



Home Innovation
RESEARCH LABS™

2021 IECC Residential Cost Effectiveness Analysis

Prepared For

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

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

BACKGROUND

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

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

METHODOLOGY

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

The analysis for this study is based on a methodology¹ 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 changes².

For analysis in this report, annual energy use costs were developed using BEopt³ 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency⁴. The energy prices are national average annual 2019 residential prices: \$0.1301/kWh for electricity; \$1.051/therm for natural gas.

Construction costs were developed based on RSMeans⁵ 2021 Residential Cost Data. Costs for mechanical equipment were sourced from distributor web sites. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of fees on rater web sites. Cost details are provided for individual code changes in Appendix A and by climate zone in Appendix B.

Appendix A costs are reported as both total to the builder and total to consumer. The total cost to builder includes overhead and profit (designated in the tables as “w/O&P”) applied to individual component costs (materials and labor) to represent the cost charged by the sub-contractor. The total cost to consumer is based on applying a builder’s gross profit margin of 19.0% to the builder’s total cost⁶. These represent national average costs. For specific locations, the Appendix A costs could be

¹ Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012.

² 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012.

³ BEopt (Building Energy Optimization Tool) software: <https://beopt.nrel.gov/home>

⁴ Energy Information Agency: <https://www.eia.gov/>

⁵ RSMeans, <https://www.rsmeans.com/>

⁶ Industry average gross profit margin for 2017, as reported in NAHB’s Builder’s Cost of Doing Business Study, 2019 Edition.

https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/?_ga=2.73913042.1310550892.1620653840-1896975365.1593698293

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

Standard Reference House

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

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

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

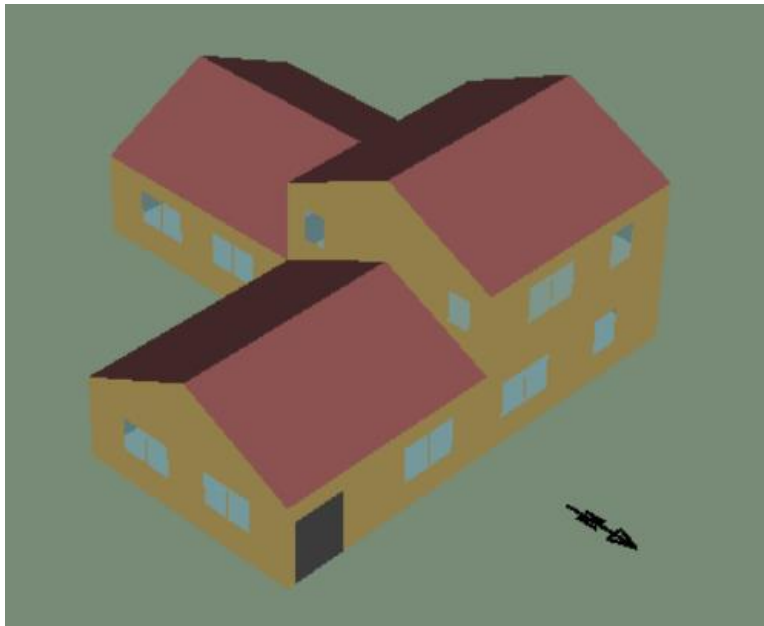


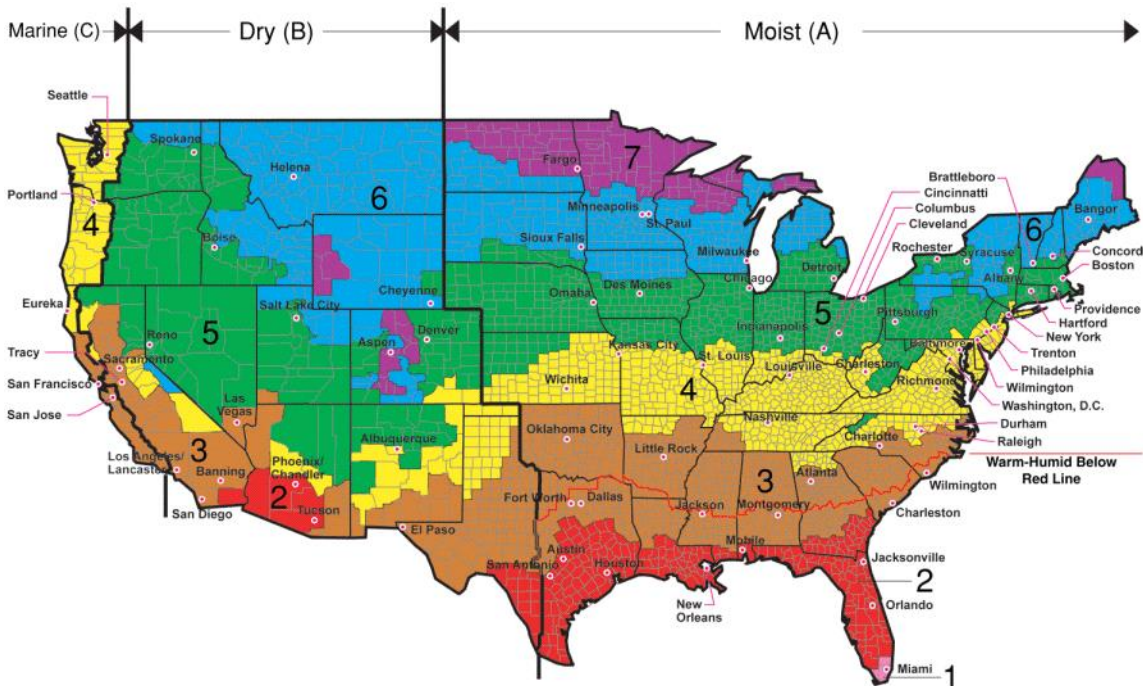
Figure 1. Simulation Model of Standard Reference House

