Home Innovation
RESEARCH LABS™

ESTIMATED COSTS OF THE 2021 IRC CODE CHANGES

Prepared For

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400 Prince George's Blvd. | Upper Marlboro, MD 20774 | 800.638.8556 | HomeInnovation.com

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

ASTM	American Society for Testing and Materials
CPVC	Chlorinated polyvinyl chloride
CY	Cubic yards
DHW	Domestic hot water
dia.	Diameter
EA	Each
ESS	Energy storage systems
HR	Hour
HVAC	Heating, ventilation, and air conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IN	Inch
IRC	International Residential Code
LF	Linear feet
MPH	Miles per hour
NPT	National pipe thread
O&P	Overhead and profit
PEX	Cross-linked polyethylene
PSF	Pounds per square foot
SF	Square feet
u.i.	United inches, a metric for window size consisting of the sum of the height and width of the window
WSP	Wood structural panel

BACKGROUND

The 2021 International Residential Code (IRC) includes several changes which impact construction costs for residential construction.[1] The objective of this analysis is to quantify the incremental construction cost associated with constructing a house compliant with the 2021 IRC relative to a 2018 IRC baseline. Home Innovation Research Labs (Home Innovation) estimated the expected cost impacts of selected code changes provided by the National Association of Home Builders (NAHB) using four standard Reference Houses sited in various cities nationwide. Cost estimates are aggregated in ranges of high to low based on various methods or components that might be used to comply with the code.

METHODOLOGY

National Construction Cost

Reference Houses and their site locations were initially defined in a report titled *Estimated Costs of the 2015 IRC Code Changes.*[2] The four Reference Houses were selected for their similarity to new home offerings in the six metropolitan areas selected as site locations – Miami, Dallas, Los Angeles, Seattle, New York, and Chicago, and their size proximity to a national average of 2,607 SF. Additional information on the basis for the Reference House configurations is provided in Appendix C. Elevations and floor plans for these Reference Houses are provided in Appendices D through G. These single-family detached houses define the reference or base house that provides the starting point for estimation of the incremental cost or savings of the code change for the 2021 IRC relative to the 2018 IRC.

For this study, construction costs were developed primarily based on RSMeans 2021 Residential Cost Data.[3] Costs for some materials were sourced from distributor websites. Costs associated with testing or fees provided by an energy rater, engineer, or other third party were estimated based on an internet search of associated web sites. Cost details are provided for individual code changes in Appendix A.

Appendix A costs are reported as both total to the builder and total to consumer. The total cost to builder includes overhead and profit (designated in the tables as "w/O&P") applied to individual component costs (materials and labor) to represent the cost charged by the sub-contractor. The total cost to consumer is based on applying a builder's gross profit margin of 19.0% to the builder's total cost.[4] These costs represent national average costs. For specific locations, the Appendix A costs could be modified by applying the appropriate location adjustment factor from RSMeans; selected location adjustment factors from RSMeans are listed in Appendix B.

[1] International Code Council, www.iccsafe.org/Pages/default.aspx

[2] Estimated Costs of the 2015 Code Changes, Home Innovation Research Labs, www.homeinnovation.com/trends_and_reports/featured_reports/estimated_costs_of_the_2015_irc_code_changes

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

[4] 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

Reference House Features

The Reference House features used in this analysis are shown in Table 1.

Table 1. Features of the Reference Houses

	Reference House			
Feature	**1**	**2**	**3**	**4**
Square Feet	2,607	2,607	2,607	2,607
Foundation	Slab	Slab	Basement	Basement
Number of Stories	1	2	1	2
Number of Bedrooms	3	4	3	4
Number of Bathrooms	2	2.5	2	3
Garage, attached	2-car	2-car	2-car	2-car
Heat, Gas Furnace	Yes	Yes	Yes	Yes
Cooling, (Electric) central air	Yes	Yes	Yes	Yes
Hot Water, Gas 50 gallon tank	Yes	Yes	Yes	Yes
9 ft. Ceilings, 1st	Yes	Yes	Yes	Yes
8 ft. Ceilings, 2nd	n/a	n/a	Yes	Yes
Energy Star appliances	Yes	Yes	Yes	Yes
Laundry Room	Yes	Yes	Yes	Yes
Walls, 2x4 (Climate Zones 1 & 2)	Yes	Yes	n/a	n/a
Walls, 2x6 (Climate Zones 3 thru 8)	n/a	n/a	Yes	Yes
Basement, Conditioned, Unfinished	n/a	n/a	Yes	Yes
Furnace Location	Attic	Attic	Basement	Basement
Water Heater Location	Interior	Garage	Basement	Basement
Window SF/% gross wall	360/18%	315/12%	360/18%	330/12%
Cladding	Brick, 4 sides	Brick, 4 sides	Brick, 4 sides	Stucco
Roof Pitch	12/12	6/12	9/12	4/12

RESULTS

Estimated Cost of 2021 IRC Code Compliance for Reference Houses by Location

Table 2 summarizes the estimated construction costs of the selected code changes that affect the Reference Houses. The costs are aggregated by location and house configuration. The results are grouped into four climate zone categories and reported in ranges of "High" and "Low" based on the code changes that would typically be applicable to the Reference Houses in those locations. It was assumed that the Reference Houses were not built in coastal zones or subject to flooding.

Table 3 summarizes the estimated construction costs of selected code changes that may or may not affect the Reference Houses and are not included in the aggregated summary. These code changes typically apply only in specific locations (e.g., hurricane-prone areas or flood zones), to items that would be an optional feature for most homes (e.g., decks), or to alternative methods of compliance. Those costs can be added to or subtracted from the aggregated costs in Table 2 as applicable to a particular location or a specific building.

The energy efficiency requirements in the IRC (Chapter 11) are the same as the residential provisions in the International Energy Conservation Code (IECC). Tables 2 and 3 include a line item cost for code changes in the 2021 IECC. This cost represents the total cost of selected changes that were estimated separately in a previous report by Home Innovation.[5]

A detailed analysis of each individual code change is provided in Appendix A.

