producing conservative results. Unless noted, the majority of labor costs from the HIRL report were used and were sourced from hour estimates and labor rates from RS Means.[12] Some code changes that the HIRL report contained a cost were determined to result in no incremental cost after a review of the code change, and those are noted as well.

The total cost to the builder has a 17.5% markup applied to reflect the builder's gross profit margin and therefore the cost to the consumer. Many aspects of homebuilding are subcontracted out, so individual costs for labor, materials have markups applied by the subcontractor with a markup of 10% on material and equipment and 17.5% on labor, the columns marked "w/O&P" include these markups. To reflect that the majority, but not all, aspects of homebuilding are subcontracted out a factor of 79.3% is applied to these subcontractor markups to reflect the average share of construction costs that are subcontracted dating back to 2012.[13] The 10% markup is based on RS Means assumptions,[14] and the 17.5% markup is based on an average gross profit margin for homebuilders over multiple years, with a low of 14.4% in 2008, a high of 20.8% in 2006, and with 18.3% as the most recent value from 2020.[15, 16]

RE7

Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

Summary of Code Change:

This code change revises the definition of high-efficacy lighting to reflect current lighting market conditions more accurately. Previously the definition used the following for efficacy requirements:

1. 60 lumens per watt for lamps over 40 watts.
2. 50 lumens per watt for lamps over 15 watts to 40 watts.
3. 40 lumens per watt for lamps 15 watts or less.

Now the definition uses 65 lumens per watt, or 45 lumens per watt for luminaires.

Cost Implication of the Code Change

This code change does not impact the cost of construction because CFL and LED lighting that was being used to meet the definition of 'High-Efficacy' already exceeded the new requirements. Therefore, no cost impact is assumed for the reference home.

12 https://www.rsmeans.com/
13 Source: https://www.nahb.org/-/media/NAHB/news-and-economics/docs/housing-economics-plus/special-studies/2020/special-study-average-new-home-uses-24-different-subcontractors.pdf
14 Source: https://www.rsmeans.com/resources/articles/what-is-construction-estimating
15 Source: https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/
16 Source: https://www.coconstruct.com/blog/despite-turbulent-2020-home-builder-profit-margins-grew-8-5-yoy

RE18, RE20, RE21

Reference Code Section

R401.3 Certificate

Summary of Code Change:

This code change requires additional information on the certificate for the home. RE18 requires information for onsite renewable systems (e.g., capacity). RE20 requires additional information on the certificate about the builder, code edition, and compliance path. RE21 requires additional information about insulation and ERI scores.

Cost Implication of the Code Change

The code change proposal will not increase or decrease the cost of construction. The administrative change of reporting additional, readily-available, information on a certificate that is already produced takes no additional time for a builder or rater. Therefore, no cost impact is assumed for the reference home.

RE29

Reference Code Section

Table R402.1.2; Table R402.1.3

Summary of Code Change:

This code change increases insulation required in above-grade walls in climate zones 4 and 5 to match existing requirements in climate zone 6.

Cost Implication of the Code Change

This code change will increase the cost of construction for all homes in climate zones 4 and 5. For 2x4 walls the cost is based on an increase from R-13+5 to R-13+10, and for 2x6 walls the cost is based on an increase from R-20 to R-20+5. A weighted average of these two costs is used in the analysis based on data collected by the U.S. DOE's Residential Energy Code Field Studies for homes built in climate zones 4 and 5.

Cost to add information to the certificate, Climate zone 4

Component	Unit	Cost, from below	Weight[17]	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	$1,112.07	73%	$810.20
2x6 wall, increase c.i. from R0 to R5	$/house	$3,433.00	27%	$931.90
Total to Consumer				$1,742.10

Cost to add information to the certificate, Climate zone 5

Component	Unit	Cost, from below	Weight[17]	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	$1,112.07	32%	$360.58
2x6 wall, increase c.i. from R0 to R5	$/house	$3,433.00	68%	$2,319.88
Total to Consumer				$2,680.46

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[18]	SF	$0.70	$0.45	$1.15	$1.27	(2,300)	($2,921.81)
XPS, 15 psi, 2", R10 [19]	SF	$1.04	$0.49	$1.53	$1.68	2,300	$3,868.29
Total to Builder							$946.48
Total to Consumer							$1,112.07

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[18]	SF	$0.70	$0.45	$1.15	$1.27	2,300	$2,921.81
Total to Builder							$2,921.81
Total to Consumer							$3,433.00

17 Source: https://www.energycodes.gov/residential-energy-code-field-studies
18 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-5-polystyrene-foam-board-insulation-1-x-4-x-8/565243/p-1444450471646-c-5779.htm?tid=4167155398492965668&ipos=2
19 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-10-polystyrene-foam-board-insulation-2-x-4-x-8/654957/p-1444450471143-c-5779.htm?tid=-9057347254943865747&ipos=6

RE32

Reference Code Section

Table R402.1.3

Summary of Code Change:

This code change increases slab insulation in climate zones 3, 4 and 5 specified by Table R402.1.3. Climate zone 2 is increased from no insulation to R-10, for a depth of 2 ft. Climate zones 4 and 5 are increased from R-10 for a depth of 2 ft, to R-10 for a depth of 4 ft.

Cost Implication of the Code Change

This code change will increase the cost of construction by requiring more slab insulation to be installed in climate zones 3, 4, and 5. All climate zones will require an additional 400 sq. ft. of R-10 extruded polystyrene (XPS) slab insulation because the slab perimeter is 200 sq. ft. and the additional slab edge depth is an additional 2 ft.

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[20]	SF	$0.98	$0.40	$1.38	$1.51	400	$603.28
Total to Builder							$603.28
Total to Consumer							$708.83

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[20]	$603.28	$0.98	$0.40	$1.38	$1.51	400	$654.65
Total to Builder							$603.28
Total to Consumer							$708.83

20 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-10-polystyrene-foam-board-insulation-2-x-4-x-8/271000/p-1444450496132.htm

RE33, RE36

Reference Code Section

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

Summary of Code Change:

This code change increases the ceiling insulation in climate zones 2 through 8 by a net of R-11. Climate zones 2 and 3 are increased to R-49 from R-38 by RE33, and climate zones 4 through 8 are increased to R-60 from R-49 by RE36.

Cost Implication of the Code Change

This code change will increase the cost of construction in climate zones 2 through 8. The cost is based on the incremental cost of blown cellulose in a vented attic and is assumed to be the same for both code changes, including the same labor and equipment costs. A portion of the attic will not be impacted by this code change because the full-height of the insulation cannot be achieved (i.e., at the eave). So, when the nominal R-value required increase from R-38 to R-49, only the area of the attic where the full R-38 was achieved previously will have improved performance, and an associated cost. Therefore, the areas below were adjusted to reflect this.

Cost to Increase ceiling insulation from R-38 to R-49

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-38 attic insulation, blown cellulose[21]	SF	$0.37	$0.61	$0.36	$1.34	$1.49	(1414)	($2,103.26)
R-49 attic insulation, blown cellulose	SF	$0.50	$0.61	$0.36	$1.47	$1.62	1414	$2,295.94
Total to Builder								$192.68
Total to Consumer								$226.39

Cost to Increase ceiling insulation from R-49 to R-60

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-49 attic insulation, blown cellulose[21]	SF	$0.37	$0.61	$0.36	$1.34	$1.49	(1235)	($1,837.33)
R-60 attic insulation, blown cellulose	SF	$0.50	$0.61	$0.36	$1.47	$1.62	1235	$2,005.65
Total to Builder								$168.32
Total to Consumer								$197.76

21 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1

RE34

Reference Code Section

Table R402.1.3

Summary of Code Change:

This code change removed the exception for floor insulation R-value which allowed insulation sufficient to fill the cavity if it provided at least R-19. This exception only applied to climate zones 5 to 8.

Cost Implication of the Code Change

This code change can increase the cost of construction, by requiring more insulation, if the exception was being used. However, the reference house does not have floor insulation above unconditioned space. Therefore, no cost impact is assumed for the reference home.

RE35

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of Code Change:

This code change reduces the maximum U-factor for windows in CZ3 and 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 to 8 for buildings located at high elevations, or in regions with high wind.

Cost Implication of the Code Change

This code change will increase the cost of construction in CZ 3-4. EPA's ENERGY STAR program found that window prices vary widely, and thermal performance was not the primary driver of consumer prices, which makes it hard to develop a clear incremental cost for changes in window thermal performance. Several sources were consulted showing a wide range of estimated incremental costs for this code change. Four different window incremental cost model / methods were collected in this analysis to better understand it.

Various Sources for Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material
California Energy Commission[22]	SF	$0.15
ENERGY STAR Windows v7.0[23]	SF	$0.40
Department of Energy[24]	SF	$0.14
Energy Trust of Oregon[25]	SF	$0.58

The v6.0 ENERGY STAR window requirements, established in 2015, require a U-factor of 0.30 for the Noth-Central and South-Central climates, which generally align with climate zones 3 and 4.[26] Additionally, ENERGY STAR estimates the 2020 market penetration of windows at 84%.[27] Therefore for many builders there will be no incremental cost for the code change, but because that is not the case for all builders the lowest cost from the above sources will be used for this analysis.