Representative Locations

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

Table 2. Representative Locations

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



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

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

Figure 2. DOE Climate Zone Map

Configurations and Weighted Averaging

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

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

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

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

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

HVAC and Water Heating Equipment

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

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

High efficiency water heaters for electric houses consist of heat pump water heater, 50 gallon capacity, 2.0 EF⁷

Table 4. Standard Efficiency Equipment

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

Table 5. High Efficiency Equipment Options

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

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

Changes for 2021

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

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

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

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

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

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

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

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

RESULTS

Construction Costs

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

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

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

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

*Indicates a code change that was included in the energy modeling analysis for this study (10 total)

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

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

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

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

Energy Use Costs and Savings

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

Cost Effectiveness

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

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

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

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

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

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

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

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

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

Configuration	CZ 3 Memphis			National
	Electric	Gas	Weighted Ave*	Average
2021 without additional efficiency package options	6.8%	7.6%	7.1%	5.5%
2021 with Water Heater option	14.1%	9.9%	12.2%	9.3%

*Weighted average based on 55% electric houses and 45% gas houses, adapted from ABPS

Cost Effectiveness of Selected Code Changes

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

Table 13. Incremental Construction Cost of Thermal Envelope Changes

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

Table 14. Annual Energy Use Cost of Thermal Envelope Changes

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

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

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

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

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

Table 17. Cost effectiveness of HRV in CZ 7

	CZ 7
Configuration	Duluth
Incremental cost of HRV	\$3,206
Annual energy cost, 2021* without HRV	\$2,538
Annual energy cost, 2021* with HRV	\$2,514
Energy cost savings for HRV	1.0%
Simple payback, years	131

*Without additional efficiency package options

Table 18. Incremental Construction Cost of Additional Efficiency Package Options

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

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

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

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

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

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

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

CONCLUSIONS

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

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

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

APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

The estimated construction costs for the selected individual code changes are shown below. Construction costs were developed using RSMeans⁸ 2021 Residential Data. Costs for mechanical equipment were sourced from distributor web sites⁹. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of rater web sites. See Appendix B for costs by climate zone.

RE7

Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

⁸ RSMeans, <https://www.rsmeans.com/>

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

RE18, RE20, RE21

Reference Code Section

R401.3 Certificate

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost to add information to the certificate

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

RE29

Reference Code Section

Table R402.1.2; Table R402.1.3

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

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

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

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

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

RE32

Reference Code Section

Table R402.1.2, Table R402.1.3

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost of additional slab edge insulation, CZ 3

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

Cost of additional slab edge insulation, CZ 4-5

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

RE33, RE36

Reference Code Section

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

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

RE34

Reference Code Section

Table R402.1.3

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE35

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of the Code Change:

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

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 3-4. The analysis is based on an incremental material cost of \$0.15/SF for improving window U-factor from 0.32 to 0.30 as determined by the California Energy Commission¹⁰.

The Department of Energy and EPA Energy Star along with those involved in the development of energy codes have traditionally had problems developing a clear incremental cost for changes in window thermal performance. An earlier report based on cost data collected by the U.S. Department of Energy indicated an incremental cost of \$0.18/SF window area for improving U-value from 0.35 to 0.32¹¹. In this analysis, prices used to develop the incremental cost associated with the code change are a best guess based on the available data.