[5] Home Innovation Research Labs: 2021 IECC Residential Cost Effectiveness Analysis: https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf?_ga=2.27433528.541784929.1640700746-460189115.1639582871

Table 2. Estimated Cost to Consumer of 2021 IRC Code Compliance

		Selected Cities	Miami, Dallas		Los Angeles, Seattle, New York		Chicago, Helena		Duluth, Fairbanks	
		Climate Zones	1 & 2		3 & 4		5 & 6		7 & 8	
		Reference Houses	1 & 2		1, 2, 3, & 4		3 & 4		3 & 4	
			Cost Range ($)							
Ref #	**Description of Change**	**2021 IRC Section**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
R-8 (RB164)	Revises the minimum footing size in tables for consistency with common engineering practices.	R403.1; Tables R403.1(1-3)	$329	$0	$329	($398)	($346)	($1,061)	($693)	($1,061)
R-9 (RB183)	Requires vapor retarders for slab-on-ground floors be 10-mil and conform to ASTM D1743 Class A requirements (formerly required 6-mil)	R506.2.3 Vapor retarder	$1,093	$543	$1,100	$543	$1,100	$543	$1,100	$543
R-10 (RB238)	Requires an insulation stop be installed around exterior window and door openings to allow drainage of water.	R703.4.1 Flashing installation	$1,419	$1,259	$1,419	$1,259	$1,419	$1,312	$1,419	$1,312
R-11 (RB242)	Divides the water-resistive barrier requirements behind stucco into sections for dry climates and moist or marine climates, and for moist or marine climates requires a 3/16-inch air space or material with high drainage efficiency.	R703.7.3 Water-resistive barriers (stucco)	$2,654	$0	$2,802	$0	$2,802	$0	$0	$0
R-12 (RB289)	Adds testing requirements to Appendix AF Radon Control Methods.	AF104 Testing	$278	$0	$278	$0	$278	$0	$278	$0
Sub-Total IRC Building Provisions to Consumer			**$5,772**	**$1,802**	**$5,927**	**$1,404**	**$5,252**	**$794**	**$2,105**	**$794**
Sub-Total IECC Provisions to Consumer			**$8,369**	**$3,979**	**$11,755**	**$3,474**	**$11,900**	**$4,426**	**$8,354**	**$6,618**
Total to Consumer			**$14,141**	**$5,781**	**$17,682**	**$4,878**	**$17,152**	**$5,220**	**$10,459**	**$7,412**

Table 3. Additional Cost to Consumer of 2021 IRC Code Compliance Not Attributed to the Reference Houses

		Selected Cities	Miami, Dallas		Los Angeles, Seattle, New York		Chicago		Fairbanks	
		Climate Zones	1 & 2		3 & 4		5 & 6		7 & 8	
		Reference Houses	1 & 2		1, 2, 3, & 4		3 & 4		3 & 4	
			Cost Range ($)							
Ref #	Description of Change	2021 IRC Section	High	Low	High	Low	High	Low	High	Low
R-1 (G12.2)	Modifies the definition of "windborne debris region" to include sites within one mile of the mean high water line of an Exposure D condition.	R202 Definitions	$7,174	$6,105	$7,174	$6,105	$7,174	$6,378	NA	NA
R-2 (RB40)	Adds hillside homes as an irregular building type to be addressed by engineered design.	R301.2.2.6 Irregular buildings	$2,222	$1,728	$2,222	$1,728	$2,222	$1,728	$2,222	$1,728
R-3 (RB43)	Restores the ability to construct a story of a dwelling using 12-foot-high bearing walls without requiring an engineered design.	R301.3 Story height	$0	($1,481)	$0	($1,481)	$0	($1,481)	$0	($1,481)
R-4 (RB46)	Separates the live load requirements for guards and handrails and only requires guards to resist a 200-pound load in the outward and downward directions.	R301.5 Live load; Table R301.5	$394	($301)	$394	($301)	$394	($301)	$394	($301)
R-5 (RB90)	For emergency escape and rescue openings, adds a requirement that window opening control devices shall not exceed 70 inches above the finished floor.	R310.1.1 Operational constraints - control devices	$1,031	$0	$1,031	$0	$1,031	$0	$1,031	$0
R-6 (RB152)	Requires a habitable attic to be considered a story above grade plan except where it meets specific criteria.	R326 Habitable attics	$5,031	$4,671	$5,031	$4,671	$5,031	$4,671	$5,031	$4,671

R-7 (RB154)	Replaces the term "Stationary Storage Battery Systems" with "Energy Storage Systems (ESS)" and expands requirements for ESS installations.	R202 Definitions; R328 Energy Storage Systems	$1,919	$667	$3,548	$1,919	$3,548	NA	$3,548	NA
R-13 (RB3)	Requires glazed areas in kitchens be openable unless a local exhaust system is installed.	R303.1 Habitable rooms	$0	($222)	$0	($222)	$0	($222)	$0	($222)
R-14 (RP10)	Limits the developed length of hot water piping to 100 feet.	P2905.3 Hot water supply to fixtures	$784	$0	$784	$0	$784	$0	$784	$0
IECC Provisions			**$1,401**	**$0**	**$4,045**	**$0**	**$4,164**	**$0**	**$4,105**	**$0**

APPENDIX A: COST DETAILS OF INDIVIDUAL CODE CHANGES

R-1 (G12.2)

IRC R202 Definitions

Summary of Code Change:

The code change modifies the definition of "windborne debris region" to include sites within one mile of the mean high water line of an Exposure D condition (defined by 5,000 feet or more of open water upwind of the site) instead of just one mile from a coastal mean high water line.

Cost Implication of Code Change:

This revision could require buildings adjacent to wide rivers or large inland lakes but not directly fronting on the Atlantic Ocean or Gulf of Mexico to provide windborne debris protection where not already required by code. Analysis is based on the additional cost to install impact resistant glass (Table R-1-A) or panel type hurricane shutters (Table R-1-D) for the Reference Houses.

Note that installing wood structural panels for protection is an option that is primarily used for existing homes. Table R-1-F shows the estimated cost of wood structural panels as a low cost option for reference, but this cost is not included in rollup Table 3.

Applicability of Code Change:

Applicable for areas within hurricane-prone regions, Exposure D condition, ultimate design wind speed of 140 mph or greater.