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	$0.14	$0.00	$0.14	$0.15	375	$56.67
Total to Builder							$56.67
Total to Consumer							$66.58

22 Source: https://efiling.energy.ca.gov/GetDocument.aspx?tn=222199&DocumentContentId=27369
23 Source: https://www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%201_Criteria%20Analysis%20Report.pdf
24 Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf
25 https://www.energytrust.org/wp-content/uploads/2019/02/Energy-Trust-of-Oregon-Windows-2018-Market-Research-final.pdf
26 Source: https://www.energystar.gov/sites/default/files/Windows_Doors_and_Skylights_Program_Requirements%20v6.pdf
27 Source: https://www.energystar.gov/sites/default/files/asset/document/2020%20USD%20Summary%20Report_Lighting%20%20EVSE%20Update.pdf

RE37

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of Code Change:

This code change revised the climate zone 5 glazed fenestration SHGC to 0.40, where there previously was no requirement.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. Data provided by the ENERGY STAR program shows that many windows meeting the climate zone 5 U-factor requirement of 0.30, meet a SHGC of 0.40.[28] Additionally, if a home was complying with code through the Total Building Performance Option (Section R405), a 0.40 SHGC would have been used for modeling where there was no requirement. Therefore, no cost impact is assumed for the reference home.

28 Source: https://www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%201_Criteria%20Analysis%20Report.pdf

RE46

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change does not add any new requirements, instead it separates prescriptive and mandatory provisions into separate sections.

Cost Implication of the Code Change

There is no direct cost implication from this code change because it does not add any new requirements. However, the cost of the additional ceiling insulation required in all climate zones (RE33 and RE36) is reflected here where more insulation would be required on an attic access hatch. The cost is based on securing an additional 3" of EPS foam board to an 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-12[29]	SF	$0.40	$0.40	$0.80	$0.89	6	$5.34
Total to Builder							$5.34
Total to Consumer							$6.28

29 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/expanded-polystyrene-foam-board-insulation-4-x-8/1632105/p-1444435971090.htm

RE47

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change adds an exception attic pull-down stairs in CZ 0-4, which are not required to comply with the insulation level of the surrounding surfaces if the hatch meets:

- Average U-factor of 0.10 or R-value of R-13 or greater,
- 75% of panel area is insulated to R-13 or greater,
- Net area of the opening is less than 13.5 square feet, and
- The permitter is weather-stripped.

Cost Implication of the Code Change

This code change may decrease the cost of construction but is likely to have no impact on costs in most cases. No cost impact is assumed for the reference home, however, these costs are shown below for illustrative purposes.

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) [18]	SF	$0.70	$0.45	$1.15	$1.27	13.5	$17.15
XPS, 15 psi, 2", R10 (one 2" layer)[19]	SF	$1.04	$0.49	$1.53	$1.68	13.5	$22.71
XPS, 15 psi, 2", R10 (five 2" layers)[19]	SF	$1.04	$0.49	$1.53	$1.68	(67.5)	($113.53)
Total to Builder							($73.67)
Total to Consumer							($86.56)

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)[18]	SF	$0.70	$0.45	$1.15	$1.27	13.5	$17.15
XPS, 15 psi, 2", R10 (one 2" layer)[19]	SF	$1.04	$0.49	$1.53	$1.68	13.5	$22.71
XPS, 15 psi, 2", R10 (six 2" layers)[19]	SF	$1.04	$0.49	$1.53	$1.68	(81)	($136.23)
Total to Builder							($96.38)
Total to Consumer							($113.24)

RE49

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change adds a requirement to prevent loose-fill insulation in the attic from spilling from higher to lower sections with a baffle or retainer.

Cost Implication of the Code Change

This code change may increase the cost of construction where there is variation in the ceiling / attic height, but is likely to have no impact in most cases. Generally, this code change will not increase the cost of construction. illustrate this potential cost, the incremental cost of the insulation and the baffle is shown below. No cost is assumed for the reference home; however, these costs are shown below for illustrative purposes.

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[30]	SF	$1.25	$0.60	$1.85	$2.03	4	$8.13
Total to Builder							$8.13
Total to Consumer							$9.56

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[31]	SF	$0.74	$0.52	$1.26	$1.40	76	$106.04
Total to Builder							$106.04
Total to Consumer							$124.59

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[31]	SF	$0.74	$0.52	$1.26	$1.40	96	$133.95
Total to Builder							$133.95
Total to Consumer							$157.38

30 Source: https://www.menards.com/main/building-materials/panel-products/plywood-sheathing/3-4-x-4-x-8-plywood-sheathing/1231182/p-1444431334153-c-13331.htm?tid=5612448418558004 42&ipos=1

31 Source: https://www.menards.com/main/building-materials/panel-products/plywood-sheathing/1-2-x-4-x-8-plywood-sheathing-3-ply/1231085/p-1444431324783-c-13331.htm?tid=5612448418558004 42&ipos=6

RE52

Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

Summary of Code Change:

This code change deleted a section that allowed continuous insulation (c.i.) to be reduced to result in a consistent sheathing thickness. The exception was limited to 40% of the gross wall area and by no more than R-3.

Cost Implication of the Code Change

This code change may increase the cost of construction where the exception was used, but is likely to have no impact in most cases. Generally, this code change will not increase the cost of construction. To illustrate this potential cost, the incremental cost of additional c.i. is shown below. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to install additional ½-inch thickness of continuous insulation

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3[32]	SF	$0.37	$0.43	$0.80	$0.89	(1,070)	($956.68)
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	1,070	$1,359.28
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(1,065)	($2,038.92)
XPS, 15 psi, 1.5", R7.5[33]	SF	$1.03	$0.49	$1.52	$1.67	1,065	$2,680.45
Siding attachment, 2" roofing nail galv[34]	LB	$1.58		$1.58	$1.71	(17)	($29.02)
Siding attachment, 2.5" roofing nail galv[35]	LB	$3.39		$3.39	$3.66	21	$76.88
Total to Builder							$1,091.99
Total to Consumer							$1,283.04

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

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3[32]	SF	$0.37	$0.43	$0.80	$0.89	(1,070)	($956.68)
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	1,070	$1,359.28
OSB, wall, 1/2"[36]	SF	$0.60	$0.44	$1.04	$1.15	1,065	$1,840.91
Siding attachment, 2" roofing nail galv[34]	LB	$1.58		$1.58	$1.71	(17)	($29.02)
Siding attachment, 2.5" roofing nail galv[35]	LB	$3.39		$3.39	$3.66	21	$76.88
Total to Builder							$2,291.37
Total to Consumer							$2,692.26

32 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-3-polystyrene-foam-board-insulation-1-2-x-4-x-8/452873/p-1444450501960-c-5779.htm?tid=8495412447645832707&ipos=4

33 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-7-5-polystyrene-foam-board-insulation-1-1-2-x-4-x-8/654955/p-1444450473323-c-5779.htm?tid=8495412447645832707&ipos=7

34 Source: https://www.homedepot.com/p/Grip-Rite-11-x-2-in-Electro-Galvanized-Steel-Roofing-Nails-30-lb-Pack-2EGRFGBK/100114825?MERCH=REC-_-searchViewed-_-NA-_-100114825-_-N&

35 Source: https://www.fastenal.com/products/details/0228959

36 Source: https://www.menards.com/main/building-materials/panel-products/osb-sheathing/1-2-x-4-x-8-osb/1242809/p-1444422395209-c-13330.htm?tid=8336731822554623792&ipos=2

RE55

Reference Code Section

R402.2.8 Basement walls

Summary of Code Change:

This code change adds requirement for how to insulate and seal unconditioned basements. It includes insulating at the floor overhead, walls surrounding the stairway, door(s) leading to the basement from conditioned space. It also states that no uninsulated duct, domestic hot water or hydronic heating surfaces may be exposed to the basement, and no HVAC supply or return diffusers may serve the basement.

Cost Implication of the Code Change

This code change may increase the cost of construction for a home with unconditioned basement. To illustrate this potential cost, this analysis develops a cost to increase c.i. in the walls surrounding the stairway. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to increase wall insulation in the stairway

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(200)	($254.07)
XPS, 15 psi, 2", R10[19]	SF	$1.04	$0.49	$1.53	$1.68	200	$336.37
Drywall screw, 2.5"[37]	LB	$1.59		$1.59	$1.72	(1.3)	($2.23)
Drywall screw, 3.5"[38]	LB	$1.59		$1.59	$1.72	1.6	$2.75
Total to Builder							$82.82
Total to Consumer							$97.31

37 Source: https://www.menards.com/main/hardware/fasteners-connectors/screws/drywall-screws/grip-fast-reg-8-x-2-1-2-phillips-drive-flat-head-coarse-thread-drywall-screw-25-lb-box/229-2557/p-1444441860201.htm

38 https://www.menards.com/main/hardware/fasteners-connectors/screws/drywall-screws/grip-fast-reg-10-x-3-1-2-phillips-drive-flat-head-coarse-thread-drywall-screw-25-lb-box/229-2735/p-1444441853388.htm

RE72

Reference Code Section

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

Summary of Code Change:

This code change clarifies that "Narrow cavities, of an inch or less, not able to be insulated, shall be air sealed."

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. Narrow cavities are likely to already be air sealed (e.g., with expanding foam) as part of a standard air sealing package to achieve the required air leakage rates in code. Additionally other air sealing criteria in this Table are likely to already cover "Narrow Cavities", for example "The space between framing and skylights, and the jambs of windows and doors, shall be sealed." Therefore, no cost impact is assumed for the reference home.

RE82

Reference Code Section

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

Summary of Code Change:

This code change clarifies requirements for rim joists, specifying that the air barrier provided must be air sealed to the sill plate and sub floor.

Cost Implication of the Code Change

This code change will not increase the cost of construction because it clarifies and states explicitly that the rim joist air barrier must be sealed, which was already included in the general requirement of this table that any breaks or joints in the air barriers must be sealed. Therefore, no cost impact is assumed for the reference home.

RE96

Reference Code Section

R402.4.1.2 Testing

Summary of Code Change:

This code change adds flexibility by making the mandatory air leakage 5.0 ACH50, therefore allowing some tradeoffs where 3.0 ACH50 was required before. Because the overall performance target, and prescriptive requirements are unchanged there is no impact on the overall efficiency.

