Home Innovation
RESEARCH LABS™

COST IMPACT OF BUILDING A HOUSE IN COMPLIANCE WITH IWUIC

Prepared For

National Association of Home Builders

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

EA	Each
CY	Cubic Yard
HI	Home Innovation Research Labs
IBC	International Building Code
IR 1	Ignition Resistant Class 1
IR 2	Ignition Resistant Class 2
IR 3	Ignition Resistant Class 3
IRC	International Residential Code
IWUIC	International Wildfire Urban Interface Code
LF	Linear Feet
MSF	Thousand Square Feet
NAHB	National Association of Home Builders
O&P	Overhead and Profit
SF	Square Feet

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BACKGROUND

The National Association of Home Builders (NAHB) asked Home Innovation Research Labs (HI) to study the cost impact of building a house to the 2018 ICC *International Wildland Urban Interface Code* (IWUIC 2018)[1].

METHODOLOGY

Baseline metrics were identified for two representative single-family homes, a single story and a 2-story home, built to the International Residential Code (IRC) in three different locations – Los Angeles, CA; Dallas, TX; and Denver, CO. Materials and type of construction were selected for the specific location based on market research data from HI (Appendix B).

The cost impacts in this analysis have been developed primarily with data adapted from *2020 Residential Costs with RSMeans Data*[2]. The costs for individual code changes are shown in Appendix A. Costs are reported at the national level and modified for selected locations by applying a location factor adjustment. 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 (i.e., materials and labor) to represent the cost charged by the sub-contractor. The total cost to consumer is based on the builder's gross margin, reported as 18.9% of construction cost in NAHB's *Cost of Doing Business Study, 2016 edition*[3].

Reference House Characteristics

The features of the single-story and 2-story Reference Houses are summarized in Table 1. The basis for the selection of the characteristics of the Reference Houses are provided in Appendix E.

Table 1. Reference House Features

Reference House Features	1-story	2-story
Conditioned floor area, total, SF	2,600	2,600
First floor area, SF	2,600	1,080
Second floor area, SF	NA	1,520
First floor dimensions, ft.	40 x 75	40 x 38
Second floor dimensions, ft.	NA	40 x 38
Garage dimensions, ft.	20 x 20	20 x 22
Attic	Vented	Vented
Foundation: slab-on-grade (SOG)	SOG	SOG
Slab Perimeter, LF	230	156
Ceiling height, first floor, ft.	9	9
Ceiling height, second floor, ft.	NA	8

[1] https://codes.iccsafe.org/content/IWUIC2018
[2] https://www.rsmeans.com/products/books/2020-cost-data-books/2020-residential-costs-book
[3] http://eyeonhousing.org/2016/03/whats-the-average-profit-margin-of-single-family-builders/

Walls, gross area, includes 1' rim for 2-story, SF	2070	2808
Window area, SF	360	360
Roof type (gable or hip)	Hip	Hip
Roof slope	7:12	7:12
Roof overhang at eaves/gables, ft.	1	1
Deck area, based on 20'x14' deck, SF	280	280
Roof cladding material	Asphalt shingle	Asphalt shingle
Wall cladding material	Varies	Varies
Soffit/trim cladding material	Lumber	Lumber
Window construction/material	Vinyl	Vinyl
Lot size/house setbacks, SF	11,250	11,250

Median lot size varies by region[4] so a suitable size within the range was selected for the reference houses.

Construction practices vary depending on location and climate zone. Table 2 shows common construction practices used for given reference houses in selected location based on HI market research data.

Table 2. Common Construction Practices in Selected Locations

Construction	Colorado	East TX	Southern CA
1-story, % of all homes	50%	71%	36%
Foundation	Basement	Slab	Slab
Wall Cladding	Fiber Cement	Brick	Stucco
Roofing	Asphalt Shingle	Asphalt Shingle	Clay/Cement Tile
Exterior Trim	Wood Fiber Composite	Fiber Cement	Lumber Boards

(source: Home Innovation Research Labs)

Costs were compared for IWUIC Ignition Resistant Class 1 (IR 1) construction versus the baseline practices in Table 2.

For comparison, the baseline practice for wall cladding was assumed to be wood in this study even though the most common materials used there are fiber cement, brick, and stucco. For other components addressed in the IWUIC, such as windows, doors, exterior decks, etc., non-compliant vs. compliant materials were compared to evaluate the cost difference. The range of cost impact is

[4] http://eyeonhousing.org/2019/10/lot-size-remains-low-in-2018/#:~:text=The%20median%20lot%20size%20of,different%20from%20the%202017%20median.

provided to show low and high cost impact for common practices that had more than one method of compliance.

IWUIC Requirements

IWUIC 2018 requires a house constructed, modified, or relocated into or within wildland-urban interface areas to be in compliance with one of the three classes of ignition resistant construction: Class 1 Ignition Resistant Construction (IR 1), Class 2 Ignition Resistant Construction (IR 2), or Class 3 Ignition Resistant Construction (IR 3,) depending on whether the site conforms to the water supply and defensible space requirements for the appropriate fire hazard severity.

Fire Hazard Severity

IWUIC 2018 classifies the fire hazard severity of locations as moderate hazard, high hazard, or extreme hazard based on the fuel type in the area. Vegetation of selected locations were studied to see if any location followed a particular fuel model. Appendix C shows fuel classification and fire hazard severity per the IWUIC 2018. The selected locations did not conform to a specific fuel model, so all three hazard severities were considered. To narrow down the study, only the cost impact for Class 1 Ignition Resistant Construction (IR 1) was analyzed and shown in the report.

Water Supply

The water sources, both manmade and natural, are required to be equipped with an approved hydrant in order to conform to the water supply requirements of the IWUIC, along with other provisions. IWUIC 2018 requires mandatory conformance with defensible space requirements for building in extreme hazard areas that do not conform to the water supply requirements (IWUIC Table 503.1).

Defensible Space

The IWUIC 2018 defines defensible space as “an area either natural or man-made, where material capable of allowing a fire to spread unchecked has been treated, cleared or modified to slow the rate and intensity of an advancing wildfire and to create and area for fire suppression operations to occur.”

Fuel Modification for Reference House

Depending on whether the building is located in a moderate, high, or extreme hazard area, homeowners are responsible for providing fuel modification over a distance of 30 feet, 50 feet, or 100 feet, as shown in Table 5 and illustrated in Image 1, for conformance with the defensible space requirements. For the purposes of this study, the cost of providing defensible space is limited up to the lot line, assuming that the reference house is on a developed lot and all the neighboring lots are complying with the defensible space requirements.