Table R-1-A. Incremental Cost of Impact Resistant Windows

	Reference House			
Component	**1**	**2**	**3**	**4**
Standard window, insulated	(5,133)	(4,525)	(5,133)	(4,728)
Impact resistant window	10,944	9,648	10,944	10,080
Total to Builder	**5,811**	**5,123**	**5,811**	**5,352**
Total to Consumer	**7,174**	**6,324**	**7,174**	**6,607**

Table R-1-B. Unit Cost of Windows

Component	Unit	Material	Labor	Total	w/O&P	Cost/SF
Vinyl double-hung, 101 u.i.	EA	197.00		197.00	216.70	13.51
Impact resistant vinyl double-hung, 101 u.i.	EA	420.00		420.00	462.00	28.80

Table R-1-C. Window and Glass Door Area, SF

Reference House	Window	Door	Total
1	360	20	380
2	315	20	335
3	360	20	380
4	330	20	350

Table R-1-D. Cost of Hurricane Panels, Clear Polycarbonate

	Reference House			
Component	**1**	**2**	**3**	**4**
Hurricane panel, clear polycarbonate	5,609	4,945	5,609	5,166
Total to Builder	**5,609**	**4,945**	**5,609**	**5,166**
Total to Consumer	**6,925**	**6,105**	**6,925**	**6,378**

Table R-1-E. Unit Cost of Polycarbonate Hurricane Panels

Component	Unit	Material	Labor	Total	w/O&P
Hurricane panels, clear polycarbonate	SF	10.00	2.28	12.28	14.76

Table R-1-F. Cost of Hurricane Panels, Wood Structural Panels

	Reference House			
Component	**1**	**2**	**3**	**4**
WSP, 1/2 CDX	2,737	2,395	2,737	2,509
Total to Builder	**2,737**	**2,395**	**2,737**	**2,509**
Total to Consumer	**3,379**	**2,956**	**3,379**	**3,097**

Table R-1-G. Unit Cost of Wood Structural Panel

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
4' x 8' x 1/2 CDX	EA	16.64		16.64	18.30	1	18
Storm panel screws	EA	2.34		2.34	2.58	16	41
Labor: cut, install, remove, store	HR				108.90	0.5	54
Total							**114**

R-2 (RB40)

IRC R301.2.2.6 Irregular buildings

Summary of Code Change:

The code change adds hillside light-frame construction houses as an irregular building type to be addressed by an engineered design, where all criteria apply for grade slope, cripple wall height, and living space below the lowest framed floor, with an exception for concrete or masonry foundations over the full length of all sides except the downhill side.

Cost Implication of Code Change:

This code change may increase the cost of hillside light-frame construction where applicable. Analysis is based on the estimated cost of an engineered design for an average size house. The analysis does not include the additional cost of foundation reinforcing, blocking within the lowest framed floor, tie-backs, and other structural elements as the design of such elements will be project-specific and depend on the seismic design category, grade slope, cripple wall height, foundation type and other features of the house.

Applicability of Code Change:

This code change is applicable to hillside light-frame construction (not applicable to the Reference Houses because those have either slab-on-grade or full basement foundations).

Table R-2-A. Cost of an engineered design for a hillside home: high estimate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Engineering fee	EA				1800.00	1	1,800
Total to Builder							**1,800**
Total to Consumer							**2,222**

Table R-2-B. Cost of an engineered design for a hillside home: low estimate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Engineering fee	EA				1400.00	1	1,400
Total to Builder							**1,400**
Total to Consumer							**1,728**

R-3 (RB43)

IRC R301.3 Story height

Summary of Code Change:

The code change adds an exception allowing a story of a dwelling to be constructed using 12-foot-high bearing walls provided the wall studs meet Exception 2 or 3 of Section R602.3.1 or are engineered for gravity and out-of-plane wind loads, and wall bracing amounts for the story in question are adjusted in accordance with Section R602.10.

Cost Implication of Code Change:

Analysis is based on the estimated cost savings where an engineered design is no longer required. The analysis does not include any additional cost savings associated with reduced wall bracing, hold-downs, and other structural elements as the design of such elements will be project-specific and depend on the seismic design category and other features of the house.

Applicability of Code Change:

Applicable for designs with bearing walls up to 12-feet-high.

Table R-3-B. Cost saving where an engineered design is no longer required: high estimate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Engineered design	EA				1200.00	(1)	(1,200)
Total to Builder							**(1,200)**
Total to Consumer							**(1,481)**

Table R-3-A. Cost saving where an engineered design is no longer required: low estimate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Engineered design	EA				600.00	(1)	(600)
Total to Builder							**(600)**
Total to Consumer							**(741)**

R-4 (RB46)

IRC Table R301.5

Summary of Code Change:

The code change separates the live load requirements for guards and handrails and only requires guards to resist a 200-pound load in the outward and downward directions, i.e., the guard system is intended to protect against a fall from a higher elevation to a lower elevation.

Cost Implication of the Code Change:

This change may increase or decrease the cost of construction. For 2021, IRC Section R507 Exterior Decks adds a new section R507.10 Exterior guards that requires guard loads be transferred to the deck framing with a continuous load path to the deck joists. Where guards are connected to the side of a deck joist, the joist must be connected to the adjacent joists to prevent rotation of the joist. Section R507.10 does not prescribe methods of attachment.

Analysis is based on two scenarios for a 20-foot wide by 14-foot deep deck, with 11 guard posts (based on maximum 6-foot spacing) installed inside the deck joists. The first scenario represents a cost increase, assuming the guard posts were previously only bolted to the rim joist or side joist with two ½" diameter bolts each post, and no blocking or other method of transferring loads to adjacent joists or deck framing is provided, and now blocking and longer bolts are required (Table R-4-A). The second scenario represents a cost savings, assuming loads from the guard posts were previously transferred to the deck framing using blocking and tension ties at both the top and bottom bolts, and now tension ties are only required for the top bolts (Table R-4-B).

Applicability of Code Change:

Applicable where outdoor decks are installed that require a guard.

Table R-4-A. Incremental Cost of Guard Post Connection Using Blocking & Commodity Fasteners

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Blocking, 2x10 treated	LF	2.08	1.35	3.43	4.49	50	224
Blocking, 4x4 treated	LF	2.26	1.35	3.61	4.68	8	37
Drill hole for bolts	IN		0.65	0.65	1.06	33	35
1/2 galv bolts, 6"	EA	2.11	2.09	4.20	5.72	(22)	(126)
1/2 galv bolts, 10"	EA	2.77	2.26	5.03	6.73	22	148
Total to Builder							**319**
Total to Consumer							**394**

Table R-4-B. Cost Savings of Guard Post Connection Using Blocking and (1) Tension-Tie per post instead of (2)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Tension tie, with screws	EA	14.89	3.56	18.45	22.17	(11)	(244)
Total to Builder							**(244)**
Total to Consumer							**(301)**

R-5 (RB90)

IRC R310.1.1 Operational constraints and opening control devices (R310 Emergency Escape and Rescue Openings)

Summary of Code Change:

For emergency escape and rescue openings, the code change adds a requirement that window opening control devices shall be not more than 70 inches above the finished floor.