Cost Implication of the Code Change

This code change will not impact the cost of construction because it only adds flexibility to meet the same level of performance and does not meaningfully impact the efficiency of a home. Therefore, no cost impact is assumed for the reference home.

RE103

Reference Code Section

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

Summary of Code Change:

This code change adds a new section to define "air-sealed boxes" that are already required by Table R402.4.1.1 Air Barrier, Air Sealing and Insulation Installation. Specifically, for "Electrical/phone boxes on exterior walls" the table states "The air barrier shall be installed behind electrical and communication boxes. Alternatively, air-sealed boxes shall be installed" which is unchanged from the 2018 IECC.

The new section R402.4.6 adds that air sealed boxes must be tested and sealed per NEMA OS 4, essentially clarifying the intent of the requirement in Table R402.4.1.1

Cost Implication of the Code Change

This code change may increase the cost of construction if the requirements of Table R402.4.1.1 were misinterpreted or not met, and are now met with the clarification of the new section. Additionally, there are no changes to the assumed air leakage rate, which could be achieved by using air-sealed boxes as a detail. Therefore, no cost impact is assumed for the reference home.

RE105

Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

Summary of Code Change:

This code change revises the weighted average maximum fenestration SHGC permitted using tradeoffs from Section R405 in climate zones 1 through 3 from 0.50 to 0.40.

Cost Implication of the Code Change

This code change is unlikely to impact the cost of construction because windows in climate zones 1 through 3 typically have much better SHGC than the backstop this code change revises. Therefore, no cost impact is assumed for the reference home.

RE106

Reference Code Section

R403.1.1 Programmable thermostat

Summary of Code Change:

This code change clarifies the required capabilities of a programmable thermostat. Specifically, this code change clarifies that programmable thermostats shall be capable of maintaining different temperature set points for different days of the week, where it only previously required different times of the day.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction, even though the code change does require additional capabilities of a programmable thermostat. A review of retailors shows that the lowest-priced programmable thermostat often meets the requirements of this code change, so no cost was assigned to this code change. [39] Therefore, no cost impact is assumed for the reference home.

39 Source: https://hvacdirect.com/braeburn-1-heat-1-cool-universal-programmable-thermostat.html

RE109

Reference Code Section

R403.3.2 Ducts located in conditioned space

Summary of Code Change:

This code change clarifies requirements for ducts to be considered in conditioned space based on location. For example, it clarifies that for ducts in floor cavities to be considered within conditioned space, they must have R-19 insulation between the duct and the unconditioned space.

Cost Implication of the Code Change

Generally, this code change will not increase the cost of construction. However, in climate zones 1 and 2 there potentially could be an increase in cost because the prescriptive floor insulation in those climate zones is R-13. To illustrate this potential cost the incremental cost of the insulation and moving to an oval duct is shown below. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost of 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[40]	SF	$0.52	$0.42	$0.94	$1.04	(80)	($83.35)
R-19 unfaced fiberglass batt[41]	SF	$0.57	$0.49	$1.06	$1.17	80	$93.54
7" round metal duct[42]	LF	$2.77		$2.77	$2.99	(40)	($119.48)
7" oval metal duct[43]	LF	$3.19		$3.19	$3.45	40	$137.81
Total to Builder							$28.52
Total to Consumer							$33.51

40 Source: https://www.homedepot.com/p/Knauf-Insulation-R13-EcoBatt-Unfaced-Fiberglass-Insulation-Batt-3-1-2-in-x-16-in-x-96-in-15-Bags-691011/313646784
41 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748
42 Source: https://www.menards.com/main/heating-cooling/ductwork/ductwork-pipe/heating-cooling-products-30-gauge-round-metal-duct-pipe/10107241/p-1444432222926.htm
43 Source: https://www.menards.com/main/heating-cooling/ductwork/ductwork-pipe/heating-cooling-products-oval-metal-duct-pipe/11107600/p-1444432220354.htm

RE112

Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

Summary of Code Change:

This code change removes an exception, and not requires total duct leakage testing for systems where ducts and air handlers are located entirely within the building thermal envelope. For these systems, a leakage limit of 8.0 cubic feet per minute per 100 square feet of conditioned floor area applies.

Cost Implication of the Code Change

This code change will increase the cost of construction for the subset of homes that have ducts in conditioned space, or for homes with conditioned basements and unvented crawlspaces in this analysis. The cost is estimated based on an estimated 30 minutes to conduct the test by a Rater already on site to conduct other tests, as estimated by the ENERGY STAR Multifamily New Construction Program.[44] It does not include any additional costs for additional sealing or re-testing if the system does not meet the leakage limits.

Estimated cost of the duct leakage test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	HR				$80.00	0.5	$40.00
Total to Builder							$40.00
Total to Consumer							$47.00

44 Source: https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/multifamily_national_page

RE130

Reference Code Section

R403.6.3 Testing (new)

Summary of Code Change:

This code change requires testing of mechanical ventilation systems to verify that they meet the minimum ventilation flow rates. An exemption exists for testing certain kitchen local ventilation systems.

Cost Implication of the Code Change

This code change will increase the cost of construction for all houses. Additional testing will need to be conducted by personnel already on-site conducting other tests (e.g., air leakage and duct leakage tests). The code change proposal was based on requirements of the ENERGY STAR program, which estimates testing will take 5 minutes per system by a rater.[45] The Reference House contains 3 bathrooms (with local mechanical ventilation), one kitchen (which may be exempted from testing if local ventilation is present), and potentially one whole-house mechanical ventilation system (if the existing bathroom ventilation system is not used as part of this system). Therefore, it is estimated that there will be 4 tests taking a total of 20 minutes of a Rater's time at a rate of $80 an hour.

Estimated cost of the mechanical ventilation test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	HR				$80.00	0.33	$26.67
Total to Builder							$26.67
Total to Consumer							$31.33

45 Source: Cost & Savings Document https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/national_page

RE133

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of Code Change:

This code change updates the mechanical ventilation system fan efficacy to align with the ENERGY STAR v4.0 requirements established in 2015. For a bath fan rated < 90CFM the efficacy increased from 1.4 to 2.8 CFM/Watt, and for a bath fan rated ≥ 90 CFM the efficacy increased from 2.8 to 3.5 CFM/Watt.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. The reference house uses a bath fan for whole-dwelling mechanical ventilation rated at 90 CFM. A review of fans that meet this airflow rate on Home Depot shows that the least cost fan available is rated at 3.6 CFM/Watt, exceeding the 2021 IECC requirement.[46],[47] Further an analysis by DOE determined that there was no incremental cost because all fans on the market exceed these requirements according to the fans listed in the Home Ventilating Institute's database, and all ventilation fans reviewed at Home Depot showed efficacies well above the fan efficacy requirements in the 2021 IECC. [48] Therefore, no cost impact is assumed for the reference home.

46 Source: https://www.homedepot.com/b/Bath-Bathroom-Exhaust-Fans-Bath-Fans/N-5yc1vZc4kq?NCNI-5&searchRedirect=90%2520cfm%252Obath%2520fan&semanticToken=310r20400g22000100_20211118163942961O972139167_us-east1-m01v%20310r20400g22000100%20%3E%20rid%3A%7B998426db4b7693b2887d863123f5ed3b%7D%3Arid%20st%3A%7B90%20cfm%20bath%20fan%7D%3Ast%20ct%3A%7Bbath%20fan%7D%3Act%20pt%3A%7Bbath%20fan%7D%3Apt%20nr%3A%7B90%20cfm%20bath%20fan%7D%3Anr%20nf%3A%7Bn%2Fa%7D%3Anf%20qu%3A%7B90%20cfm%20bath%20fan%7D%3Aqu%20qr%3A%7B90%20cfm%20bath%20fan%7D%3Aqr&sortorder=asc&sortby=price

47 Source: https://cyclonerangehoods.com/bath-fans/c90/

48 Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf

RE134

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of Code Change:

This code change adds efficacy requirements for whole-dwelling mechanical ventilation systems that utilize the air-handler fan. Specifically, a minimum 1.2 cfm/watt.

Cost Implication of the Code Change

This code change may increase the cost of construction of central fan integrated supply ventilation systems, where there is ductwork bringing in outdoor air to the return. This change will not impact homes with exhaust ventilation. The cost is based on upgrading the furnace to a variable-speed furnace, from a multi-speed furnace to meet the required efficacy. For this type of system, when there is no call for heating or cooling the air handler blower fan my still operate to meet ventilation requirements, this will be accomplished through a controller, the controller could wither activate a separate fan (e.g., an existing bath exhaust fan), or activate the air handler to run to only provide ventilation needs. This code change does not require changes to the ventilation controls, which are already commonly used prior to this code change, but the costs are shown below for illustrative purposes.

Incremental cost of variable-speed furnace

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 AFUE, multi-speed[49]	EA	$852.00		$852.00	$919.59	(1)	($919.59)
Gas furnace, 80 AFUE, variable-speed[50]	EA	$1,421.00		$1,421.00	$1533.73	1	$1,533.73
Total to Builder							$614.14
Total to Consumer							$721.59

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							$614.14
Air Cycler Controller[51]	EA	$150.50	$0.00	$150.50	$162.44	1	$162.44
Damper[52]	EA	$90.39	$0.00	$90.39	$97.56	1	$97.56
15-amp circuit, duplex outlet, 20' 14/2 NM[53]	EA	$6.82	$23.50	$30.32	$35.58	1	$35.58
Wire, 14/2, add 20'[54]	LF	$0.45	$1.37	$1.82	$1.97	20	$39.41
Total to Builder							$949.13
Total to Consumer							$1,115.18

49 Source: https://hvacdirect.com/goodman-60-000-btu-80-afue-multi-speed-single-stage-gas-furnace-gmes800603an.html
50 Source: https://hvacdirect.com/goodman-80-afue-60-000-btu-upflow-variable-speed-gas-furnace-gmvc80604bn.html
51 Source: https://www.aircycler.com/collections/shop/products/g2?variant=289397892
52 Source: https://www.homedepot.com/p/Leviton-15-Amp-Residential-Grade-Grounding-Duplex-Outlet-White-10-Pack-M24-05320-WMP/100055784
53 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4
54 Source: https://www.homedepot.com/p/Southwire-1-000-ft-14-2-Solid-Romex-SIMpull-CU-NM-B-W-G-Wire-28827401/202316473

RE139

Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

Summary of Code Change:

This code change adds a new section to require a heat or energy recovery ventilation (HRV or ERV) in climate zones 7 and 8. The equipment mush have a minimum sensible heat recovery efficiency of 65%.

