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ESTIMATED COSTS OF THE 2018 ICC CODE CHANGES FOR MULTIFAMILY BUILDINGS

Prepared For

National Association of Home Builders

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

ASCE	American Society of Civil Engineers
BPS	Builder Practices Survey—national survey conducted annually by Home Innovation Research Labs
CFM	Cubic feet per minute (a measure of flow)
CZ	Climate zone, as defined by the International Code Council (ICC)
EERO	Emergency escape and rescue opening
ERI	Energy rating index
ERV	Energy recovery ventilator
HVAC	Heating, ventilation, and cooling
IBC	International Building Code
ICC	International Code Council
IECC	International Energy Conservation Code
IFC	International Fire Code
IMC	International Mechanical Code
IRC	International Residential Code
LF	Linear feet
NAHB	National Association of Home Builders
NEHRP	National Earthquake Hazards Reduction Program
O&P	Overhead and profit
OSB	Oriented strand board
PSF	Pounds per square foot
SDC	Seismic design category
SDPWS	Special Design Provisions for Wind and Seismic
SF	Square feet
WFCM	Wood Frame Construction Manual

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BACKGROUND

The National Association of Home Builders (NAHB) provided a list of 26 code changes affecting multifamily construction which were approved for incorporation into the 2018 International Codes. The changes affect the International Building Code (IBC), International Energy Conservation Code (IECC), International Fire Code (IFC), and International Mechanical Code (IMC). A companion report, *Estimated Costs of the 2018 IRC Code Changes*, covers changes approved for the 2018 International Residential Code (IRC) and their impact on one- and two-family dwellings. Home Innovation Research Labs estimated the expected cost impact of these code changes on construction practices and materials. 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

Baseline metrics for five representative multifamily buildings built to the 2015 IBC, IECC, IFC and IMC[1] were defined in order to determine the cost impact resulting from the revisions approved for the 2018 codes. Elevations and floor plans for these reference buildings are provided in Appendices C through G.

The reference buildings define a starting point for the analysis of the cost impact to a builder resulting from adoption of the 2018 codes (relative to the 2015 IBC/IECC/IFC/IMC baseline).

National Construction Cost

Cost impacts in this analysis have been developed primarily with data adapted from the following sources: (1) RSMeans' *Light Commercial Cost Data 2017*,[2] (2) distributors' or big box retailers' websites, and (3) U.S. government reporting from the Census Bureau[3] and the Bureau of Labor Statistics[4]. Other cost sources are cited in *Appendix A* of this report as applicable to a specific code change. Costs are reported at the national level and can be modified for a region using builders' known bid prices or by applying a location factor adjustment shown in *Appendix B*. Costs reported are the cost to the builder; the compiled costs do not reflect the consumer price.

Reference Building Configurations

The five multifamily building designs (see *Appendices C-G)* used in this analysis were selected based on data contained in the Census Bureau report, *Characteristics of New Multifamily Buildings Completed*[5] and a tabulation provided by Home Innovation of multifamily buildings certified to the National Green Building Standard. The Census Bureau report provides information as to the number of stories (Table 1) and number of units (Table 2) in multifamily new construction. The Home Innovation data was listed by climate zone, number of stories, and number of units.

[1] International Code Council, www.iccsafe.org/Pages/default.aspx
[2] http://rsmeans.reedconstructiondata.com
[3] http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk
[4] http://www.bls.gov/oes/current/oes_nat.htm#47-0000
[5] www.census.gov/construction/chars/mfb.html

Table 1. New Construction Number of Stories

One- and two-story	38%
Three story	43%
Four-story or more	19%

Table 2. New Construction Number of Units

2 – 9	43%
10 – 49	48%
50 or more	9%

Using the Census Bureau and Home Innovation data, five reference buildings were selected as follows:

- Two-story apartment building with 24 units
- Three-story “garden-style” building (non-enclosed shared stairways, no elevators) and 36 units
- Four-story enclosed building on grade with 48 units and communal spaces (amenities)
- Four-story enclosed building with 167 units on top of a one-story podium
- Four-story townhouse with three bedrooms and a garage

Reference Buildings Definition

The statistics presented in the previous tables support reference building features enumerated in Table 3. These five buildings, in compliance with the minimum requirements of the 2015 IBC, IECC, IFC and IMC, will serve as the baseline(s) for adding or subtracting costs to estimate the impact of code changes approved for the 2018 IBC, IECC, IFC and IMC.