Table 3 Fuel Modification for Defensible Space[5]

WILDLAND-URBAN INTERFACE AREA	FUEL MODIFICATION DISTANCE (feet)[3]
Moderate hazard	30
High hazard	50
Extreme hazard	100[6]

For SI = 1 foot = 304.8 mm

Distances can be increased to reflect site-specific analysis based on local conditions and fire protection plans.

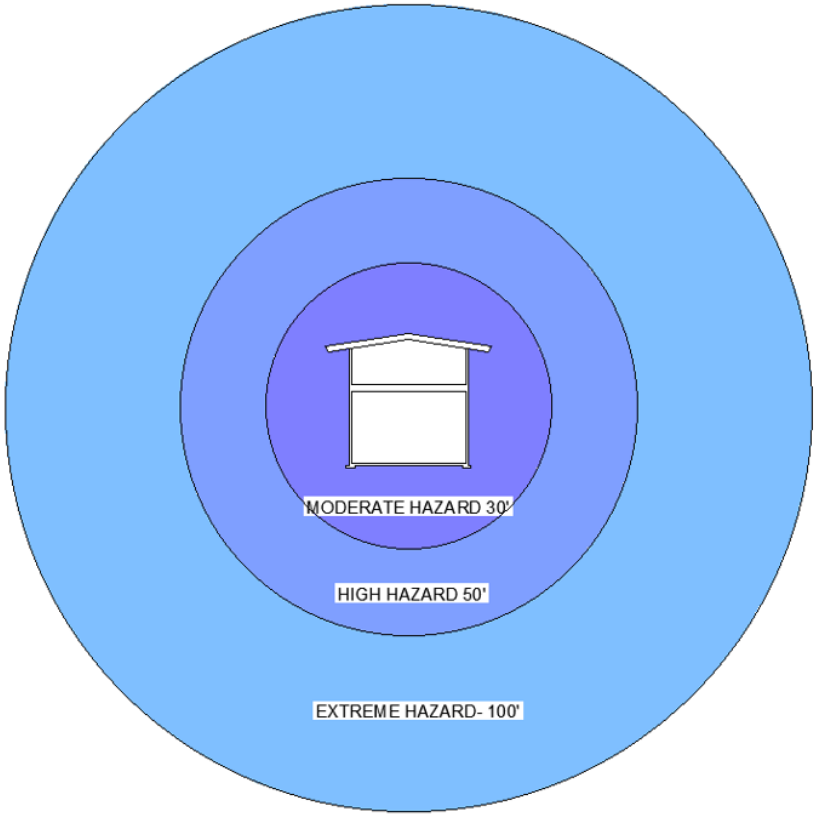


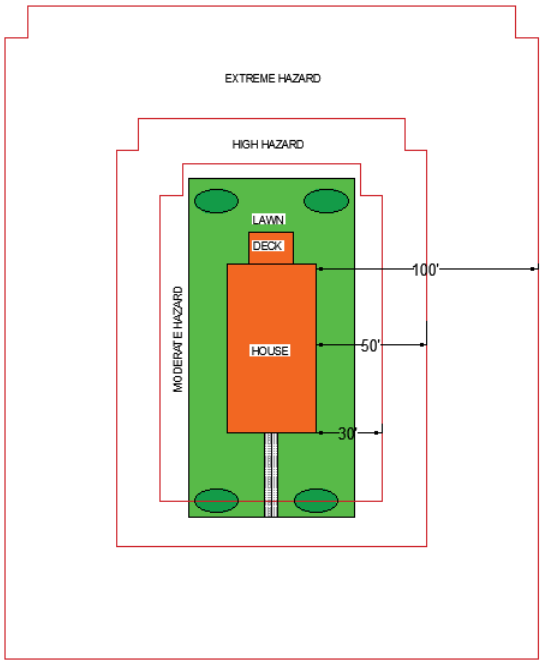
Image 1. Fuel Modification Requirement for Defensible Space

[5] IWUIC 2018, Table 603.2

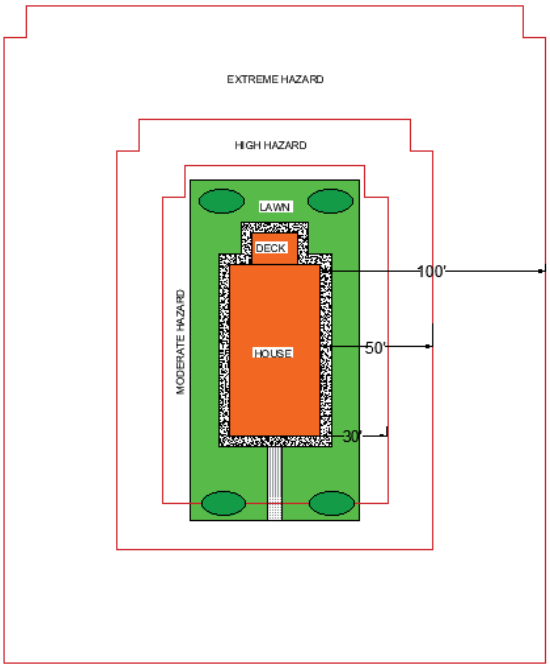
Assuming new construction on a developed lot as illustrated in Figure 1, the areas of fuel modification for the reference houses are shown in Table 6.

Table 4 Fuel modification area

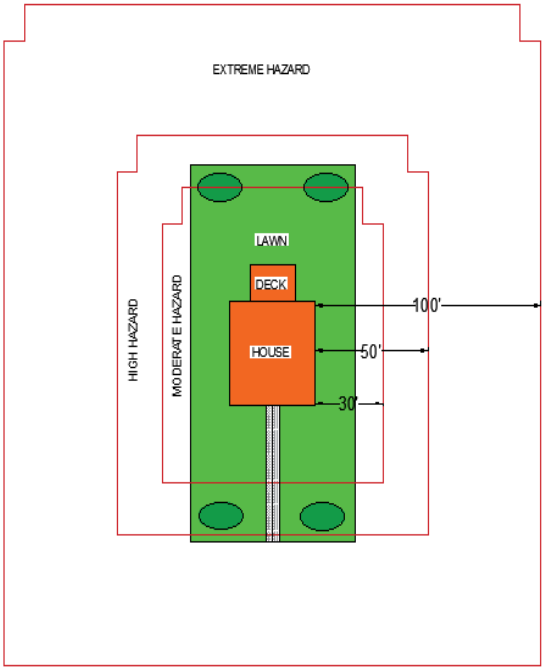
Reference house	Lot area (SF)	Area of house and deck (SF)	Area of gravel addition (SF)	Area of sidewalk (SF)	Area of lawn modification (SF)
Single story	11250	3,275	**1,395**	195	**6,385**
2 story	11250	1,791	**1,029**	285	**8,145**