Cost Implication of the Code Change

This code change will increase the cost of construction in climate zones 7 and 8. The cost is estimated based on the incremental cost of installing an ERV instead of an ENERGY STAR bath fan which would have provided whole-house mechanical ventilation, therefore there is some cost savings when downgrading the bath fan. The ERV includes fans which meet the required fan efficacy of 1.2 CFM/Watt, and also includes integrated controls to ensure minimum ventilation needs are met. It is assumed that he ERV will be integrated into the existing HVAC distribution, so limited new ductwork is required.

Cost to install an ERV

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[55]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[56]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[57]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[58]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86
Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[59]	EA	$36.37	$23.50	$59.87	$66.02	1	$66.02
Wire, 14/2, add 20'[60]	LF	$0.38	$1.37	$1.75	$1.97	20	$39.41
GFCI 15-amp 1-pole breaker[61]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[62]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[63]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,483.02
Total to Consumer							$1,742.48

55 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362
56 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls
57 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495
58 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate
59 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
60 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4
61 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
62 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935
63 Source: https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent

RE145

Reference Code Section

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

Summary of Code Change:

This code change increases the percent of high efficacy lighting from 90% to 100% for permanently installed lighting fixtured, and also defines high-efficacy light sources as lamps with an efficacy not less than 65 lumens per watt, or luminaires with an efficacy of 45 lumens per watt. Additionally, it adds a requirement to provide lighting controls (e.g., a dimmer) for all permanently installed light fixtures except for bathrooms, hallways, exterior fixtures, fixtures designed for safety or security.

Cost Implication of the Code Change

The increase of high-efficacy lighting is unlikely to increase the cost of construction in most cases. The use of non-high-efficacy lamps (i.e., incandescent) is uncommon, and recent actions by the Department of Energy indicate a new Standard set at 45 lumens per watt is likely to be established per requirements of the Energy Policy and Conservation Act. [64] Additionally, when incandescent bulbs are available, there are often less expensive high-efficacy (CFL) options available. This is shown in the tables below, but to be conservative the net negative cost is not used in the analysis.

The additional cost of adding dimmer switches will increase the cost of construction, and this is estimated by including the cost of one dimmer for each room that is not-exempted from the requirement.

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

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
CFL lamp (excluded from total)[65]	EA	$1.25		$1.25	$1.35	4	$5.39
Incandescent lamp (excluded from total)[66]	EA	$1.99		$1.99	$2.15	(4)	($8.59)
Dimmer switch, toggle[67]	EA	$8.32		$8.32	$8.98	4	$35.92
Standard toggle switch[68]	EA	$1.77		$1.77	$1.91	(4)	($7.64)
Total to Builder							$28.28
Total to Consumer							$33.23

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

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
CFL lamp (excluded from total)[65]	EA	$1.25		$1.25	$1.35	4	$5.39
Incandescent lamp (excluded from total)[66]	EA	$1.99		$1.99	$2.15	(4)	($8.59)
Dimmer switch, toggle[67]	EA	$8.32		$8.32	$8.98	5	$44.90
Standard toggle switch[68]	EA	$1.77		$1.77	$1.91	(5)	($9.55)
Total to Builder							$35.35
Total to Consumer							$41.53

64 https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0001
65 Source: https://www.lightbulbs.com/product/maxlite-01504
66 Source: https://www.lowes.com/pd/GE-Classic-60-Watt-Dimmable-A15-Light-Fixture-Incandescent-Light-Bulb-2-Pack/1000444103
67 Source: https://www.homedepot.com/p/Leviton-Trimatron-600-Watt-Single-Pole-Universal-Rotary-Dimmer-White-Light-Almond-R00-RNL06-0TW/301370402
68 Source: https://www.menards.com/main/electrical/light-switches-dimmers-outlets/light-switches/legrand-reg-trademaster-reg-15-amp-1-pole-toggle-light-switch/rc151wcc24/p-1444451212422-c-6324.htm?tid=-3681600139528539746&ipos=3

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	4	1
Crawlspace	4	0
Total, basement	36	5
Total, crawlspace	36	4
Total, slab	32	4
Additional lamps required	4	

RE148

Reference Code Section

R404.1.1 Exterior lighting

Summary of 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. Therefore, no cost impact is assumed for the reference home.

RE149

Reference Code Section

R404.3 Exterior lighting controls (new)

Summary of Code Change:

This code change requires controls on exterior lighting that exceeds 30 Watts.

Cost Implication of the Code Change

This code change will increase the cost of construction, and is estimated by installing two screw-in light sensing controls. No cost impact is assumed for the reference home because the energy savings impact was not modeled, however, these costs are shown below for illustrative purposes.

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[69]	EA	$8.51		$8.51	$9.19	2	$18.37
Total to Builder							$18.37
Total to Consumer							$21.58

69 Source: https://www.homedepot.com/p/Westek-Dusk-to-Dawn-Light-Control-SLC5BCB-4/202524822#product-overview

RE151

Reference Code Section

R405.2 Simulated Performance Alternative - Mandatory Requirements

Summary of Code Change:

This code change establishes a thermal envelope backstop for the performance path of the 2009 IECC.

Cost Implication of the Code Change

Due to the significant increase in stringency of the 2021 IECC over the 2009 IECC this code change is unlikely to have an impact on the cost of construction. Therefore, no cost impact is assumed for the reference home.

RE178

Reference Code Section

Table R405.4.2

Summary of Code Change:

When using the performance compliance option, this code change updates the mechanical ventilation system type for the standard reference design to be the same as the proposed design.

Cost Implication of the Code Change

This code change will have no impact on the cost of construction. Therefore, no cost impact is assumed for the reference home.

RE209

Reference Code Section

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

Summary of Code Change:

This code change creates a new requirement for an 'additional efficiency package options.' This is implemented in Section R401.2.5 by selecting one of five options for the prescriptive path, achieving an additional 5% savings in the performance or Energy Rating Index paths. The five options are:

1. Enhanced envelope performance option
    - Requires a 5% improvement in the total building thermal envelope UA, and weighted average SHGC.
2. More efficient HVAC equipment performance option
    - Requires a ≥ 95 AFUE gas furnace, and 16 SEER air conditioner, or ≥ 10 HSPF / 16 SEER air source heat pump, or ≥ 3.5 COP ground source heat pump.
3. Reduced energy use in service water-heating option
    - Requires a ≥ 0.82 EF fossil fuel service water heating system (i.e., a tankless water heater), or ≥ 2.0 EF electric service water heating system (i.e., a heat pump water heater), or ≥ 0.4 solar fraction solar water heating system.
4. More efficient duct thermal distribution system
    - Requires 100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless or hydronic systems, or 100% of ducts within conditioned space.
5. Improved air sealing and efficient ventilation option
    - Requires air leakage ≤ 3.0 ACH50, and an energy recovery ventilator (ERV) or heat recovery ventilation (HRV) with at least 75% sensible recovery efficiency.

Cost Implication of the Code Change

This code change will increase the cost of construction. Costs for each option, except the enhanced envelope option, were evaluated.

For the HVAC option, the gas home was upgraded from an 80 AFUE to a 95 AFUE furnace and to a 16 SEER air conditioner, with 13 SEER as a baseline for climate zones 5 to 7 and 14 SEER for climate zones 1 to 4 based on federal appliance standards. The electric home costs reflect an upgrade from an 8.2 HSPF / 14 SEER heat pump to a 10.0 HSPF / 18 SEER unit, which exceeds the 16 SEER requirement, but the cost data used did not have a 16 SEER unit that also met the 10.0 HSPF requirement.

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, 80 kBtuh, AFUE 80%[70]	EA	$897.00		$897.00	$968.16	(1)	($968.16)
Gas Chimney Vent, 4" dia.[71]	LF	$7.57	$8.45	$16.02	$17.80	(25)	($444.94)
Gas Chimney Vent, 3" dia. (water heater)[72]	LF	$6.29	$8.00	$14.29	$15.90	25	$397.38

70 Source: https://hvacdirect.com/goodman-80-000-btu-80-afue-multi-speed-single-stage-gas-furnace-gmes800803bn.html
71 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F385
72 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F381

Gas furnace, 80 kBtuh, AFUE 95%[73]	EA	$1,308.10		$1,308.10	$1,411.88	1	$1,411.88
Vent piping, PVC, 2" dia.[74]	LF	$1.65	$3.02	$4.67	$5.22	40	$208.63
2" concentric vent kit[75]	EA	$37.69		$37.69	$40.68	1	$40.68
Condenser, 3 ton, 13 SEER[76]	EA	$1,254.00		$1,254.00	$1,353.48	(1)	($1,353.48)
Condenser, 3 ton, 16 SEER[77]	EA	$1,557.00		$1,557.00	$1,680.52	1	$1,680.52
Total to Builder							$972.50
Total to Consumer							$1,142.64

HVAC equipment option for Gas House with 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							$972.50
Condenser, 3-ton, 14 SEER[78]	EA	$1404.00		$1,404.00	$1,515.38	(1)	($1,515.38)
Condenser, 3-ton, 13 SEER[79]	EA	$1254.00		$1,254.00	$1,353.48	1	$1,353.48
Total to Builder							$810.60
Total to Consumer							$952.41

HVAC equipment option for Electric House: 3 Ton 10 HSPF 18 SEER Heat Pump

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER[80]	EA	$2,769.00		$2,769.00	$2,988.67	(1)	($2,988.67)
Heat Pump, 10.0 HSPF/18 SEER[81]	EA	$4,793.00		$4,793.00	$5,173.24	1	$5,173.24
Total to Builder							$2,184.57
Total to Consumer							$2,566.77

For the water heater option, the gas home cost is estimated with an upgrade from a 40-gallon gas water heater to a tankless water heater that meets this option's performance requirement of a 0.82 EF. The electric home Is estimated with an upgrade from a 50-gallon electric water heater to a heat pump water heater. In this case the requirement is an EF of 2.0, but most heat pump water heaters significantly exceed this level of performance, so a UEF of 3.75 for the water heater is used to estimate costs. The cost of a thermostatic mixing valve was also Included which allows the heat pump water heater tank temperature to safely be set higher, essentially Increasing its capacity.