Cost Implication of the Code Change:

This change may increase the cost of construction in some cases. There is no cost impact for an example single-hung or double-hung window, 48-inches tall, installed in a 9-foot tall wall, with a 24-inch vertical opening, 44-inch sill height (maximum allowed), and 2-inch tall latch, where the latch height would be 70 inches.

For a casement window or sliding window with high and low latches, the height of the high latch could exceed 70 inches. For an example casement window, 60-inches tall, with a 32-inch sill height, low latch 20-inches above the sill, and high latch 40-inches above the sill, the height of the high latch above the floor would be 72 inches. The analysis is based on the cost to install a 24-inch tall casement above a 36-inch tall egress casement, in place of a 60-inch tall casement window, based on a quantity of two egress windows in the master bedroom and one egress window in the other three bedrooms. It is assumed that installing a compliant single-hung or double-hung window is not an acceptable choice where the house has all casement windows.

Applicability of Code Change:

Applicable where the latch height of an emergency escape window exceeds 70 inches.

Table R-5-A. Incremental Cost of Compliance for Example Casement Window

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Vinyl-clad casement, insulated low-E, 2'x5'	EA	355.00	36.50	391.50	450.00	(5)	(2,250)
Vinyl-clad casement, insulated low-E, 2'x3'	EA	266.00	29.50	295.50	340.00	5	1,700
Vinyl-clad casement, insulated low-E, 2'x2'	EA	208.00	29.50	237.50	277.00	5	1,385
Total to Builder							**835**
Total to Consumer							**1,031**

R-6 (RB152)

IRC R326 Habitable attics (new)

Summary of Code Change:

The code change requires a habitable attic to be considered a story above grade plane except where it meets specific criteria. For a habitable attic not to be considered a story above grade plane, it must be no greater than 1/3 of the floor area below and can only be located over a first or second story above grade plane. A habitable attic can be up to 1/2 of the floor area below or located over a third story above grade plane if an automatic fire sprinkler system is installed.

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases. Analysis is based on the additional cost to install a fire sprinkler system for an example townhouse where a habitable attic is provided above the third story of the townhouse, effectively creating a four-story townhouse.[6] The estimated cost of the sprinkler system is shown in Table R-6-A. The water source is assumed to be public (municipal); homes on well water commonly require a stored water source with pump and tank which can add significantly to the cost of a sprinkler system.

The National Fire Protection Agency (NFPA) reports that the average cost of a residential sprinkler system in 2013 was $1.35 per "sprinklered" square foot.[7] That cost rises to $1.63 when adjusted for inflation through 2021.[8] The estimated cost of a sprinkler system based on this value for the example townhouse is shown in Table R-6-C.

Applicability of Code Change:

Applicable where a space meeting the criteria to be considered a habitable attic is provided.

[6] Example townhouse adapted from the Standard Reference Townhouse used by Home Innovation in a prior study: https://www.homeinnovation.com/trends_and_reports/featured_reports/2018_icc_cost_analysis_for_mf_buildings

[7] Home Fire Sprinkler Cost Assessment – 2013: https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Suppression/HomeFireSprinklerCostAssessment2013.ashx

[8] CPI Inflation Calculator: https://www.bls.gov/data/inflation_calculator.htm

Table R-6-A. Cost of Sprinkler System

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
Flow alarm	EA	116.00	12.70	128.70	149.00	1	149
Flow switch (valve supervisory switch)	EA	267.00	20.50	287.50	330.00	1	330
Sprinkler head, fast response glass bulb, 135-155°F	EA	37.00	20.50	57.50	74.00	12	888
Sprinkler head escutcheons, standard, brass tone, 1"	EA	3.80	8.25	12.05	17.65	12	212
CPVC fire suppression pipe, 1"	LF	1.81	1.74	3.55	4.84	200	968
CPVC fire suppression tee, 1"	EA	5.05	21.50	26.55	41.00	14	574
CPVC fire suppression 90 elbow, 1"	EA	4.11	14.55	18.66	28.50	12	342
CPVC fire suppression cap, 1"	EA	1.55	7.35	8.90	13.70	4	55
CPVC fire suppression coupling, 1"	EA	2.38	14.55	19.93	26.50	2	53
CPVC fire suppression adapter, metal thread, 1"x1/2"	EA	5.25	7.35	12.60	17.75	12	213
Total to Builder							**3,784**
Total to Consumer							**4,671**

***Table R-6-B. Quantity of Sprinkler Heads, 4-story townhouse**

Room	Qty
Bedrooms (3)	4
Bedroom Hallway	1
Attic Loft	1
Living Room	1
Dining Room	1
Family Room	1
Kitchen	1
Garage, ground level	2
Total	**12**

Table R-6-C. Cost of Sprinkler System based on NFPA reported average cost

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Reported Cost	SF				1.63	2,500	4,075
Total to Builder							**4,075**
Total to Consumer							**5,031**

R-7 (RB154)

IRC R328 Energy Storage Systems

Summary of Code Change:

The code change replaces the term “Stationary Storage Battery Systems” with “Energy Storage Systems (ESS)” and expands requirements for ESS installations. ESS can only be installed in garages, detached accessory structures, outdoors, or inside a dwelling in enclosed utility closets, basements, storage, or utility spaces with finished or noncombustible walls and ceilings. Depending on where an ESS is installed, smoke alarms (and in certain cases heat detectors), vehicle barriers, mechanical ventilation (where charging could produce hydrogen or other flammable gases), and/or an enclosed space with finished or noncombustible walls and ceilings must be provided.