Table 3. Features of the Reference Multifamily Buildings

Reference Building	**1**	**2**	**3**	**4**	**T.H.**
Approx. Total Size	19,500 SF	43,150 SF	44,500 SF	462,600 SF	2,500 SF
Approx. Footprint	60' x 162'	62' x 263'	57'x175'	186'x348'	16'x37'
Foundation	Crawlspace	Slab on grade	Slab on grade	Basement (garage)	Slab on grade
Number of Stories	2	3	4	5	4
Number of Units	24	36	48 + shared	167	1
Large Projections	None	Wood-framed balconies	None	Bolt-on balconies	Deck
Elevators	1	0	2	2	0
Stairways	3	6	2	2	1
Type/Location	Enclosed	Open	Enclosed	Enclosed	In-Unit
Parking	Surface Lot	Surface Lot	Surface Lot	Enclosed public parking garage	Private garage
Sprinklers		Yes	Yes	Yes	Yes
HVAC	Building boiler + in-unit radiators	Split system air cond. (outdoor condenser + in-unit air handler)	Split system heat pump (roof condenser + in-unit air handler)	Split system heat pump (roof condenser + in-unit air handler)	Outdoor condenser + indoor furnace
Laundry	Communal	In unit	In unit	In unit	In unit
1st Floor Ceiling	9 ft	9 ft	10 ft	13 ft	11 ft
2nd Floor Ceiling	8ft	9 ft	10 ft	11 ft	10 ft
3rd Floor Ceiling	N/A	9 ft	10 ft	11 ft	10 ft
4th Floor Ceiling	N/A	N/A	10 ft	11 ft	10 ft
5th Floor Ceiling	N/A	N/A	N/A	10 ft	N/A
Attic Height	12 ft	12 ft	12 ft	N/A	N/A
Building Height	29 ft	39 ft	52 ft	56 ft	41 ft
Roof Slope	5/12 pitch	7/12 pitch	8/12 pitch	¼"/foot slope	¼" foot slope

RESULTS

Estimated Cost of 2018 Code Compliance for Reference Buildings by Location

Table 4 summarizes the estimated cumulative impact of the selected code changes on the cost of constructing reference buildings 1 – 4. These changes are applicable to all buildings nationwide, but may not affect each reference building. The aggregated costs are reported in ranges of "High" and "Low" impact based on the applicability of the changes to the features of the reference buildings. Table 5 summarized the cost estimates of code changes that affect optional features or location-specific features; these costs are not included in the aggregated summary.

Table 6 summarizes the estimated cumulative impact of the selected code changes on the costs of constructing the reference townhouse. Table 7 summarizes the cost estimated of the code changes that do not directly apply to the selected reference building and are not included in the aggregated summary. Those costs can be added or subtracted from the aggregated costs if applicable to a particular location or a specific building.

A detailed analysis of each individual code change is provided in Appendix A. [Style note: red numbers in parentheses in the tables in this report indicate a negative cost or saving.]

Table 4. Estimated Cost of 2018 Code Compliance; Reference Building 1 - 4

Description	Ref.	Reference Building							
		1		2		3		4	
		Low	High	Low	High	Low	High	Low	High
Elevator video relay service	ELV1	2,500	5,000	N/A	N/A	2,500	5,000	2,500	5,000
Roof wind loads	STR1	0	2,376	0	4,280	0	3,507	8,380	16,724
Deck and balcony live loads	STR2	N/A	N/A	960	1,120	N/A	N/A	N/A	3,700
Balcony ventilation	WOD1	N/A	N/A	960	1,263	N/A	N/A	N/A	N/A
Positive drainage for permeable floors	WOD2	N/A	N/A	1,280	1,810	N/A	N/A	N/A	N/A
Exterior lighting controls	COM2	N/A	N/A	N/A	N/A	584	1,796	N/A	N/A
TOTAL		**2,500**	**7,376**	**3,200**	**8,473**	**3,084**	**10,303**	**10,880**	**25,424**

Table 5. Additional Costs of 2018 Code Compliance; Optional Features or Location-Specific

Description	Ref.	Reference Building							
		1		2		3		4	
		Low	High	Low	High	Low	High	Low	High
Seismic loads	STR3	16,506	16,920	44,187	44,861	Not analyzed[1]	Not analyzed[1]	Not analyzed[1]	Not analyzed[1]
Fire watch during temporary heating	SAF1	740	10,820	740	10,820	740	20,900	740	30,980
Fire watch for construction ≥ 40 ft.	SAF2	N/A	N/A	N/A	N/A	233,280	328,320	233,280	328,320

Description	Ref.	Reference Building							
		1		2		3		4	
		Low	High	Low	High	Low	High	Low	High
Smoke detector dust protection	SAF3	4	4	11	11	9	9	30	30
Return air wall cavity and floor joist plenums	DCT1	N/A	N/A	N/A	N/A	(10,676)	(10,676)	N/A	N/A
Longitudinal duct joints	DCT2	N/A	N/A	(1,814)	(1,814)	(2,016)	(2,016)	(11,222)	(11,222)

[1.] The impact of seismic loads is evaluated for Reference Buildings 1 and 2 only. The analysis of cost implications on Reference Buildings 3 and 4 were not part of the scope of the study. It is noted that a significant impact would be expected for both buildings.