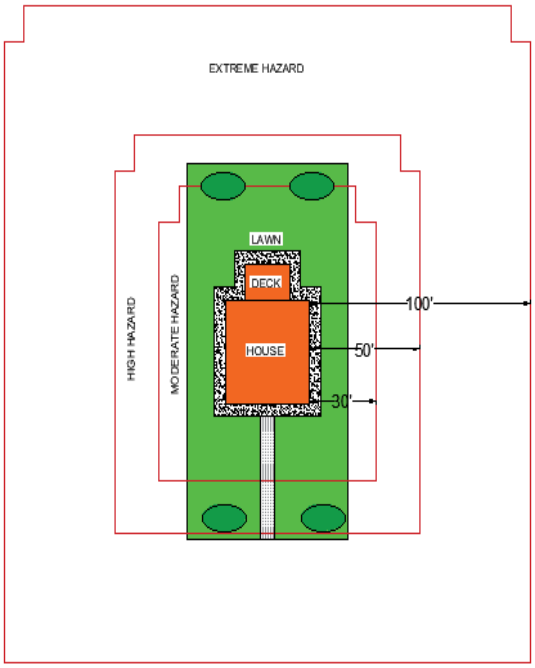
Single story house without defensible space



Single story house with defensible space



Two story house without defensible space



Two story house with defensible space

Figure 1 Fuel modification for defensible space

Automatic Sprinkler Systems

IWUIC 2018 requires an approved automatic sprinkler system be installed in all occupancies in new buildings meeting the requirements for IR 1 construction. California is not impacted by this cost because an automatic sprinkler system is mandated for residential buildings by the local code.

Building Components

Characteristics of a house that make it vulnerable to wildland-urban interface fires include exterior features like roof covering, exterior siding, door and window trim, the presence of an exterior deck, and the presence of trees, vegetation or other landscaping on the surrounding lot.

IWUIC 2018 requirements for IR 1 construction mandate specific practices for various exterior components of the building. Building components of the reference houses analyzed for this study include soffit and fascia, vents, downspouts and gutters, exterior wall cladding, exterior windows and exterior doors.

Cost of an automatic sprinkler, exterior deck and defensible space are provided as separate costs in Table 7 and 8 to differentiate the cost of the basic house components from the cost of additional features. The cost estimate does not include landscape maintenance costs.

RESULTS

Summary of Cost Impact of IWUIC Code Compliance

Tables 5 and 6 summarize the estimated cumulative impact of constructing the reference houses to the 2018 IWUIC. The cost is adjusted for selected city's location factor in each state.

Table 5 Cost Impact Summary, Single-Story House

	Southern California (L.A, 0.99)		Colorado (Denver, 1.05)		Eastern Texas (Dallas, 0.98)	
Component*	**Low Cost**	**High Cost**	**Low Cost**	**High Cost**	**Low Cost**	**High Cost**
Roof covering	$0	$0	$0	$0	$0	$0
Soffit and Fascia	$1,839	$1,839	$1,950	$1,950	$1,820	$1,820
Gutters and Downspouts	$860	$860	$912	$912	$852	$852
Exterior wall (siding)	($3,839)	$21,391	($4,071)	$22,688	($3,800)	$21,175
Windows	$2,509	$2,678	$2,661	$2,840	$2,483	$2,651
Door	$0	$0	$0	$0	$0	$0
Vents	$484	$484	$514	$514	$479	$479
Total impact for house components	**$1853**	**$27,253**	**$1966**	**$28,905**	**$1,835**	**$26,978**
Exterior Deck	$1,293	$1,293	$1,371	$1,371	$1,280	$1,280
Defensible space	$883	$883	$937	$937	$874	$874
Automatic Sprinklers	NA[7]	NA	$4,311	$6,743	$4,024	$6,294
Total	**$4,029**	**$29,429**	**$8,584**	**$37,955**	**$8,012**	**$35,425**

Table 6 Cost Impact Summary, Two-Story House

	Southern California		Colorado		Eastern Texas	
Component*	**Low Cost**	**High Cost**	**Low Cost**	**High Cost**	**Low Cost**	**High Cost**
Roof covering	$0	$0	$0	$0	$0	$0
Soffit and Fascia	$1,247	$1,247	$1,323	$1,323	$1,235	$1,235
Gutters and Downspouts	$470	$470	$499	$499	$466	$466
Exterior wall (siding)	($5,628)	$31,364	($5,969)	$33,265	($5,571)	$31,047
Windows	$2,509	$2,678	$2,661	$2,840	$2,483	$2,651
Door	$0	$0	$0	$0	$0	$0
Vents	$386	$386	$410	$410	$382	$382
Total impact for house components	**($1,016)**	**$36,146**	**($1,077)**	**$38,337**	**($1,005)**	**$35,781**
Exterior Deck	$1,293	$1,293	$1,371	$1,371	$1,280	$1,280
Defensible space	$1,550	$1,550	$1,644	$1,644	$1,534	$1,534
Automatic Sprinklers	NA	NA	$4,311	$6,743	$4,024	$6,294
Total	**$1,827**	**$38,989**	**$6,248**	**$48,095**	**$5,832**	**$44,888**

[7] NA: Not Applicable

APPENDIX A: COST IMPLICATION OF IWUIC COMPLIANCE

Reference Code Section

2018 IWUIC Section 504.2 Roof Covering.

Summary of the Code:

IR 1 construction requires roof assemblies that comply with a Class A rating. For roof coverings where the profile allows a space between the roof covering and roof decking, this section requires the space at the eave ends to be firestopped to preclude entry of flames or embers or have one layer of 72-pound mineral-surfaced, nonperforated cap sheet complying with ASTMD 3909 installed over the combustible decking.

Cost Implication of the Code Compliance:

Compliance with this code section does not have any cost impact as the reference houses are assumed to have asphalt or clay/cement tiles that meet the Class A roofing requirement. These materials are the most common roofing materials for the three selected locations.