Water Heater option for Gas House: Direct Vent Water Heater

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
40 gal gas water heater, 0.58 UEF[82]	EA	$469.00	$165.00	$634.00	$694.11	(1)	($694.11)

73 Source: https://www.lowes.com/pd/MRCOOL-88000-Max-BTU-Input-Natural-gas-95-Percent-Upflow-Horizontal-Forced-Air-Furnace/1002553456
74 Source: https://www.menards.com/main/plumbing/pipe-fittings/pvc-pipe-fittings/pvc-sch-40-plain-end-solid-core-pipe/pvc072000600/p-1444426391701-c-8571.htm?tid=-3946052023881235O&ipos=3
75 Source: https://www.supplyhouse.com/Rheem-SP20897-2-PVC-Concentric-Vent-Termination-Kit
76 Source: https://hvacdirect.com/goodman-3-ton-13-seer-air-conditioner-condenser-with-r410a-refrigerant-gsx130361.html
77 Source: https://hvacdirect.com/goodman-3-ton-16-seer-air-conditioner-condenser-gsx160361.html
78 Source: https://hvacdirect.com/goodman-3-ton-14-seer-air-conditioner-condenser-gsx140361.html
79 Source: https://hvacdirect.com/goodman-3-ton-13-seer-air-conditioner-condenser-with-r410a-refrigerant-gsx130361.html
80 Source: https://hvacdirect.com/goodman-3-ton-14-seer-heat-pump-air-conditioner-system-id694.html
81 Source: https://hvacdirect.com/3-ton-18-seer-goodman-heat-pump-air-conditioner-system-id14356.html
82 Source: https://www.menards.com/main/plumbing/water-heaters/gas-water-heaters/sure-comfort-reg-40-gallon-3-year-34-000-btu-tank-natural-gas-water-heater/scg40t03st34u1/p-1512113333694-c-1541513694149.htm?tid=-6803961517209927632&ipos=4

Tankless gas water heater, 0.82 UEF[83]	EA	$749.00	$174.00	$923.00	$1,006.57	1	$1,006.57
Concentric vent wall termination kit[84]	EA	$68.34		$68.34	$73.76	1	$73.76
Concentric vent 39" extension[85]	EA	$38.03		$38.03	$41.05	1	$41.05
Gas Chimney Vent, 3" dia. (WH connector)[86]	LF	$6.29	$8.00	$14.29	$15.90	(4)	($63.58)
Gas piping, 1/2"[87]	LF	$1.81	$5.25	$7.06	$7.93	(10)	($79.34)
Gas piping, 1"[88]	LF	$2.64	$6.25	$8.89	$9.96	10	$99.62
15-amp circuit, toggle, 40' #14/2 NM[89]	EA	$15.97	$23.50	$39.47	$44.00	1	$44.00
GFCI 15-amp, 1-pole breaker[90]	EA	$36.37		$36.37	$39.26	1	$39.26
Total to Builder							$467.23
Total to Consumer							$548.97

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

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
50 gal electric water heater[91]	EA	$499.00		$499.00	$538.59	(1)	($538.59)
HPWH, 50 gal, minimum 2.0 EF[92]	EA	$1,359.00		$1,359.00	$1,466.81	1	$1,466.81
Thermostatic Mixing Valve[93]	EA	$51.56	$16.50	$68.06	$74.44	1	$74.44
Total to Builder							$1,002.67
Total to Consumer							$1,178.09

For the ventilation option, costs were evaluated for the electric and gas house. In climate zone 2 there was an additional cost of improving the infiltration from 5 to 3 ACH50, while the other climate zones were already at 3 ACH50. There was no cost assumed for this option for climate zone 7 because a cost for an ERV from RE139 already met the requirements for this option.

Ventilation Option Gas House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[94]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[95]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[96]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[97]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86

83 Source: https://www.menards.com/main/plumbing/water-heaters/gas-water-heaters/richmond-reg-mid-efficiency-7-gpm-160-000-btu-tankless-natural-gas-water-heater/rmtg70dvln-1/p-1523946516023-c-1541513694149.htm?tid=-8262144216229885l&ipos=2
84 Source: https://www.supplyhouse.com/Noritz-PVC-2CT-2-PVC-Concentric-Horizontal-Termination?utm_source=bingad&utm_medium=shopping&msclkid=cfe17b3f2b2f169466d21a98cfa62d6e#product-overview
85 Source: https://www.supplyhouse.com/Rinnai-224053-39-Vent-Pipe-Extension-Non-Condensing
86 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F381
87 Source: https://www.homedepot.com/p/HOME-FLEX-1-2-in-CSST-x-25-ft-Corrugated-Stainless-Steel-Tubing-11-00525/203073939
88 Source: https://www.homedepot.com/p/HOME-FLEX-1-in-CSST-x-150-ft-Corrugated-Stainless-Steel-Tubing-11-010150/204767408
89 Source: https://www.homedepot.com/p/Leviton-15-Amp-Single-Pole-Toggle-Switch-Ivory-R51-01451-02I/100356974
90 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
91 Source: https://www.homedepot.com/p/Rheem-Performance-50-Gal-Medium-6-Year-4500-4500-Watt-Elements-Electric-Tank-Water-Heater-XE50M06ST45U1/205810732
92 Source: https://www.menards.com/main/plumbing/water-heaters/heat-pump-water-heaters/hybrid-water-heater/10e50-hp530/p-1106005120884848l-c-8688.htm?tid=2340475535233083866&ipos=1
93 Source: https://www.lowes.com/pd/Cash-Acme-HG110-D-3-4-in-ID-FNPT-x-3-4-in-OD-FNPT-Brass-Thermostatic-Mixing-Valve/1003193690
94 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362
95 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls
96 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495
97 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate

Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[98]	EA	$8.17	$23.50	$31.67	$35.58	1	$35.58
Wire, 14/2, add 20'[99]	LF	$0.38	$1.37	$1.75	$1.97	20	$39.41
GFCI 15-amp 1-pole breaker[100]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[101]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[102]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,452.58
Total to Consumer							$1,706.72

Ventilation Option Electric House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[103]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[104]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[105]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[106]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86
Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[107]	EA	$8.17	$23.50	$31.67	$35.58	1	$35.58
Wire, 14/2, add 20'[108]	LF	$0.38	$1.37	$1.75	$1.97	2	$39.41
GFCI 15-amp 1-pole breaker[109]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[110]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[111]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,452.58
Total to Consumer							$1,706.72

For the ventilation option in climate zone 2 there was an additional cost of improving the infiltration from 5 to 3 ACH50. Decreasing infiltration generally includes additional labor time to complete air sealing details with materials on site. NREL's National Residential Efficiency Measure Database estimates that as a *retrofit* measure improving infiltration from 5 to 3 ACH 50 will cost between $0.22/SF and $0.82/SF, with an average of $0.52/SF. Note that these are costs for a retrofit, and air sealing new construction can be performed at a

98 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
99 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4
100 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
101 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935
102 Source: https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent
103 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362
104 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls
105 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495
106 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate
107 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
108 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4
109 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
110 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935
111 Source: https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent

substantially lower cost. NREL's BEopt 2.8.0.0 includes a cost for air sealing new construction, which shows an incremental cost of $0.105/SF for this level of improvement, which was ultimately used in this analysis.

Ventilation Option Electric House in CZ 2

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Associated ERV cost to builder from above							$1,452.58
Improve ACH50 from 5 to 3, estimate[112]	SF	$0	$0.105	$0.10	$0.12	2500	$298.14
Total to Builder							$1,750.72
Total to Consumer							$2,057.02

For the ventilation option, conditioned basements and conditioned crawlspaces were not evaluated, typically they would include the air handlers and ductwork, so there would be no incremental cost for homes with these foundations to meet this option. Slab homes were considered to meet the requirement by burying ducts per section R403.3.3, which required at least R-19 insulation above the duct, and R-13 insulation wrapped around the duct in climate zones 1 through 3. The air handler was located in a newly constructed mechanical closet to meet the requirements of R403.3.2.