Cost Implication of the Code Change:

Analysis is based on the additional cost for an ESS-ready space in a garage or basement. It is assumed that the ESS does not produce hydrogen or flammable gases and therefore does not require ventilation (otherwise, an explosion-proof ventilation fan would be required). For an ESS-ready space in a garage, it is assumed bollards for protection from vehicles and a smoke detector are provided (Table R-7-A). Alternatively, a cost is provided for protection from vehicles using a curb (Table R-7-B). For an ESS-ready space in a basement, it is assumed a 12-foot by 12-foot enclosed space with wood-frame walls finished with Type X gypsum is provided with a smoke detector for the enclosed space (Table R-7-C).

Applicability of Code Change:

Applicable where an indoor ESS or ESS-ready space is to be installed. Note that manufacturer instructions may limit ESS installation in garages to where the garage temperature will not fall below freezing.

Table R-7-A. ESS-Ready Garage Location: Bollards for Protection from Vehicles

Component	Unit	Material	Labor	Equipment	Total	w/O&P	Quantity	Cost
Impact protection: (3) Safety Bollards, steel, bolted, concrete filled, 5" dia.	LF	58.00	1.93	1.68	61.61	68.50	16	1,096
Footing for bollard	CY	208.00	140.00	0.96	348.96	460.00	0.5	230
Smoke detector, hardwired, ceiling	EA	126.00	55.00		181.00	228.00	1	228
Total to Builder								**1,554**
Total to Consumer								**1,919**

Table R-7-B. ESS-Ready Garage Location: Curbs for Protection from Vehicles

Component	Unit	Material	Labor	Equipment	Total	w/O&P	Quantity	Cost
Impact protection: precast concrete curb, 6" wide	LF	9.05	2.10	1.22	12.37	14.70	16	235
Drilling concrete floor for rebar	EA	0.05	5.85		5.90	9.65	8	77
Smoke detector, hardwired, ceiling	EA	126.00	55.00		181.00	228.00	1	228
Total to Builder								**540**
Total to Consumer								**667**

Table R-7-C. ESS-Ready Basement Location: 12' x 12' Room

Component	Unit	Material	Labor	Equipment	Total	w/O&P	Quantity	Cost
Partition wall, 2x4, 16oc, 8' tall	LF	6.35	4.89		11.24	15.00	48	720
Door, pre-hung interior, louvered	EA	216.00	34.50		250.50	294.00	1	294
Door, lockset	EA	14.23	24.50		38.73	56.08	1	56
Electrical, duplex outlet, 120V	EA	7.30	23.50		30.80	46.00	4	184
Electrical, lighting switch & outlet	EA	6.85	20.00		26.85	40.00	1	40
Electrical, porcelain lamp holder	EA	2.75	8.55		11.30	16.95	1	17
Electrical, exhaust fan hook-up	EA	5.90	10.70		16.60	24.00	1	24
Smoke detector, hardwired, ceiling	EA	126.00	55.00		181.00	228.00	1	228
HVAC supply branch duct	LF	1.94	2.05		3.99	5.50	15	83
HVAC supply branch register	EA	61.50	21.50		83.00	103.00	1	103
Drywall, 5/8" Type X, finished	SF	0.43	0.61		1.04	1.46	576	841
Paint, latex, spray primer & 1 coat	SF	0.15	0.15		0.30	0.41	576	236
Paint, door	EA	10.70	22.50		33.20	48.00	1	48
Total to Builder								**2,874**
Total to Consumer								**3,548**

R-8 (RB164)

IRC R403.1 General (R403 Footings); Tables R403.1(1-3)

Summary of Code Change:

The code change revises the minimum footing width in the footing tables to correct errors in applying structural load combinations and revise the dead and live load assumptions to reflect the most common framing and finishes used in houses. The revisions generally result in smaller footing widths due to the less conservative loading assumptions, though footings for one- and two-story slab-on-grade homes may increase due to correcting the errors in the engineering calculations.

Cost Implication of the Code Change:

The cost analysis compares footing requirements for the Reference Houses using a soil bearing capacity of 2,000 psf, and live/snow loads of 30 psf and 70 psf. The difference in the amount of concrete required for the footings in cubic yards (CY) is used to calculate the cost impact. It is assumed that excavation costs remain the same.

Applicability of Code Change:

Applicable for all Reference Houses.

Table R-8-A. Incremental Cost of Footing, 30 psf snow load

	Reference House			
Component	**1**	**2**	**3**	**4**
Concrete, 3000 psi, over 5 CY			(280)	(322)
Concrete, 3000 psi, 1-5 CY	0	266		
Total to Builder	**0**	**266**	**(280)**	**(322)**
Total to Consumer	**0**	**329**	**(346)**	**(398)**

Table R-8-B. Incremental Cost of Footing, 70 psf snow load

	Reference House			
Component	**1**	**2**	**3**	**4**
Concrete, 3000 psi, over 5 CY			(561)	(859)
Concrete, 3000 psi, 1-5 CY	0	133		
Total to Builder	**0**	**133**	**(561)**	**(859)**
Total to Consumer	**0**	**164**	**(693)**	**(1,061)**

Table R-8-C. Unit Cost of Footing

Component	Unit	Material	Labor	Equip	Total	w/O&P
Concrete, 3000 psi, over 5 CY	CY	245.00	52.50	0.36	297.86	355.00
Concrete, 3000 psi, 1-5 CY	CY	266.00	91.00	0.63	357.63	440.00

Table R-8-D. Quantity of Additional Concrete based on Minimum Footing Size, for Brick Veneer/Stucco, 2,000 psf soil

		Snow	2018 IRC			2021 IRC			Additional
Reference House	LF	Load	Width	Thickness	CY	Width	Thickness	CY	CY
1 (1-story slab)	256	30 psf	12	6	4.7	12	6	4.7	0.0
2 (2-story slab)	196		12	6	3.6	14	6	4.2	0.6
3 (1-story basement)	256		16	6	6.3	14	6	5.5	(0.8)
4 (2-story basement)	196		21	6	6.4	18	6	5.4	(0.9)
1 (1-story slab)	256	70 psf	12	6	4.7	12	6	4.7	0.0
2 (2-story slab)	196		15	6	4.5	16	6	4.8	0.3
3 (1-story basement)	256		20	6	7.9	16	6	6.3	(1.6)
4 (2-story basement)	196		24	7	8.5	20	6	6.0	(2.4)

R-9 (RB183)

IRC R506.2.3 Vapor retarder

Summary of Code Change:

The code change requires vapor retarders for slab-on-ground floors to be minimum 10-mil and conform to ASTM D1743 Class A requirements (formerly required minimum 6-mil construction-grade sheet polyethylene).