Reference Code Section

2018 IWUIC Section 504.3 Protection of Eaves.

Summary of the Code:

IR1 construction requires soffits to be protected on the exposed underside by ignition-resistant materials or by materials approved for not less than 1-hour fire-resistance-rated construction, 2-inch nominal dimension lumber, or 1-inch nominal fire-retardant-treated lumber or ¾-inch nominal fire-retardant treated plywood identified for exterior use and meeting the requirements of Section 2303.2 of the IBC. It also requires fascia to be protected on the backside by ignition resistant materials of my materials approved for not less than 1-hour fire-resistant construction or 2-inch nominal dimension lumber.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction for the given reference houses due to replacing 1" thick fascia board with 2" thick lumber and addition of fire retardant-treated soffit panels. The costs are applicable to all three locations.

Table A 1Cost Impact, protection of eaves, single story reference house

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Fascia board, 1" x 6" lumber	LF	0.86	1.38	2.24	3.21	(230)	(738)
Fascia board, 2" x 6" lumber	LF	0.69	2.31	3.00	4.55	230	1,047
Soffit panels, plywood, fire-retardant treated, 3/4"	SF	2.03	1.95	3.98	5.45	230	1,254
Total to Builder							**1,562**
Total to Consumer							**1,857**

Table A 2 Cost Impact, protection of eaves, 2-story reference house

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Fascia board, 1" x 6" lumber	LF	0.86	1.38	2.24	3.21	(156)	(501)
Fascia board, 2" x 6" Lumber	LF	0.69	2.31	3.00	4.55	156	710
Soffit covering, plywood, Fire treated, 3/4"	SF	2.03	1.95	3.98	5.45	156	850
Total to Builder							**1,059**
Total to Consumer							**1,260**

Reference Code Section

2018 IWUIC Section 504.4 Gutters and Downspouts

Summary of the Code:

IR 1 construction requires gutters and downspouts to be constructed of noncombustible material. It also requires gutters be provided with an approved means to prevent accumulation of leaves and debris in the gutter.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction for the given reference houses due to replacing vinyl gutters and downspouts with aluminum gutters and downspouts and providing gutter guards to cover the gutters. The costs are applicable to all three locations.

Table A 3 Cost Impact, Gutter and Downspouts, Single Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gutter, Vinyl, O.G., 5" wide	LF	1.51	2.50	4.03	5.80	(150)	(870)
Downspouts, vinyl, rectangular, 2"x3"	LF	2.17	1.50	3.67	4.87	(40)	(195)
Downspouts elbow	EA	1.00	3.14	4.14	6.30	(12)	(76)
Aluminum , stock units, 5" K type, .027" thick, plain	LF	2.85	2.51	5.36	7.30	150	1,095
Downspouts, aluminum, embossed, .020" thick, 2"x3"	LF	0.95	1.65	2.60	3.79	40	152
Gutter guard, 6" wide strip, aluminum mesh	LF	2.46	0.58	3.04	3.66	150	549
Downspouts elbow	EA	1.00	3.14	4.14	6.30	12	76
Total to Builder							**731**
Total to Consumer							**869**

Table A 4 Cost Impact, Gutter and Downspouts, 2-Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gutter, Vinyl, O.G., 5" wide	LF	1.51	2.50	4.03	5.80	(80)	(464)
Downspouts, vinyl, rectangular, 2"x3"	LF	2.17	1.50	3.67	4.87	(80)	(390)
Downspouts elbow	EA	1.00	3.14	4.14	6.30	(12)	(76)
Aluminum , stock units, 5" K type, .027" thick, plain	LF	2.85	2.51	5.36	7.30	80	584
Downspouts, aluminum, embossed, .020" thick, 2"x3"	LF	0.95	1.65	2.60	3.79	80	303
Gutter guard, 6" wide strip, aluminum mesh	LF	2.46	0.58	3.04	3.66	100	366
Downspouts elbow	EA	1.00	3.14	4.14	6.30	12	76
Total to Builder							**400**
Total to Consumer							**475**

Reference Code Section

2018 IWUIC Section 504.5 Exterior Walls

Summary of the Code:

IR 1 construction requires the exterior walls of the buildings or structure to be constructed with materials approved for not less than 1-hour fire-resistance-rated construction on the exterior side, approved noncombustible material, heavy timber or log wall construction, fire-retardant-treated wood on the exterior side or ignition-resistant materials complying with the code on exterior side.

Cost Implication of the Code Compliance:

Compliance with this code section will decrease the cost of construction for the given reference houses where a more-costly material such as wood siding is replaced with a less-costly material such as fiber cement siding, but will increase the cost of construction where a less-costly material such as vinyl siding is replaced with a more costly-material such as fiber cement siding or brick veneer. The costs are not necessarily applicable to all three locations as the most common siding materials in the selected locations are either fiber cement, stucco or brick veneer which all comply with IWUIC requirement for Class 1 ignition-resistant construction. However, to provide a range of cost implications, both low and high cost impact changes are included in the report assuming a change in siding is required.

Table A 5 Cost Impact, Siding, Single Story Reference House
(Lower Cost Impact: Substitute Fiber Cement Siding for Wood Siding)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Wood, cedar bevel, A grade, 1/2" x 6"	SF	4.46	0.98	5.44	6.50	(1,583)	(10,290)
Fiber cement siding, 6-1/4" exposure	SF	2.00	1.36	3.36	4.44	1,583	7,029
Total to Builder							**(3,261)**
Total to Consumer							**(3,877)**

Table A 6 Cost Impact, Siding, Single Story Reference House
(Higher Cost Impact: Substitute Brick Veneer for Vinyl Siding)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Vinyl siding, .048" thick, double 4	SF	1.09	1.17	2.26	3.12	(1,583)	(4,939)
Brick veneer masonry	SF	4.52	5.80	10.32	14.60	1,583	23,112
Total to Builder							**18,173**
Total to Consumer							**21,608**

Table A 7 Cost Impact, Siding, 2-Story Reference House
(Lower Cost Impact: Substitute Fiber Cement Siding for Wood Siding)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Wood, cedar bevel, A grade, 1/2" x 6"	SF	4.46	0.98	5.44	6.50	(2,321)	(15,087)
Fiber cement siding, 6-1/4" exposure	SF	2.00	1.36	3.36	4.44	2,321	10,305
Total to Builder							**(4,781)**
Total to Consumer							**(5,685)**

Table A 8 Cost Impact, Siding, 2-Story Reference House
(Higher Cost Impact: Substitute Brick Veneer for Vinyl Siding)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Vinyl siding, .048" thick, double 4	SF	1.09	1.17	2.26	3.12	(2,321)	(7,242)
Brick veneer masonry	SF	4.52	5.80	10.32	14.60	2,321	33,887
Total to Builder							**26,645**
Total to Consumer							**31,681**

Reference Code Section

2018 IWUIC Section 504.6 Underfloor enclosure

Summary of the Code:

IR 1 construction requires underfloor areas (e.g. crawlspaces) be enclosed down to the ground with exterior walls in accordance with IWUIC Section 504.5 on exterior walls.