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[113]	SF	$0.31	$1.70		$2.01	$2.15	680	$1,461.21
Add ceiling insulation, R19 blown[114]	SF	$0.17	$0.61	$0.36	$1.14	$1.24	340	$421.79
Mechanical closet, 3'x4', partition wall	LF	$7.40	$4.89		$12.29	$12.68	10	$126.78
Mechanical closet, drywall, finished[115]	SF	$0.26	$0.61		$0.87	$0.92	140	$128.40
Mechanical closet door[116]	EA	$53.73	$34.50		$88.23	$90.97	1	$90.97
Delete attic platform decking, 3/4, 8'x8'[117]	SF	$1.46	$0.38		$1.84	$1.87	(64)	($119.41)
Delete attic platform joist framing, 2x12[118]	LF	$1.60	$0.58		$2.18	$2.22	(40)	($88.87)
Total to Builder								$2,020.87
Total to Consumer								$2,374.43

112 Source: BEopt 2.8.0.0 https://www.nrel.gov/buildings/beopt.html
113 Source: https://www.plumbersstock.com/qflex-dwr83048050-2inx48x50ft-r8-ductwrap.html
114 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1
115 Source: https://www.menards.com/main/building-materials/drywall/drywall-sheets/1-2-x-4-x-8-lightweight-drywall/1311223/p-1444421962026-c-5656.htm?tid=-5114540465575422448&ipos=3
116 Source: https://www.lowes.com/pd/Masonite-Left-Hand-Outswing-Primed-Fiberglass-Prehung-Entry-Door-with-Insulating-Core-Common-32-in-x-80-in-Actual-33-5-in-x-80-375-in/1000054363
117 Source: https://www.lowes.com/pd/23-32-Category-SYP-Rated/1003124582
118 Source: https://www.lowes.com/pd/Top-Choice-2-in-x-12-in-x-12-ft-Southern-Yellow-Pine-Lumber-Common-1-5-in-x-11-25-in-x-12-ft-Actual/1000009756

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

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Add ceiling insulation, R19 blown[119]	SF	$0.17	$0.61	$0.36	$1.14	$1.24	340	$421.79
Mechanical closet, 3'x4', partition wall	LF	$7.40	$4.89		$12.29	$12.68	10	$126.78
Mechanical closet, drywall, finished[120]	SF	$0.26	$0.61		$0.87	$0.92	140	$128.40
Mechanical closet door[121]	EA	$53.73	$34.50		$88.23	$90.97	1	$90.97
Delete attic platform decking, 3/4, 8'x8'[122]	SF	$1.46	$0.38		$1.84	$1.87	(64)	($119.41)
Delete attic platform joist framing, 2x12[123]	LF	$1.60	$0.58		$2.18	$2.22	(40)	($88.87)
Total to Builder								$559.65
Total to Consumer								$657.57

For the ventilation option, crawl space homes were converted from a vented to an unvented crawlspace, which resulted in a decrease in construction costs.

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

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19[124]	SF	$0.57	$0.49		$1.06	$1.10	(1,875)	($2,053.44)
Wall insulation, foil-faced polyiso, 1", R6[125]	SF	$0.53	$0.37		$0.90	$0.93	1,000	$929.98
Foundation vents[126]	EA	$7.98			$7.98	$7.98	(6)	($47.88)
Class 1 vapor retarder on ground[127]	SF	$0.08	$0.08		$0.16	$0.17	1,875	$321.24
Supply duct, 38 cfm (1 cfm/50sf)	EA				$125.00	$125.00	1	$125.00
Transfer grille[128]	EA	$22.48	$13.30		$35.78	$36.84	1	$36.84
Total to Builder								($688.27)
Total to Consumer								($808.69)

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

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19[129]	SF	$0.57	$0.49		$1.06	$1.10	(1,875)	($2,053.44)

119 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1
120 Source: https://www.menards.com/main/building-materials/drywall/drywall-sheets/1-2-x-4-x-8-lightweight-drywall/1311223/p-1444421962026-c-5656.htm?tid=-5114540465575422448&ipos=3
121 Source: https://www.lowes.com/pd/Masonite-Left-Hand-Outswing-Primed-Fiberglass-Prehung-Entry-Door-with-Insulating-Core-Common-32-in-x-80-in-Actual-33-5-in-x-80-375-in/1000054363
122 Source: https://www.lowes.com/pd/23-32-Category-SYP-Rated/1003124582
123 Source: https://www.lowes.com/pd/Top-Choice-2-in-x-12-in-x-12-ft-Southern-Yellow-Pine-Lumber-Common-1-5-in-x-11-25-in-x-12-ft-Actual/1000009756
124 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748
125 Source: https://www.lowes.com/pd/Common-1-in-x-4-ft-x-8-ft-Actual-0-9375-in-x-3-875-ft-x-7-875-ft-R-Expanded-Polystyrene-Foam-Board-Insulation/3365576
126 Source: https://www.lowes.com/pd/Master-Flow-16-87-in-x-7-5-in-Plastic-Foundation-Vent/999972074
127 Source: https://www.lowes.com/pd/BARRICADE-10-ft-x-100-ft-Clear-6-mil-Plastic-Sheeting/1000158151
128 Source: https://www.homedepot.com/p/Everbilt-4-in-x-12-in-Heavy-Duty-Steel-Floor-Return-Air-Grille-in-Brown-E154R-04X12/300713055?source=shoppingads&locale=en-US
129 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748

Wall insulation, foil-faced polyiso, 2", R12[130]	SF	$1.16	$0.40		$1.56	$1.59	1,000	$929.98
Foundation vents[131]	EA	$7.98			$7.98	$7.98	(6)	($47.88)
Class 1 vapor retarder on ground[132]	SF	$0.08	$0.08		$0.16	$0.16	1,875	$321.24
Supply duct, 38 cfm (1 cfm/50sf)	EA				$125.00	$125.00	1	$125.00
Transfer grille[133]	EA	$22.48	$13.30		$35.78	$36.84	1	$36.84
Total to Builder								($30.89)
Total to Consumer								($36.30)

130 Source: https://www.lowes.com/pd/Johns-Manville-Common-2-in-x-4-ft-x-8-ft-Actual-2-in-x-4-ft-x-8-ft-AP-Foil-1-R-13-Faced-Polyisocyanurate-Foam-Board-Insulation/3851107
131 Source: https://www.lowes.com/pd/Master-Flow-16-87-in-x-7-5-in-Plastic-Foundation-Vent/999972074
132 Source: https://www.lowes.com/pd/BARRICADE-10-ft-x-100-ft-Clear-6-mil-Plastic-Sheeting/1000158151
133 Source: https://www.homedepot.com/p/Everbilt-4-in-x-12-in-Heavy-Duty-Steel-Floor-Return-Air-Grille-in-Brown-E154R-04X12/300713055?source=shoppingads&locale=en-US

CE40.2

Reference Code Section

R303.1.2 Insulation mark installation

Summary of Code Change:

This code change requires that for insulation materials without an observable R-value (e.g., blown-in insulation), that the R-value must be left after installation in a conspicuous location in the building.

Cost Implication of the Code Change

This code change will not change the cost of construction. Other code requirements in this same section already require the R-value to be known or displayed and this change mostly clarifies when that data must be communicated. Therefore, no cost impact is assumed for the reference home.

CE151.2

Reference Code Section

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

Summary of 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 limited cases, but it will not impact any homes in this analysis. Therefore, no cost impact is assumed for the reference home.

APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

Proposal	Description	Affected CZ	Reference House	CZ 2 Phoenix Mass (30%) Electric Slab 100%	CZ 2 Phoenix Frame (70%) Electric Slab 100%
RE7	Lighting: revised definition of high-efficacy	All	$0		
RE18, RE20, RE21	Certificate: additional info	All	$0		
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742		
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680		
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709		
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226	$226	$226
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198		
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	$67		
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	$6	$6	$6
RE49	Baffles at attic access	All	$0		
RE72	Air seal narrow framing cavities	All	$0		

RE82	Air seal rim (basement; unvented crawlspace	All	$0		
RE82	Air seal rim (slab, vented crawlspace)	All	$0		
RE96	House tightness, allows trade-off for performance path	All	$0		
RE103	Air seal electrical & communication outlet boxes	All	$0		
RE106	Thermostat: requires 7-day programming	All	$0		
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0		
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742		
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33	$33
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		
RE148	Lighting, commercial	All	NA		
RE149	Lighting: exterior controls	All	$0		
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	$0		
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA		
	Sub-total without additional efficiency package option			$297	$297
	Weighted average, foundations				$297
			Nat Ave	CZ 2	
	Without additional efficiency package options		$1,373	$297	
RE209	HVAC option		$1,900	$2,567	
RE209	Water Heater option		$901	$1,178	
RE209	Ventilation option		$1,788	$2,057	

RE209	Duct option, slab house		$1,870	$2,374
RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$2,864
	Total with Water Heater option		$2,274	$1,475
	Total with Ventilation option		$3,161	$2,354
	Total with Duct option, slab house		$3,243	$2,672
	Total with Duct option, vented crawlspace house			

Proposal	Description	Affected CZ	Reference House	CZ 3					
				Memphis					
				Mass (10%)			Frame (90%)		
				Electric			Electric		
				Slab	Base ment	Crawl	Slab	Base ment	Crawl
				75%	10%	15%	75%	10%	15%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18, RE20, RE21	Certificate: additional info	All	$0						
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742						
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709	$709			$709		
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709						
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226	$226	$226	$226	$226	$226	$226
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198						
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	$67	$67	$67	$67	$67	$67	$67
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	$6	$6	$6	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0						
RE72	Air seal narrow framing cavities	All	$0						
RE82	Air seal rim (basement; unvented crawlspace	All	$0						
RE82	Air seal rim (slab, vented crawlspace)	All	$0						
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$0						
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47			$47	
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0						
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33			$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42		$42	$42
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$0						

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	$0						
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package option			$1,073	$419	$372	$1,073	$419	$372
	Weighted average, foundations					$1,347			$1,347
			Nat Ave	CZ 3					
	Without additional efficiency package options		$1,373	$902					
RE209	HVAC option		$1,900	$2,567					
RE209	Water Heater option		$901	$1,178					
RE209	Ventilation option		$1,788	$1,707					
RE209	Duct option, slab house		$1,870	$2,545					
RE209	Duct option, vented crawlspace house			($1,339)					
	Total with HVAC option		$3,273	$3,469					
	Total with Water Heater option		$2,274	$2,080					
	Total with Ventilation option		$3,161	$2,609					
	Total with Duct option, slab house		$3,243	$3,447					
	Total with Duct option, vented crawlspace house			($437)					