Cost Implication of the Code Change:

This code change will increase the cost of construction. Analysis is based on the additional cost of slab-on-ground floors for the Reference Houses, including basements and garages. Note that the vapor barrier is not required for garages, but garages are included as conventional practice and so the contractor need not stock two types of vapor barrier.

Applicability of Code Change:

Applicable for all Reference Houses.

Table R-9-A. Incremental Cost of Vapor Retarder

	Reference House			
Component	**1**	**2**	**3**	**4**
Vapor retarder, 6-mil poly	(498)	(247)	(502)	(247)
10-mil, ASTM E1745 Class A	1,383	687	1,393	687
Total to Builder	**885**	**440**	**891**	**440**
Total to Consumer	**1,093**	**543**	**1,100**	**543**

Table R-9-B. Unit Cost of Vapor Retarder

Component	Unit	Material	Labor	Total	w/O&P
Vapor retarder, 6-mil poly	SF	0.04	0.08	0.12	0.17
10-mil, ASTM E1745 Class A	SF	0.31	0.08	0.39	0.46

Table R-9-C. Slab-on-ground floor area, SF

Reference House	First floor	Garage	Basement	Total
1 (1-story slab)	2,600	380		2,980
2 (2-story slab)	1,080	400		1,480
3 (1-story basement)		400	2,600	3,000
4 (2-story basement)		400	1,080	1,480

R-10 (RB238)

IRC R703.4.1 Flashing installation

Summary of Code Change:

The code change requires air sealing be installed around exterior window and door openings, on the interior side of the rough opening gap, to allow for drainage of water.

Cost Implication of the Code Change:

This code change will increase the cost of construction. Analysis is based on the additional cost to install backer rod, to maintain the rough opening gap for drainage, and seal the backer rod from the interior.

Applicability of Code Change:

Applicable for all Reference Houses.

Table R-10-A. Incremental Cost of Backer Rod and Sealant

	Reference House			
Component	**1**	**2**	**3**	**4**
Backer rod, polyethylene, 1/4" dia.	443	393	443	410
Sealant, latex acrylic, 1/4" x 1/4" bead	706	627	706	653
Total to Builder	**1,150**	**1,020**	**1,150**	**1,063**
Total to Consumer	**1,419**	**1,259**	**1,419**	**1,312**

Table R-10-B. Unit Cost of Backer Rod and Sealant

Component	Unit	Material	Labor	Total	w/O&P
Backer rod, polyethylene, 1/4" dia.	LF	0.03	0.63	0.65	1.06
Sealant, latex acrylic, 1/4" x 1/4" bead	LF	0.10	0.96	1.06	1.69

Table R-10-C. Total Perimeter of Windows and Doors, LF

Reference House	Window Area	Window Perimeter	Door Area	Door Perimeter	Total Perimeter
1	360	378	42	40	418
2	315	331	42	40	371
3	360	378	42	40	418
4	330	347	42	40	387

R-11 (RB242)

IRC R703.7.3 Water-resistive barriers (R703.7 Stucco)

Summary of Code Change:

The code change divides the water-resistive barrier requirements behind stucco into sections for dry climates and moist or marine climates, and for moist or marine climates requires a 3/16-inch air space or material with high drainage efficiency.

Cost Implication of the Code Change:

This code change will increase the cost of construction where applicable. Analysis is based on the incremental cost to install a drainage mat product in addition to the required two layers of water resistive barrier, as shown in Table R-11-A; this cost represents the "high" cost. The low cost would be zero where the code change is not applicable. A cost was also developed for an alternative approach: a drainable house wrap (e.g., Tyvek StuccoWrap) applied as the second layer of water resistive barrier instead of Grade D building paper (Table R-11-D); this cost represents an intermediate cost and therefore is not included in Table 2.

Applicability of Code Change:

Applicable for houses with stucco exterior wall cladding in moist and marine climates.

Table R-11-A. Incremental Cost of Drainage Mat

	Reference House			
Component	**1**	**2**	**3**	**4**
Drainage Mat (Rainscreen)	1,585	2,150	1,761	2,269
Total to Builder	1,585	2,150	1,761	2,269
Total to Consumer	1,957	2,654	2,174	2,802

Table R-11-B. Unit Cost of Water Resistive Barrier & Drainage Mat Products

Component	Unit	Material	Labor	Total	w/O&P
Drainage Mat (Rainscreen)	SF	0.58	0.08	0.66	0.77
House wrap, drainable	SF	0.24	0.08	0.32	0.39
Building Paper	SF	0.06	0.08	0.14	0.19

Table R-11-C. Gross Wall Area, SF

Reference House	SF
1 (1-story slab)	2,070
2 (2-story slab)	2,808
3 (1-story basement)	2,300
4 (2-story basement)	2,964

Table R-11-D. Incremental Cost of Drainable House Wrap as the Second Layer of Water Resistive Barrier

	Reference House			
Component	**1**	**2**	**3**	**4**
House wrap, drainable	811	1,100	901	1,161
Building paper	(393)	(534)	(437)	(563)
Total to Builder	417	566	464	598
Total to Consumer	515	699	572	738

R-12 (RB289)

IRC AF104 Testing (Radon)

Summary of Code Change:

The code change adds testing requirements to Appendix AF Radon Control Methods. Testing may be performed by the contractor, a registered design profession (engineer or architect), or an independent third party (i.e., a radon tester certified by the National Radon Proficiency Program or National Radon Safety Board), and the code change includes detailed testing instructions.

Cost Implication of the Code Change:

Analysis is based on the additional cost of radon testing by a certified third party professional.

Applicability of Code Change:

Applicable where radon-resistant construction is required.

Table R-12-A. Cost of Radon Testing

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Radon testing, third party	EA				225.00	1	225
Total to Builder							**225**
Total to Consumer							**278**

R-13 (RB3)

IRC R303.1 Habitable rooms

Summary of Code Change:

The code change requires the glazed areas in the kitchen be openable unless a local exhaust system is installed in accordance with section M1505.

Cost Implication of the Code Change:

Since now the kitchen window need not be openable where an exhaust hood is installed in accordance with M1505 (required), the analysis is based on a potential cost saving to install a non-openable kitchen window.