Cost Implication of the Code Compliance:

Compliance with this code section has no cost impact as the reference houses have no underfloor enclosures.

Reference Code Section

2018 IWUIC Section 504.7 Appendages and Projections

Summary of the Code:

IR 1 construction requires unenclosed accessory structures attached to buildings with habitable spaces, and projections such as decks, to have a minimum of 1-hour fire-resistance-rated construction.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction where a concrete patio is substituted for a non-fire-rated wood deck. A different cost impact is possible for replacing a non-fire-rated wood deck with a fire-rated wood deck, but due to the lack of pricing data for lumber that is both fire-retardant treated and preservative-treated for exterior use, only the costs for substituting a concrete patio for a non-fire-rated wood deck.

Table A 9 Cost Impact, Exterior Deck, Single and 2-Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Posts, 4x6, treated	LF	2.24	2.10	4.34	5.90	(12)	(71)
Girder, double 2x10	LF	2.49	1.05	3.99	4.97	(20)	(99)
Ledger, 2x10, treated, bolted 4' o.c.	LF	1.59	1.50	3.09	4.22	(20)	(84)
Joists, 2x10 treated	LF	1.47	0.64	2.11	2.68	(210)	(563)
Decking, 2x6, treated	SF	1.66	0.90	2.56	3.32	(280)	(930)
Excavation for footing, 12" x 36" deep	CY		55.50	55.50	91.50	5	458
Gravel for footing	CY	28.93	4.89	33.82	40.00	5	200
Gravel below slab, 4" deep	SF	0.52	0.14	0.66	0.80	280	224
Concrete slab on grade, 4", 3500 psi	CY	147.45	51.00	198.45	246.00	4	984
Thickened slab edge, reinforced 8" x 8"	LF	6.72	2.31	9.03	11.20	48	538
Concrete stair	LF	6.72	20.50	27.22	41.00	6	246
Concrete slab finishing	SF		0.43	0.43	0.70	280	196
Total to Builder							**1,098**
Total to Consumer							**1,306**

Reference Code Section

2018 IWUIC Section 504.8 Exterior Glazing

Summary of the Code:

IR 1 construction requires exterior windows, window walls and glazed doors, windows within exterior doors and skylights to be tempered glass, multilayered glazed panels, glass block or have a fire protection rating of not less than 20 minutes.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction where vinyl windows are replaced with metal-clad wood windows. There is a higher cost impact for replacing plain glass wood windows with tempered glass metal clad wood windows.

Table A 10 Cost Impact, Window, Single and 2-Story Reference House
(Lower Cost Impact: Substitute Vinyl with Metal Clad Wood Window)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Vinyl, double hung, 3040	SF	20.58	2.67	23.25	27.08	(360)	(9,749)
Metal clad wood, double hung, 3050	SF	26.33	2.40	28.73	33.00	360	11,880
Total to Builder							**2,131**
Total to Consumer							**2,534**

Table A 11 Cost Impact, Window, Single and 2-Story Reference House
(Higher Cost Impact: Substitute Plain Glass Vinyl Window with Tempered Glass Metal Clad Wood Window)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Vinyl, double hung, 3040	SF	20.58	2.67	23.25	27.08	(360)	(9,749)
Metal clad wood, double hung, 3050	SF	26.33	2.40	28.73	33.00	360	11,880
Float glass, 3/16" plain	SF	7.10				(360)	(2,556)
Float glass, 3/16" tempered, clear	SF	7.50				360	2,700
Total to Builder							**2,275**
Total to Consumer							**2,705**

Reference Code Section

2018 IWUIC Section 504.9 Exterior Doors

Summary of the Code:

IR 1 construction requires the exterior doors to be approved noncombustible construction, solid core wood not less than 1 ¾ inches thick or have a fire protection rating of not less than 20 minutes.

Cost Implication of the Code Compliance:

Compliance with this code section does not have any cost impact as the reference houses have solid wood core 1 ¾ inches thick exterior doors that are already compliant with the IWUIC.

Reference Code Section

2018 IWUIC Section 504.10 Vents

Summary of the Code:

IR 1 construction requires attic ventilation openings, foundation or underfloor vents, or other ventilation openings in vertical exterior walls and vents through roofs to not exceed 144 square inches each. It also requires such vents to be covered with noncombustible corrosion-resistant mesh with openings not to exceed ¼ inch or be designed and approved to prevent flame or ember penetration into the structure. Further, vents are not permitted in the soffit areas.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction for the reference houses. The cost analysis is based on replacing soffit and ridge vents with gable wall louvers and static roof vents[8] located close to the ridge. The total required vent area is calculated per the IRC 2018, and the quantity of gable vents and roof vents is determined based on the 144 square inch limit requirement per vent. Note that no deduction is taken for soffit vents; it is assumed that non-perforated soffit material (same cost) will still be installed.

Table A 12 Cost Impact, Vents, Single Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gable wall louver, aluminum 12"x12"	EA	17.85	7.60	25.45	32.00	4	128
Roof vent, aluminum 12"x12"	EA	27.00	10.30	37.30	48.00	14	672
Ridge vent	LF	2.54	1.55	4.09	5.55	(70)	(389)
Total to Builder							**412**
Total to Consumer							**489**

Table A 13 Cost Impact, Vents, 2-Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gable wall louver, aluminum 12"x12"	EA	17.85	7.60	25.45	32.00	6	192
Roof vent, aluminum 12"x12"	EA	27.00	10.30	37.30	48.00	7	336
Ridge vent	LF	2.54	1.55	4.09	5.55	(36)	(200)
Total to Builder							**328**
Total to Consumer							**390**

[8] Example static roof vents: https://www.tamtech.com/product/static-roof-vent-large-capacity-round-vent-vx25-series/

Reference Code Section

2018 IWUIC Section 504.8 Detached accessory structures

Summary of the Code:

IR 1 construction requires detached accessory structures located less than 50 feet from a building containing habitable space to have exterior walls constructed with materials approved for not less than 1-hour fire-resistance-rated construction, heavy timber, log wall construction, or constructed with approved noncombustible materials or fire-retardant-treated wood on the exterior side.

Cost Implication of the Code Compliance:

Compliance with this code section does not have any cost impact as the lots for the reference houses do not have any detached structures within 50 feet of habitable space.