Proposal	Description	Affected CZ	Reference House	CZ 4 Baltimore Frame Wall Gas		
				Slab	Basement	Crawl
				20%	60%	20%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742	$1,742	$1,742	$1,742
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
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	$67	$67	$67	$67
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	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			

RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
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	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$2,786	$2,133	$2,086
	Weighted average, foundations					$2,254
			Nat Ave		CZ 4	
	Without additional efficiency package options		$1,373		$2,254	
RE209	HVAC option		$1,900		$952	
RE209	Water Heater option		$901		$549	
RE209	Ventilation option		$1,788		$1,707	
RE209	Duct option, slab house		$1,870		$1,190	

RE209	Duct option, vented crawlspace house			($205)
	Total with HVAC option		$3,273	$3,206
	Total with Water Heater option		$2,274	$2,803
	Total with Ventilation option		$3,161	$3,961
	Total with Duct option, slab house		$3,243	$3,444
	Total with Duct option, vented crawlspace house			$2,049

Proposal	Description	Affected CZ	Reference House	CZ 5 Chicago Frame Wall Gas		
				Slab	Basement	Crawl
				15%	70%	15%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680	$2,680	$2,680	$2,680
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
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	$67			

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	$6	$6	$6	
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			
RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
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	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			

	Sub-total without additional efficiency package option			$3,658	$3,004	$3,004
	Weighted average, foundations					$3,102
			Nat Ave	CZ 5		
	Without additional efficiency package options		$1,373	$3,102		
RE209	HVAC option		$1,900	$1,143		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$1,213		
RE209	Duct option, vented crawlspace house					
	Total with HVAC option		$3,273	$4,245		
	Total with Water Heater option		$2,274	$3,651		
	Total with Ventilation option		$3,161	$4,809		
	Total with Duct option, slab house		$3,243	$4,315		
	Total with Duct option, vented crawlspace house					

Proposal	Description	Affected CZ	Reference House	CZ 6 Helena Frame Wall Gas		
				Slab	Basement	Crawl
				5%	90%	5%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709			
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
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	$67			
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	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			

RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
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	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$269	$324	$324
	Weighted average, foundations					$321
			Nat Ave	CZ 6		
	Without additional efficiency package options		$1,373	$321		
RE209	HVAC option		$1,900	$1,143		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$605		

RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$1,464
	Total with Water Heater option		$2,274	$870
	Total with Ventilation option		$3,161	$2,028
	Total with Duct option, slab house		$3,243	$926
	Total with Duct option, vented crawlspace house			

Proposal	Description	Affected CZ	Reference House	CZ 7 Duluth Frame Wall Gas Slab 30%	Basement 5%	Crawl 65%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709			
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
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	$67			
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	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			
RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742	$1,742	$1,742	$1,742
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
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	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$2,011	$2,066	$2,066

	Weighted average, foundations			$2,050
			Nat Ave	CZ 7
	Without additional efficiency package options		$1,373	$2,050
RE209	HVAC option		$1,900	$1,143
RE209	Water Heater option		$901	$549
RE209	Ventilation option		$1,788	$0
RE209	Duct option, slab house		$1,870	$619
RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$3,192
	Total with Water Heater option		$2,274	$2,599
	Total with Ventilation option		$3,161	$2,050
	Total with Duct option, slab house		$3,243	$2,669
	Total with Duct option, vented crawlspace house			

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

APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

The table below shows the insulation minimum R-values and fenestration requirements for the 2021 IECC, with redline text indicating changes from the 2018 IECC.

Insulation Minimum R-value and Fenestration Requirements. Source: adapted from the 2018 and 2021 IECC

Climate Zone	Fenestration U-factor	Skylight U-factor	Fenestration SHGC	Ceiling R-value	Frame Wall R-value	Mass Wall R-value	Floor R-value	Basement wall R-value*	Slab R-value & depth	Crawl Space wall R-value*
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	~~38~~ 49	13	4/6	13	0	0	0
3	~~0.32~~ 0.30	0.55	0.25	~~38~~ 49	20	8/13	19	5/13	~~0~~ 10, 2 ft	5/13
4 except Marine	~~0.32~~ 0.30	0.55	0.40	~~49~~ 60	~~20~~ 20+5	8/13	19	10/13	~~10, 2 ft~~ 10, 4 ft	10/13
5 and Marine 4	0.30	0.55	~~NR~~ 0.40	~~49~~ 60	~~20~~ 20+5	13/17	30	15/19	~~10, 2 ft~~ 10, 4 ft	15/19
6	0.30	0.55	NR	~~49~~ 60	20+5	15/20	30	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	~~49~~ 60	20+5	19/21	38	15/19	10, 4 ft	15/19

* Cavity insulation / continuous insulation

APPENDIX E: ENERGY USE BY CLIMATE ZONE

CZ	Fuel	Foundations	Wall	Code	Efficiency Option	kWh/yr	thrm/yr	$/yr
2	Electric	Slab	Mass	2018	Base	17,107	0	$2,225.62
2	Electric	Slab	Frame	2018	Base	17,087	0	$2,223.02
2	Electric	Slab	Mass	2018	2021 ceiling insulation	17,052	0	$2,218.47
2	Electric	Slab	Frame	2018	2021 ceiling insulation	17,028	0	$2,215.34
2	Electric	Slab	Mass	2021	Base	16,638	0	$2,164.60
2	Electric	Slab	Frame	2021	Base	16,615	0	$2,161.61
2	Electric	Slab	Mass	2021	HVAC option	15,727	0	$2,046.08
2	Electric	Slab	Frame	2021	HVAC option	15,715	0	$2,044.52
2	Electric	Slab	Mass	2021	Water Heater option	15,618	0	$2,031.90
2	Electric	Slab	Frame	2021	Water Heater option	15,589	0	$2,028.13
2	Electric	Slab	Mass	2021	Ventilation option	16,506	0	$2,147.43
2	Electric	Slab	Frame	2021	Ventilation option	16,465	0	$2,142.10
2	Electric	Slab	Mass	2021	Duct option	15,768	0	$2,051.42
2	Electric	Slab	Frame	2021	Duct option	15,715	0	$2,044.52
3	Electric	Slab	Mass	2018	Base	15,618	0	$2,031.90
3	Electric	Slab	Frame	2018	Base	15,557	0	$2,023.97
3	Electric	Cond Basement	Mass	2018	Base	16,612	0	$2,161.22
3	Electric	Cond Basement	Frame	2018	Base	16,547	0	$2,152.76
3	Electric	Vented Crawl	Mass	2018	Base	15,144	0	$1,970.23
3	Electric	Vented Crawl	Frame	2018	Base	15,056	0	$1,958.79
3	Electric	Slab	Mass	2018	2021 ceiling insulation	15,536	0	$2,021.23
3	Electric	Slab	Frame	2018	2021 ceiling insulation	15,472	0	$2,012.91

3	Electric	Cond Basement	Mass	2018	2021 ceiling insulation	16,521	0	$2,149.38
3	Electric	Cond Basement	Frame	2018	2021 ceiling insulation	16,451	0	$2,140.28
3	Electric	Vented Crawl	Mass	2018	2021 ceiling insulation	15,053	0	$1,958.40
3	Electric	Vented Crawl	Frame	2018	2021 ceiling insulation	14,959	0	$1,946.17
3	Electric	Slab	Mass	2018	2021 slab insulation	14,938	0	$1,943.43
3	Electric	Slab	Frame	2018	2021 slab insulation	14,877	0	$1,935.50
3	Electric	Slab	Mass	2018	2021 window U-Factor	15,566	0	$2,025.14
3	Electric	Slab	Frame	2018	2021 window U-Factor	15,501	0	$2,016.68
3	Electric	Cond Basement	Mass	2018	2021 window U-Factor	16,553	0	$2,153.55
3	Electric	Cond Basement	Frame	2018	2021 window U-Factor	16,489	0	$2,145.22
3	Electric	Vented Crawl	Mass	2018	2021 window U-Factor	15,091	0	$1,963.34
3	Electric	Vented Crawl	Frame	2018	2021 window U-Factor	14,994	0	$1,950.72
3	Electric	Slab	Mass	2021	Base	14,408	0	$1,874.48
3	Electric	Slab	Frame	2021	Base	14,344	0	$1,866.15
3	Electric	Cond Basement	Mass	2021	Base	15,903	0	$2,068.98
3	Electric	Cond Basement	Frame	2021	Base	15,832	0	$2,059.74
3	Electric	Vented Crawl	Mass	2021	Base	14,610	0	$1,900.76
3	Electric	Vented Crawl	Frame	2021	Base	14,519	0	$1,888.92
3	Electric	Slab	Mass	2021	HVAC option	13,485	0	$1,754.40
3	Electric	Slab	Frame	2021	HVAC option	13,450	0	$1,749.85
3	Electric	Cond Basement	Mass	2021	HVAC option	14,824	0	$1,928.60
3	Electric	Cond Basement	Frame	2021	HVAC option	14,786	0	$1,923.66
3	Electric	Vented Crawl	Mass	2021	HVAC option	13,561	0	$1,764.29
3	Electric	Vented Crawl	Frame	2021	HVAC option	13,502	0	$1,756.61