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

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

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

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

RE37

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE105

Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE46

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

RE47

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

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

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

RE49

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

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

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

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

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

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

RE52

Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

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

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

RE55

Reference Code Section

R402.2.8 Basement walls

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost to increase wall insulation in the stairway

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

RE72

Reference Code Section

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

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost to install additional sealant for narrow framing cavities

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

RE82

Reference Code Section

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

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

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

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

RE96

Reference Code Section

R402.4.1.2 Testing

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE103

Reference Code Section

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

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost of air sealed electrical and communication outlet boxes

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

***Estimated quantity of affected boxes**

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

RE106

Reference Code Section

R403.1.1 Programmable thermostat

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE109

Reference Code Section

R403.3.2 Ducts located in conditioned space

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

RE112

Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Estimated cost of the duct leakage test

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

RE130

Reference Code Section

R403.6.3 Testing (new)

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Estimated cost of the mechanical ventilation test

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

RE133

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Incremental cost of high efficacy bath exhaust fan

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

RE134

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

Incremental cost of variable-speed furnace

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

Cost of both variable-speed furnace and ventilator fan

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

RE139

Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

Summary of the Code Change:

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

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

Cost Implication of the Code Change:

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

Cost to install an ERV

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

RE145

Reference Code Section

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

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

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

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

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

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

***Quantities**

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

RE148

Reference Code Section

R404.1.1 Exterior lighting

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE149

Reference Code Section

R404.3 Exterior lighting controls (new)

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost of exterior lighting control with light sensor

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

RE151

Reference Code Section

R405.2

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE178

Reference Code Section

Table R405.4.2

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

RE209

Reference Code Section

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

Summary of the Code Change:

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

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

Cost Implication of the Code Change:

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

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

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

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

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

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

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

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

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

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

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

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

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

Ventilation Option Gas House

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

Ventilation Option Electric House

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

Ventilation Option Electric House in CZ 2

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

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

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

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

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

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

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

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

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

CE40.2

Reference Code Section

R303.1.2 Insulation mark installation

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

Cost to provide insulation certificate

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

CE151.2

Reference Code Section

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

Summary of the Code Change:

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

Cost Implication of the Code Change:

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

APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

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

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

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

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

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

APPENDIX C: LOCATION ADJUSTMENT FACTORS

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

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

APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

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

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

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

APPENDIX E: ENERGY USE BY CLIMATE ZONE

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

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

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

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

Configuration		Annual Energy Use CZ 6 Helena Frame Wall Natural Gas				Annual Energy Use CZ 7 Duluth*** Frame Wall Natural Gas			
		kWh/yr	thrm/yr	\$/yr	Savings*	kWh/yr	thrm/yr	\$/yr	Savings*
2018 Baseline	Slab	7,374	1,201	2,221		7,178	1,676	2,735	
	Basement	8,962	1,166	2,391		8,664	1,612	2,873	
	Crawl**	7,345	1,057	2,066		7,119	1,473	2,515	
2018 + 2021 ceiling insulation	Slab	7,359	1,192	2,210	0.5%	7,116	1,665	2,722	0.5%
	Basement	8,945	1,155	2,378	0.5%	8,649	1,599	2,857	0.6%
	Crawl**	7,333	1,047	2,054	0.6%	7,105	1,460	2,499	0.6%
2018 + 2021 slab insulation	Slab								
	Ave for CZ								
2018 + 2021 wall cont. insulation	Slab								
	Basement								
	Crawl**								
2018 + 2021 window U-Factor	Slab					7,087	1,671	2,678	2.1%
	Basement					8,479	1,607	2,791	2.9%
	Crawl**					7,028	1,466	2,454	2.4%
2021 without efficiency options	Slab	6,970	1,198	2,165	2.5%	7,321	1,605	2,639	3.5%
	Basement	8,379	1,162	2,311	3.3%	8,787	1,523	2,743	4.5%
	Crawl**	6,937	1,052	2,008	2.8%	7,283	1,419	2,438	3.1%
2021 + HVAC option	Slab	6,586	1,054	1,964	11.6%	6,879	1,403	2,369	13.4%
	Basement	7,984	1,024	2,115	11.5%	8,344	1,333	2,486	13.5%
	Crawl**	6,583	930	1,833	11.3%	6,870	1,244	2,201	12.5%
2021 + Water Heater option	Slab	7,037	1,188	2,155	3.0%	7,400	1,600	2,635	3.7%
	Basement	8,441	1,135	2,282	4.6%	8,854	1,499	2,718	5.4%
	Crawl**	7,005	1,038	1,993	3.5%	7,353	1,409	2,429	3.4%
2021 + Ventilation option	Slab	7,198	1,126	2,120	4.5%	7,307	1,588	2,619	4.2%
	Basement	8,672	1,068	2,250	5.9%	8,772	1,502	2,719	5.4%
	Crawl**	7,189	995	1,980	4.2%	7,271	1,403	2,420	3.8%
2021 + Duct option	Slab	6,832	1,043	1,985	10.6%	7,210	1,409	2,418	11.6%
	Crawl**								
*Cost savings (\$/yr) relative to 2018 baseline									
**Crawl: vented CZ 3-4; conditioned CZ 5-7									
***For CZ 7 all 2021 results include an HRV									



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