Reference Code Section

2018 IWUIC Section 603.2 Fuel modification (Defensible space)

Summary of the Code:

IR 1 construction requires fuel modification up to 30', 50' or 100' around a building or structure for moderate hazard, high hazard or extreme hazard areas respectively to create a defensible space.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction where a 5-foot-wide strip of gravel is added for ground covering around the boundary of the reference house, standard shrubs are replaced with fire resistant shrubs and standard turf grass is replaced with drought tolerant grass for the lawn. The IWUIC does not specify fuel types requiring modification so external references were studied for this purpose.[9] [10]

Table A 14 Cost Impact, Defensible Space, Single Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Ground cover, pea gravel	Ton	11.80	24.50	36.30	53.00	13.95	739
Shrub, Russian olive, 3'- 4'	EA	26.00	13.40	47.95	60.50	(4.00)	(242)
Shrub, viburnum, 3' - 4'	EA	27.00	25.00	68.05	88.50	4.00	354
Sodding, bluegrass sod on level ground	MSF	335.00	82.50	430.65	520.00	(7.78)	(4,046)
Sodding, pallet of Zoysia	MSF	530.00	82.50	625.65	733.59	6.39	4,684
Total to Builder							**750**
Total to Consumer							**892**

Table A 15 Cost Impact, Defensible Space, 2-Story Reference House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Ground cover, pea gravel	Ton	11.80	24.50	36.30	53.00	10.29	545
Shrub, Russian olive, 3'- 4'	EA	26.00	13.40	47.95	60.50	(4.00)	(242)
Shrub, viburnum, 3' - 4'	EA	27.00	25.00	68.05	88.50	4.00	354
Sodding, bluegrass sod on level ground	MSF	335.00	82.50	430.65	520.00	(9.17)	(4,770)
Sodding, pallet of Zoysia	MSF	530.00	82.50	625.65	733.59	8.15	5,975
Total to Builder							**1,317**
Total to Consumer							**1,565**

[9] https://ibhs.org/wp-content/uploads/wpmembers/files/Near-Building_Noncombustible_Zone_Report_IBHS.pdf
[10] https://www.fs.fed.us/rm/pubs_other/rmrs_2004_barkeley_y001.pdf

Reference Code Section

2018 IWUIC Section 602 Automatic sprinkler system

Summary of the Code:

IR 1 construction requires approved automatic sprinkler system to be installed in all occupancies in new buildings.

Cost Implication of the Code Compliance:

Compliance with this code section will increase the cost of construction where automatic fire sprinkler systems are not already mandated by the local code. The Home Fire Sprinkler Cost Assessment- 2013[11] report by The Fire Protection Research Foundation showed that the maximum cost for residential sprinkler system was $2.47 ($/sprinkled SF) because of the additional cost associated with different piping materials and permitting and fees for sprinkler system. This rate is used to calculate the high cost impact for the reference houses using a sprinkled area of 2600 SF. This cost is applicable to all selected location except Los Angeles, CA because California has a state-wide mandated requirement for automatic sprinkler system in residential houses.

Table A 16 Cost Impact, Automatic Sprinkler System, Single and 2-Sotry Reference House
(Lower Cost Impact: Addition of Automatic Sprinkler System)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Flow alarm	EA	112.00	12.45	124.45	144.00	1	144
Flow switch (valve supervisory switch)	EA	265.00	20.00	285.00	325.00	1	325
Sprinkler head, fast response glass bulb, 135°Fto155°F	EA	34.00	20.00	54.00	70.50	10	705
Sprinkler head escutcheons, standard, brass tone, 1"	EA	3.56	8.10	11.66	17.15	10	172
CPVC fire suppression pipe, 1"	LF	2.26	1.71	3.97	5.30	200	1,060
CPVC fire suppression tee, 1"	EA	5.10	21.50	26.20	40.50	12	486
CPVC fire suppression 90 elbow, 1"	EA	4.12	14.30	18.42	28.00	10	280
CPVC fire suppression cap, 1"	EA	1.55	7.20	8.75	13.50	4	54
CPVC fire suppression coupling, 1"	EA	2.39	14.30	16.69	26.00	2	52
CPVC fire suppression adapter, metal thread, 1"x1/2"	EA	5.25	7.20	12.45	17.55	10	176
Total to Builder							**3,453**
Total to Consumer							**4,106**

[11] https://www.nfpa.org//-/media/Files/Fire-Sprinkler-Initiative/HomeFireSprinklerCostAssessment2013.pdf

APPENDIX B: CONSTRUCTION PRACTICES IN SELECTED LOCATIONS

Table B 1 Common Construction Practices in Selected Locations

Component	Colorado	East TX	South CA
Percent 1-story	50	71	36
Foundations			
Basement	68	11	16
Crawlspace	6	3	13
Slab	23	78	71
Roofing Material (Top 4)			
Asphalt Shingles	85	92	33
Clay/Cement Tiles	9	2	38
Aluminum/Steel	3	4	2
Single ply/built-up	3	2	17
Roof Pitch			
Average Roof Pitch */12	6	7.4	4.8
Wall Cladding (Top 4)			
Fiber Cement	23	27	
Engineered Wood	17	9	10
EIFS	10		6
Stucco	12	8	37
Brick		30	7
Vinyl		11	
Stone			15
Exterior Trim Material (Top 4)			
Wood fiber composite	37	20	12
Lumber boards	12	18	49
Fiber Cement	18	40	8
Aluminum	13	9	
Stucco			19
Exterior Decking Material			
Treated lumber	9	32	14
Cedar or Redwood	7	13	26
Composite or Plastic	79	47	54
Windows			
Wood	18	17	41
Aluminum	1	5	7
Vinyl	77	66	49
Composite/Fiberglass	4	12	3

APPENDIX C: LOCATION ADJUSTMENT FACTORS

Location factors for various cities in California, Colorado and Texas from *2020 Residential Costs with RSMeans Data* are shown in the following tables.