Applicability of Code Change:

Applicable where the house design includes a kitchen with a window.

Table R-13-A. Cost Savings for Non-Openable Kitchen Window

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
47" x 47" vinyl 2-lite casement window	EA	500.00	34.50	534.50	605.00	(1)	(605)
47" x 47" vinyl picture (fixed pane) window	EA	315.00	49.00	364.00	425.00	1	425
Total to Builder							**(180)**
Total to Consumer							**(222)**

R-14 (RP10)

IRC P2905.3

Summary of Code Change:

The code change adds a new section that limits the maximum length of hot water piping, from the source of hot water to the fixtures that require hot water, to 100 feet. Where more than 100 feet of piping is required, either an additional water heater or a recirculation system would need to be installed.

Cost Implication of the Code Change:

This code change will increase the cost of construction where applicable. Analysis is based on the additional cost to install a hot water circulation system.

Applicability of Code Change:

Applicable where the developed length of hot water piping exceeds 100 feet (most likely not applicable at the Reference Houses).

Table R-14-A. Cost of Domestic Hot Water (DHW) Recirculation System

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
DHW recirculation pump, mechanical timer	HR	205.19		205.19	225.71	1	226
Electrical outlet, 120V	EA	7.30	23.50	30.80	46.00	1	46
Check valve, 3/4	EA	7.79	11.90	19.69	28.20	1	28
Shutoff valve, ball valve, 3/4	EA	13.99	11.90	25.89	35.02	2	70
Dedicated return pipe, PEX, 3/4	LF	1.05		1.05	1.16	125	145
PEX piping labor (25% of fittings labor)	EA		20.83	20.83	34.36	1	34
PEX coupling, 3/4 x 3/4 NPT	EA	1.78	11.90	13.68	21.50	4	86
Total to Builder							**635**
Total to Consumer							**784**

APPENDIX B:
LOCATION ADJUSTMENT FACTORS

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

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

APPENDIX C: REFERENCE HOUSES

Reference House Configurations

The four Reference House designs used in this analysis are based on the data contained in the Census Bureau report, *Characteristics of New Single-Family Construction Completed*.[9] The report provides information about building foundation type (Table 1) and number of stories for new single-family detached construction over the previous nine-year period. (Table 2).

Table 1. New Construction Foundation Types

Slab	54%
Crawlspace	17%
Basement	30%

Table 2. New Construction Number of Stories

One-story	53%
Two-story	43%
Three-story	3%

The Census data supports defining the four Reference Houses as follows to encompass approximately 85% of the last decade's new single-family construction:

- One-story on slab foundation
- Two-story on slab foundation
- One-story on basement foundation
- Two-story on basement foundation

Table 3 covers the locations where each type of Reference House foundation would be pragmatically constructed. All these selected cities, except Chicago, lie within the top ten states for construction starts in 2013.[10] Chicago was selected to represent a Climate Zone 5 house.

Table 3. Sites for Reference Houses

Reference House	Climate Zone	1	2	3	4
Foundation		Slab	Slab	Basement	Basement
Miami	1	X	X		
Dallas	2	X	X		
Lose Angeles	3	X	X		
Seattle	4	X	X	X	X
New York	4	X	X	X	X
Chicago	5			X	X
Fairbanks	8			X	X

[9] Characteristics of New Housing, U.S. Census Bureau, www.census.gov/construction/chars/completed.html
[10] Housing Construction Starts, www.census.gov/construction/bps/pdf/2013statepiechart.pdf

Based on data from Home Innovation's *2013 Annual Builder Practices Survey*[11]*(ABPS)*, the typical Heating, Ventilation, and Air Conditioning (HVAC) systems used in new houses are summarized in Table 4. According to the ABPS, 44% of new homes are cooled with a central air conditioner. These results influenced the selection of a gas furnace with a central (electric) air conditioner as the HVAC system in each of the Reference Houses.

Table 4. Typical HVAC Systems Supplied with New Houses

Feature	% of Stock
Furnace or Boiler, natural gas or propane	48%
Central Air Conditioner, electric	44%
Standard Heat Pump with Backup Heat	41%
Geothermal Heat Pump	4%
Electric furnace, baseboard, or radiant	4%
Furnace or Boiler, oil	2%

The furnace location has been designated as a platform in the attic for both slab Reference Houses, a practice that is common in Florida and Texas, where the weather is temperate year-round, and thus, the location is practical. A house built on a slab foundation in a cold climate zone would have the HVAC and water heating equipment located within conditioned space.

Reference House Features

The statistics presented in the foregoing tables support Reference House features that are detailed in Table 1.

Table 1. Features of the Reference Houses

	Reference House			
Feature	**1**	**2**	**3**	**4**
Square Feet	2,607	2,607	2,607	2,607
Foundation	Slab	Slab	Basement	Basement
Number of Stories	1	2	1	2
Number of Bedrooms	3	4	3	4
Number of Bathrooms	2	2.5	2	3
Garage, attached	2-car	2-car	2-car	2-car
Heat, Gas Furnace	Yes	Yes	Yes	Yes
Cooling, (Electric) central air	Yes	Yes	Yes	Yes
Hot Water, Gas 50 gallon tank	Yes	Yes	Yes	Yes
9 ft. Ceilings, 1st	Yes	Yes	Yes	Yes
8 ft. Ceilings, 2nd	n/a	n/a	Yes	Yes
Energy Star appliances	Yes	Yes	Yes	Yes
Laundry Room	Yes	Yes	Yes	Yes
Walls, 2x4 (Climate Zones 1 & 2)	Yes	Yes	n/a	n/a
Walls, 2x6 (Climate Zones 3 thru 8)	n/a	n/a	Yes	Yes
Basement, Conditioned, Unfinished	n/a	n/a	Yes	Yes
Furnace Location	Attic	Attic	Basement	Basement
Water Heater Location	Interior	Garage	Basement	Basement
Window SF/% gross wall	360/18%	315/12%	360/18%	330/12%
Cladding	Brick, 4 sides	Brick, 4 sides	Brick, 4 sides	Stucco
Roof Pitch	12/12	6/12	9/12	4/12

[11] Annual Builder Practices Survey, www.homeinnovation.com/trends_and_reports/data/new_construction