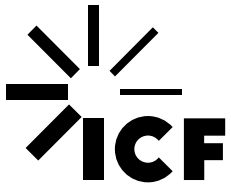
3	Electric	Slab	Mass	2021	Water Heater option	13,277	0	$1,727.34
3	Electric	Slab	Frame	2021	Water Heater option	13,212	0	$1,718.88
3	Electric	Cond Basement	Mass	2021	Water Heater option	14,742	0	$1,917.93
3	Electric	Cond Basement	Frame	2021	Water Heater option	14,669	0	$1,908.44
3	Electric	Vented Crawl	Mass	2021	Water Heater option	13,470	0	$1,752.45
3	Electric	Vented Crawl	Frame	2021	Water Heater option	13,382	0	$1,741.00
3	Electric	Slab	Mass	2021	Ventilation option	14,326	0	$1,863.81
3	Electric	Slab	Frame	2021	Ventilation option	14,259	0	$1,855.10
3	Electric	Cond Basement	Mass	2021	Ventilation option	15,727	0	$2,046.08
3	Electric	Cond Basement	Frame	2021	Ventilation option	15,651	0	$2,036.20
3	Electric	Vented Crawl	Mass	2021	Ventilation option	14,446	0	$1,879.42
3	Electric	Vented Crawl	Frame	2021	Ventilation option	14,346	0	$1,866.41
3	Electric	Slab	Mass	2021	Duct option	13,816	0	$1,797.46
3	Electric	Slab	Frame	2021	Duct option	13,749	0	$1,788.74
3	Electric	Vented Crawl	Mass	2021	Duct option	14,273	0	$1,856.92
3	Electric	Vented Crawl	Frame	2021	Duct option	14,174	0	$1,844.04
4	Gas	Slab	Frame	2018	Base	8,262	697	$1,807.43
4	Gas	Cond Basement	Frame	2018	Base	9,848	696	$2,012.72
4	Gas	Vented Crawl	Frame	2018	Base	8,669	665	$1,826.75
4	Gas	Slab	Frame	2018	2021 ceiling insulation	8,244	690	$1,797.73
4	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	9,833	689	$2,003.41
4	Gas	Vented Crawl	Frame	2018	2021 ceiling insulation	8,652	659	$1,818.23
4	Gas	Slab	Frame	2018	2021 slab insulation	8,180	674	$1,772.59
4	Gas	Slab	Frame	2018	2021 wall cont. insulation	8,177	661	$1,758.54

4	Gas	Cond Basement	Frame	2018	2021 wall cont. insulation	9,763	660	$1,963.83
4	Gas	Vented Crawl	Frame	2018	2021 wall cont. insulation	8,590	629	$1,778.64
4	Gas	Slab	Frame	2018	2021 window U-Factor	8,256	687	$1,796.14
4	Gas	Cond Basement	Frame	2018	2021 window U-Factor	9,848	686	$2,002.21
4	Gas	Vented Crawl	Frame	2018	2021 window U-Factor	8,666	656	$1,816.90
4	Gas	Slab	Frame	2021	Base	7,673	626	$1,656.18
4	Gas	Cond Basement	Frame	2021	Base	9,159	649	$1,873.68
4	Gas	Vented Crawl	Frame	2021	Base	8,174	616	$1,710.85
4	Gas	Slab	Frame	2021	HVAC option	7,348	565	$1,549.79
4	Gas	Cond Basement	Frame	2021	HVAC option	8,795	580	$1,753.81
4	Gas	Vented Crawl	Frame	2021	HVAC option	7,761	552	$1,589.86
4	Gas	Slab	Frame	2021	Water Heater option	7,629	601	$1,624.00
4	Gas	Cond Basement	Frame	2021	Water Heater option	9,144	614	$1,835.00
4	Gas	Vented Crawl	Frame	2021	Water Heater option	8,126	591	$1,678.00
4	Gas	Slab	Frame	2021	Ventilation option	7,931	586	$1,647.71
4	Gas	Cond Basement	Frame	2021	Ventilation option	9,481	584	$1,847.26
4	Gas	Vented Crawl	Frame	2021	Ventilation option	8,420	575	$1,699.77
4	Gas	Slab	Frame	2021	Duct option	7,495	581	$1,585.73
4	Gas	Vented Crawl	Frame	2021	Duct option	7,732	607	$1,643.89
5	Gas	Slab	Frame	2018	Base	7,666	1,102	$2,156.00
5	Gas	Cond Basement	Frame	2018	Base	9,297	1,089	$2,354.08
5	Gas	Cond Crawl	Frame	2018	Base	7,720	999	$2,054.32
5	Gas	Slab	Frame	2018	2021 ceiling insulation	7,691	1,090	$2,146.19
5	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	9,285	1,080	$2,343.06

5	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,702	991	$2,043.57
5	Gas	Slab	Frame	2018	2021 slab insulation	7,647	1,071	$2,120.50
5	Gas	Slab	Frame	2018	2021 wall cont. insulation	7,617	1,049	$2,093.47
5	Gas	Cond Basement	Frame	2018	2021 wall cont. insulation	9,209	1,040	$2,291.13
5	Gas	Cond Crawl	Frame	2018	2021 wall cont. insulation	7,635	952	$1,993.87
5	Gas	Slab	Frame	2021	Base	7,142	1,018	$1,999.09
5	Gas	Cond Basement	Frame	2021	Base	8,614	1,037	$2,210.57
5	Gas	Cond Crawl	Frame	2021	Base	7,216	947	$1,934.10
5	Gas	Slab	Frame	2021	HVAC option	6,770	898	$1,824.58
5	Gas	Cond Basement	Frame	2021	HVAC option	8,209	914	$2,028.60
5	Gas	Cond Crawl	Frame	2021	HVAC option	6,838	837	$1,769.31
5	Gas	Slab	Frame	2021	Water Heater option	7,137	998	$1,977.00
5	Gas	Cond Basement	Frame	2021	Water Heater option	8,618	1,003	$2,175.00
5	Gas	Cond Crawl	Frame	2021	Water Heater option	7,211	925	$1,910.00
5	Gas	Slab	Frame	2021	Ventilation option	7,400	966	$1,978.01
5	Gas	Cond Basement	Frame	2021	Ventilation option	8,927	960	$2,170.36
5	Gas	Cond Crawl	Frame	2021	Ventilation option	7,482	901	$1,920.36
5	Gas	Slab	Frame	2021	Duct option	7,022	929	$1,889.94
6	Gas	Slab	Frame	2018	Base	7,374	1,201	$2,221.61
6	Gas	Cond Basement	Frame	2018	Base	8,962	1,166	$2,391.42
6	Gas	Cond Crawl	Frame	2018	Base	7,345	1,057	$2,066.49
6	Gas	Slab	Frame	2018	2021 ceiling insulation	7,359	1,192	$2,210.20
6	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	8,945	1,155	$2,377.65
6	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,333	1,047	$2,054.42

6	Gas	Slab	Frame	2021	Base	6,970	1,198	$2,165.90
6	Gas	Cond Basement	Frame	2021	Base	8,379	1,162	$2,311.37
6	Gas	Cond Crawl	Frame	2021	Base	6,937	1,052	$2,008.16
6	Gas	Slab	Frame	2021	HVAC option	6,586	1,054	$1,964.59
6	Gas	Cond Basement	Frame	2021	HVAC option	7,984	1,024	$2,114.94
6	Gas	Cond Crawl	Frame	2021	HVAC option	6,583	930	$1,833.88
6	Gas	Slab	Frame	2021	Water Heater option	7,007	1,183	$2,155.00
6	Gas	Cond Basement	Frame	2021	Water Heater option	8,408	1,131	$2,282.00
6	Gas	Cond Crawl	Frame	2021	Water Heater option	6,973	1,033	$1,993.00
6	Gas	Slab	Frame	2021	Ventilation option	7,198	1,126	$2,119.89
6	Gas	Cond Basement	Frame	2021	Ventilation option	8,672	1,068	$2,250.70
6	Gas	Cond Crawl	Frame	2021	Ventilation option	7,189	995	$1,981.03
6	Gas	Slab	Frame	2021	Duct option	6,832	1,043	$1,985.04
7	Gas	Slab	Frame	2018	Base	7,284	1,701	**$2,735.00**
7	Gas	Cond Basement	Frame	2018	Base	8,822	1,641	$2,873.00
7	Gas	Cond Crawl	Frame	2018	Base	7,236	1,497	$2,515.00
7	Gas	Slab	Frame	2018	2021 ceiling insulation	7,239	1,694	$2,722.00
7	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	8,807	1,628	$2,857.00
7	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,221	1,484	$2,499.00
7	Gas	Slab	Frame	2021	Base	7,321	1,605	$2,639.32
7	Gas	Cond Basement	Frame	2021	Base	8,787	1,523	$2,743.86
7	Gas	Cond Crawl	Frame	2021	Base	7,283	1,419	$2,438.89
7	Gas	Slab	Frame	2021	HVAC option	6,879	1,403	$2,369.51
7	Gas	Cond Basement	Frame	2021	HVAC option	8,344	1,333	$2,486.54

7	Gas	Cond Crawl	Frame	2021	HVAC option	6,870	1,244	$2,201.23
7	Gas	Slab	Frame	2021	Water Heater option	7,374	1,594	$2,635.00
7	Gas	Cond Basement	Frame	2021	Water Heater option	8,824	1,494	$2,718.00
7	Gas	Cond Crawl	Frame	2021	Water Heater option	7,327	1,404	$2,429.00
7	Gas	Slab	Frame	2021	Ventilation option	7,307	1,588	$2,619.63
7	Gas	Cond Basement	Frame	2021	Ventilation option	8,772	1,502	$2,719.84
7	Gas	Cond Crawl	Frame	2021	Ventilation option	7,271	1,403	$2,420.51
7	Gas	Slab	Frame	2021	Duct option	7,210	1,409	$2,418.88
7	Gas	Slab	Frame	2021	No HRV	7,087	1,671	$2,678.24
7	Gas	Cond Basement	Frame	2021	No HRV	8,479	1,607	$2,792.07
7	Gas	Cond Crawl	Frame	2021	No HRV	7,028	1,466	$2,455.11



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