Table C 1 Location Factors, California Cities

SN	CALIFORNIA CITIES	LOCATION FACTORS
1	Los Angeles	0.99
2	Inglewood	0.97
3	Long Beach	0.95
4	Pasadena	0.94
5	Van Nuys	0.99
6	Alhambra	1
7	San Diego	0.98
8	Palm Springs	0.95
9	San Bernardino	0.97
10	Riverside	0.98
11	Santa Ana	0.99
12	Anaheim	0.97
13	Oxnard	0.98
14	Santa Barbara	0.97
15	Bakersfield	0.98
16	San Luis Obispo	1
17	Mojave	0.99
18	Fresno	0.99
19	Salinas	0.99
20	San Francisco	1.03
21	Sacramento	0.97
22	Palo Alto	0.98
23	San Mateo	1.03
24	Vallejo	0.96
25	Oakland	1.02
26	Berkeley	1.06
27	Richmond	1.07
28	San Rafael	1.03
29	Santa Cruz	1.05
30	San Jose	1.04
31	Stockton	1
32	Modesto	0.99
33	Santa Rosa	1

34	Eureka	1.06
35	Marysville	1.02
36	Redding	1.07
37	Susanville	1.07

Table C 2 Location Factors, Colorado Cities

SN	COLORADO CITIES	LOCATION FACTORS
1	Denver	1.05
2	Boulder	1.04
3	Golden	1.01
4	Fort Collins	1.03
5	Greeley	1.01
6	Fort Morgan	1.05
7	Colorado Springs	1
8	Pueblo	1
9	Alamosa	0.99
10	Salida	1.01
11	Durango	1.05
12	Montrose	0.97
13	Grand Junction	1.08
14	Glenwood Springs	1

Table C 3 Location Factors, Texas Cities

SN	TEXAS CITIES	LOCATION FACTORS
1	McKinney	0.94
2	Waxahachie	0.94
3	Dallas	0.98
4	Greenville	0.94
5	Texarkana	0.96
6	Longview	0.93
7	Tyler	0.95
8	Palestine	0.9
9	Lufkin	0.94
10	Fort Worth	0.98
11	Denton	1.01
12	Wichita Falls	1
13	Eastland	0.98

14	Temple	0.98
15	Waco	0.99
16	Brownwood	0.95
17	San Angelo	0.95
18	Houston	0.99
19	Huntsville	0.96
20	Wharton	0.96
21	Galveston	0.97
22	Beaumont	1.03
23	Bryan	0.91
24	Victoria	0.99
25	Laredo	0.95
26	San Antonio	0.98
27	Corpus Christi	1.02
28	McAllen	1.04
29	Austin	0.95
30	Del RIO	0.97
31	Giddings	0.96
32	Amarillo	0.99
33	Childress	0.96
34	Lubbock	0.97
35	Abilene	0.98
36	Midland	1.01
37	El Paso	0.95

APPENDIX D: FIRE HAZARD SEVERITY

Table D 1 IWUIC Fire Hazard Severity (source: adapted from 2018 IWUIC Table 502.1)

FUEL MODEL	Critical Fire Weather Frequency (days)								
	≤ 1			2 - 7			≥8		
	Slope ≤ 40;		Slope 41-60;			Slope ≥61			
Light fuel	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High
Medium fuel	Moderate	Moderate	High	High	High	High	Extreme	Extreme	Extreme
Heavy fuel	High	High	High	High	Extreme	Extreme	Extreme	Extreme	Extreme

IWUIC 2018 defines light fuel as vegetation consisting of herbaceous plants and round wood less than ¼ inch (6.4 mm) in diameter. Fuel models A, C, E, L, N, P, R and S described in IWUIC Appendix D are classified as light fuel. Medium fuel comprises vegetation consisting of round wood ¼ to 3 inches (6.4 mm to 76 mm) in diameter. Fuel models B, D, F, H, O, Q and T are classified under this category. Similarly, heavy fuel comprises vegetation consisting of round wood 3 to 8 inches (76 mm to 203 mm) in diameter. Fuel models G, I, J, K and U are classified as heavy fuel. Table D2 lists the various fuel models provided in Appendix D of IWUIC 2018.

Table D 2 Fuel Model Classification (source: adapted from 2018 IWUIC)

IWUIC Chapter 2 Definitions:	**Fuel Models**
Light Fuel: *"Vegetation consisting of herbaceous plants and round wood less than 1/4 inch (6.4 mm) in dia."*	**A C E L N P R S**
Medium Fuel: *"Vegetation consisting of round wood 1/4 to 3 inches (6.4 mm to 76 mm) in diameter."*	**B D F H O Q T**
Heavy Fuel: *"Vegetation consisting of round wood 3 to 8 inches (76 to 203 mm) in diameter."*	**G I J K U**

Table D3 provides elaborate description of various fuel models and is an excerpt from National Fire Danger Rating System, 1978, U.S. Department of Agricultural Forest Service, General Technical Report INT-39[12] that has been provided for information in Appendix D of 2018 IWUIC.

[12] https://www.fs.fed.us/rm/pubs_int/int_gtr169.pdf

Table D 3 Fuel Models (source: adapted from 2018 IWUIC APPENDIX D)

Fuel Model Type	IWUIC Description of Vegetation
Fuel Model A	*"This fuel model represents western grasslands vegetated by annual grasses and forbs. Brush or trees may be present but are very sparse, occupying less than a third of the area. Examples of types where Fuel Model A should be used are cheatgrass and medusahead. Open pinyon-juniper, sagebrush-grass, and desert shrub associations may appropriately be assigned this fuel model if the woody plats meet the density criteria. The quantity and continuity of the ground fuels vary greatly with rainfall from year to year."*
Fuel Model B	*"Mature, dense fields of brush 6 feet (1829 mm) or more in height are represented by this fuel model. One-fourth or more of the aerial fuel in such stands is dead. Foliage burns readily. Model B fuels are potentially very dangerous, fostering intense, fast-spreading fires. This model is for California mixed chaparral generally 30 years or older. The F model is more appropriate for pure chamise stands. The B model may also be used for the New Jersey pine barrens"*
Fuel Model C	*"Open pine stands typify Model C fuels. Perennial grasses and forbs are the primary ground fuel but there is enough needle litter and branchwood present to contribute significantly to the fuel loading. Some brush and shurbs may be present but they are of little consequence. Situations covered by Fuel Model C are open, longleaf, slash, ponderosa, Jeffrey and sugar pine stands. Some pinyon-juniper stands may qualify."*
Fuel Model D	*"This fuel model is specifically for the palmetto-gallberry understory-pine overstory association of the southeast coastal plains. It can also be used for the so called "low pocosins" where Fuel Model O might be too severe. This model should only be used in the Southeast, because of a high moisture of extinction."*
Fuel Model E	*"Use this model after leaf fall for hardwood and mixed hardwood-conifer types where the hardwoods dominate. This fuel is primarily hardwood leaf litter. The oat-hickory types are best represented by Fuel Model E, but E is an acceptable choice for northern hardwoods and mixed forests of the Southeast. In high winds, the fire danger may be underrated because rolling and blowing leaves are not accounted for. In summer after the trees have leafed out, Fuel Model E should be replaced by Fuel Model R."*
Fuel Model F	*"Fuel Model F is the only one of the 1972 NFDR System Fuel Models whose application has changed. Model F now represents mature closed chamise stands and oakbrush fields of Arizona, Utah and Colorado. It also applies to young, closed stands and mature, open stands of California mixed chaparral. Open stands of pinyon-juniper are represented; however, fire activity will be overrated at low wind speeds and where there is sparse ground fuels."*