APPENDIX D: REFERENCE HOUSE 1

One-Story with Slab Foundation

Courtesy: LionsGate Homes at The Creekside

APPENDIX E: REFERENCE HOUSE 2

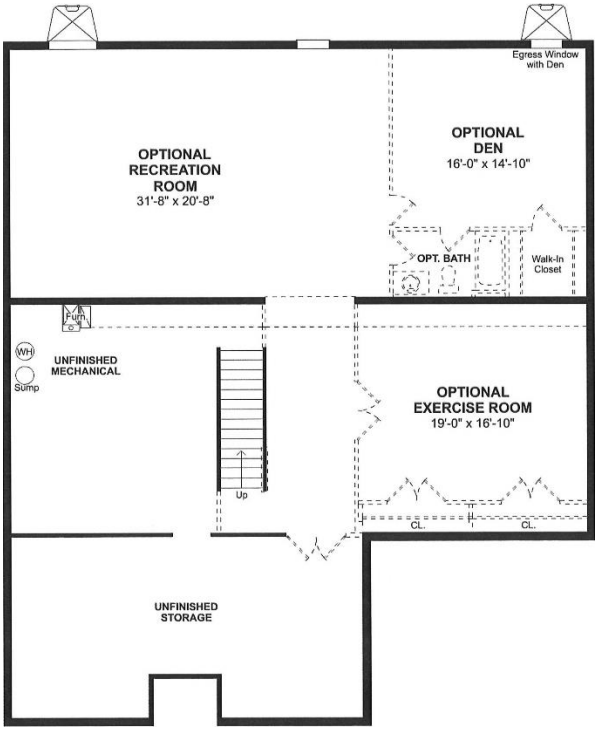
Two-Story with Slab Foundation

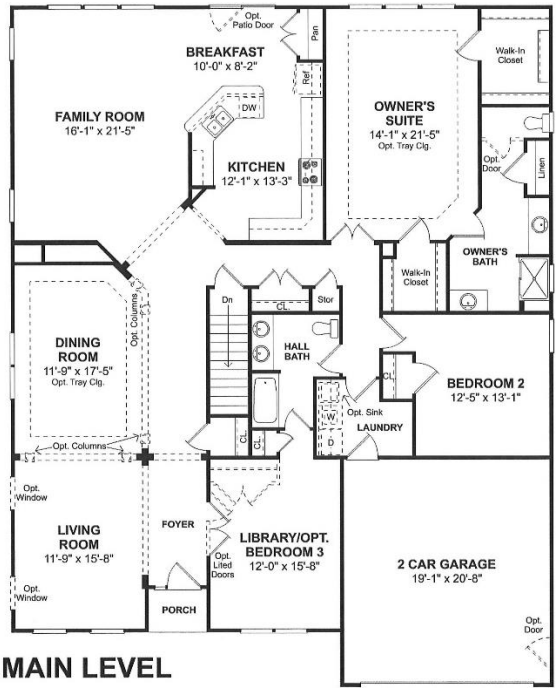
Courtesy: Meritage Homes at Riverstone

APPENDIX F: REFERENCE HOUSE 3

One-Story with Basement Foundation

Courtesy: K Hovnanian Four Seasons at New Kent Vineyards

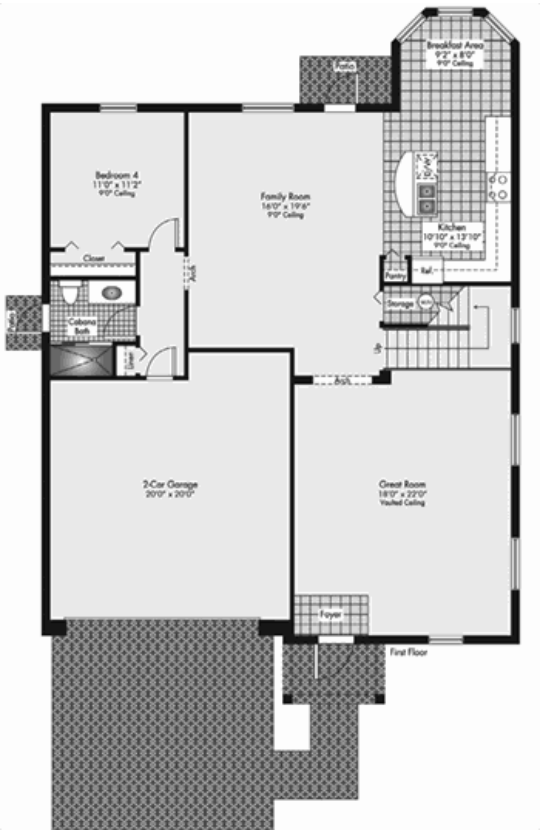


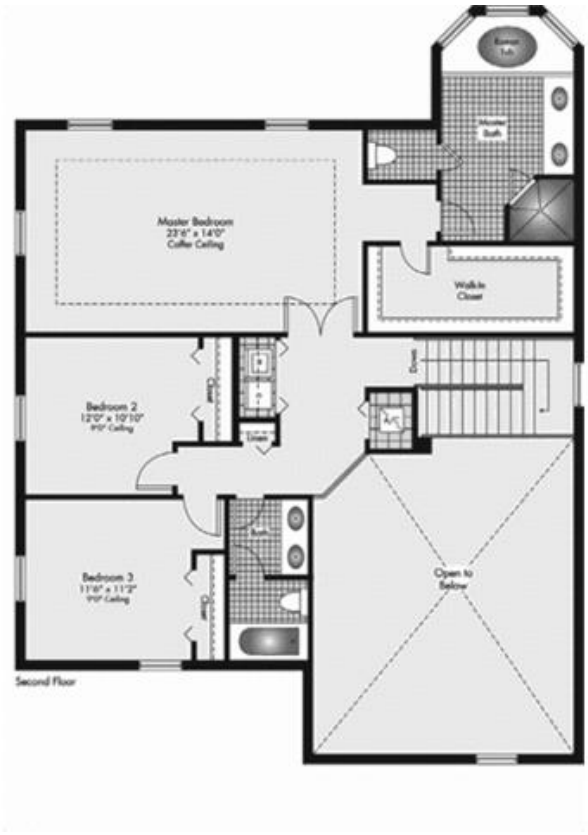


APPENDIX G: REFERENCE HOUSE 4

Two-Story with Basement Foundation

Courtesy: Lennar at Sorento Estates



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