Fuel Model G	*"Fuel Model G is used for dense conifer where there is a heavy accumulation of litter and downed woody material. Such stands are typically overmature and may also be suffering insect, disease, wind or ice damage-natural events that create a very heavy buildup of dead material or the forest floor. The duff and litter are deep, and much of the woody material is more than 3 inches (76 mm) in diameter. The undergrowth is variable, but shrubs are usually restricted to openings. Types meant to represented by Fuel Model G are hemlock-Stika spruce, Coast Douglas-fir, and wind thrown or bug-killed stands of lodgepole pine and spruce."*
Fuel Model H	*"The short-needled conifers (white pines, spruces, larches and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels. Fires in H fuels are typically slow spreading and are dangerous only in scattered areas where the downed woody material is concentrated."*
Fuel Model I	*"Fuel Model I was designed for clearcut conifer slash where the total loading of materials less than 6 inches (152 mm) in diameter exceeds 25 tons/acre (56.1 metric tons/ha). After settling and the fines (needles and twigs) fall from the branches, Fuel Model I will overrate the fire potential. For lighter loadings of clearcut conifer slash, use Fuel Model J, and for light thinnings and partial cuts where the slash is under a residual overstory, use Fuel Model K."*
Fuel Model J	*"This model is complementary to Fuel Model I. It is for clearcuts and heavily thinned conifer stands where the total loading of materials less than 6 inches (152 mm) in diameter is less than 25 tons/acre (56.1 metric tons/ ha). Again, as the slash ages, the fire potential will be overrated."*
Fuel Model K	*"Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically, the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clearcuts where the loading of all fuels is less than 15 tons/arce. (33.7 tons/ha)."*
Fuel Model L	*"This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels. Otherwise, the situations are very similar; shrubs and trees occupy less than one-third of the area. The quantity of fuel in these areas is more stable from year to year. In sagebrush areas, Fuel Model T may be more appropriate."*
Fuel Model N	*"This fuel model was constructed specifically for the saw-grass priaries of South Florida. It may be useful in other marsh situations where the fuel is coarse and reedlike. This model assumes that one-third of the aerial portion of the plants is dead. Fast-spreading, intense fires can occur even over standing water."*

Fuel Model O	*"The O fuel model applies to dense, brushlike fuels of Southeast. O fuels, except for a deep litter layer are almose entirely living in contrast to B fuels. The foliage burns readily, except during the active growing season. The plants are typically over 6 feet (1829 mm) tall and are often found under an open stand of pine. The high pocosins of Virginia, North and South Carolina coasts are the ideal of Fuel Model O. If the plants do not meet the 6-foot (1829 mm) criterion in those areas, Fuel Model D should be used."*
Fuel Model P	*"Closed, thrifty stands of long-needled southern pines are characteristic of P fuels. A 2- inch to 4-inch (51 to 102 mm) layer of lightly compacted needle litter is the primary fuel. Some small-diameter branchwood is present, but the density of the canopy precludes more than a scattering of shrubs and grass. Fuel Model P has the high moisture of extinction characteristic of the Southeast. The corresponding model for other long-needled pines is U."*
Fuel Model Q	*"Upland Alaskan black spruce is represented by Fuel Model Q. The stands are dense but have frequent openings filled with usually flammable shrub species. The forest floor is a deep layer of moss and lichens, but there is some needle litter and small-diameter branchwood. The branches are persistent on the trees, and ground fires easily reach into the tree crowns. This fuel model may be useful for jack pine stands in the Lake States. Ground fires are typically slow spreading, but a dangerous crowning potential exists."*
Fuel Model R	*"This model represents hardwood areas after the canopies leaf out in spring. It is provided as the off-season substitute for E. It should be used during summer in all hardwood and mixed conifer-hardwood stands where more than half of the overstory is deciduous."*
Fuel Model S	*"Alaskan or alpine tundra on relatively well-drained sites. Grass and low shrubs are often present, but principal fuel is a deep layer of lichens and moss. Fires in these fuels are not fast spreading or intense, but are difficult to extinguish."*
Fuel Model T	*"The bothersome sagebrush-grass types of the Great Basin and the Intermountain West are characteristic of T fuels. The shrubs must occupy at least one third of the site or the A or L fuel models should be used. Fuel model T might be used for immature scrub oak and desert shrub associations in the West, and the scrub oak-wire grass type in the Southeast."*

Fuel Model U	*"Closed stands of western long-needled pines are covered by this model. The ground fuels are primarily litter and small branchwood. Grass and shrubs are precluded by the dense canopy but occur in the occasional natural opening. Fuel Model U should be used for Ponderosa, Jeffrey, sugar pine, and red pine stans of the Lake States. Fuel model P is corresponding model for southern pine plantations."*

APPENDIX E: REFERENCE HOUSE CHARACTERISTICS

The Reference Houses for this study are based on similar reference houses that were initially defined in a report by Home Innovation titled "Estimated Costs of the 2015 Code Changes"[13]; additional details from this report are provided below.

Reference House Characteristics – Previous Studies

For earlier studies by Home Innovation, baseline metrics were defined for four representative single-family houses, built to the IRC, to determine the cost impact of any code changes. The Reference Houses and their site locations were initially defined in a report titled "Estimated Costs of the 2015 Code Changes" prepared by Home Innovation for NAHB. These single-family 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. Features of the Reference Houses are summarized in the next section.

The four residential building designs are based on the data contained in the Census Bureau report, *Characteristics of New Single-Family Construction Completed*[14]. The report provides information about building foundation type and number of stories for new single-family detached construction over the previous nine-year period.

Table E 1 New Construction Foundation Types

Slab	54%
Crawlspace	17%
Basement	30%

Table E 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

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

[14] www.census.gov/construction/chars/completed.html

The table below 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.[15] Chicago was selected to represent a Climate Zone 5 house.

Table E 3 Sites for Reference Houses

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

[15] www.census.gov/construction/bps/pdf/2013statepiechart.pdf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