Table 6. Estimated Cost of 2018 Code Compliance; Reference Townhouse

Description	Ref.	Reference Townhouse	
		Low	High
Stairways in multi-story dwelling units	EGR1	(239)	(239)
Fixed seating guard height	EGR2	(130)	(65)
Enclosed garage mechanical ventilation	OCC2	(338)	(338)
Height/area limits	HTS1	(15,500)	(15,500)
Deck and balcony live loads	STR2	1,160	1,200
Exterior lighting controls	COM2	96	247
Fire watch during temporary heating	SAF1	740	3,620
Fire watch during construction ≥ 40 ft.	SAF2	37,800	56,160
Longitudinal duct joints	DCT2	(140)	(140)
TOTAL		**23,452**	**44,957**
TOTAL WITHOUT FIRE WATCHES		**(15,088)**	**(14,823)**

Table 7[6]. Additional Costs of 2018 Code Compliance Not Attributed to the Reference Buildings

Description	Ref.	Low	High
Emergency escape and rescue opening	EGR3	(2,630)	(1,555)
Firewalls not required on lot lines	FIR1	(5,097)	(2,548)
Exterior walls fire resistance ratings	CON1	(90)	(37)
Private garage fire barrier	OCC1	(10,730)	(10,730)
Suspended ceiling, 2000 SF room	STR3	503	503
Single member headers	WOD3	(241)	(111)
Energy recovery ventilation	COM1	(2,045)	(1,749)
Smoke detector dust protection	SAF3	1	1
Attic sprinkler system	SYS1	2,119	19,174
Class III standpipe systems	SYS2	14,935	29,870

[6] These items are either optional or location-specific requirements for townhouses.

APPENDIX A
DESCRIPTION AND COST IMPACT OF 2018 CODE CHANGES

Appendix A-IBC: International Building Code

Report Reference No: EGR1

2018 IBC Code Sections: 1006.3, 1006.3.1 Egress from Stories or Occupied Roofs

Summary of Code Change:

The code change adds new exceptions to IBC Section 1006.3 allowing exiting through more than one adjacent story for R-1, R-2, R-3 dwelling units, sleeping units or live/work units, R-3 Congregate units, and R-4 occupancies. Exit access stairways internal to multi-story dwelling units that are four stories or less can now be open (i.e., non-enclosed).

Cost Implication of the Code Change:

Per Section 1023, the walls of an enclosed exit stairway must have a fire-resistance rating of not less than 2 hours for a building that is four stories or more. For a four-story townhouse, the change in Section 1006.3 results in material cost savings from not needing 2-hour fire-rated partition walls for a shaft enclosure.

This code change applies only to the reference townhouse and will eliminate the need for non-bearing partition wall segments surrounding the staircase.

Table EGR1. Estimated Cost Savings of Open Exit Stairway in 4-story Townhouse

Component	Unit	Mat	Labor	Total	w/O&P	Quant.	Cost
5/8" gypsum board, fire resistant	SF	0.35	0.27	0.62	0.84	120	101
2x4 wood studs, 8' high, 16" oc, pneumatic nailed	LF	3.6	4.52	8.12	11.5	12	138
						Total	239

Report Reference No: EGR2

2018 IBC Code Sections: 1015.3 Height

Summary of Code Change:

The code change removes “or adjacent fixed seating” from Exception #1 for measuring vertical guard heights, thus reducing the guard height behind fixed seating by 16-18 inches. The change will affect four-story townhouses. For decks, the guard height now must only measure 36 inches from the walking surface; previously, the guard height had to be measured from the back of fixed seating, if provided.

Cost Implication of the Code Change:

The change results in material cost saving: the guard height behind a common 18” fixed bench is reduced from 54 to 36 inches.

This change applies only to the reference townhouse, which has a 14x5 deck. The difference in price is for a shorter guard directly behind the fixed bench. Two scenarios are analyzed: a bench measuring 6 feet long and a bench measuring 12 feet long.

Component	Unit	Material	Labor	Total	w/O&P
Composite railing, 6' long, 36" high including balusters	Ea	161	16.95	177.95	206
Composite railing, 6' long, 54" high including balusters	Ea	221	16.95	237.95	271

Table EGR2. Estimated Savings from Shorter Railing

Cost	6 foot bench	12 foot bench
54 inch railing	(271)	(542)
36 inch railing	206	412
Savings	(65)	(130)

Report Reference No: EGR3

2018 IBC Code Sections: 1030.1 General (Emergency Escape and Rescue)

Summary of Code Change:

This code change does not contain any new requirements, but clarifies that emergency escape and rescue openings are only required for dwelling units in Group R-2 occupancies that are located on stories with only one exit or access to one exit as permitted in Section 1006.3 Egress From Stories or Occupied Roofs and Tables 1006.3.3(1) and (2). A dwelling unit which has access to two means of egress does not require an Emergency Escape and Rescue opening.

Cost Implication of the Code Change:

This change is not directly applicable to any of the reference buildings. However, a previous study conducted by Home Innovation[7] on the cost of EEROs found that not including one in a new building (or addition) saves $1,555, while not including one in an existing building saves $2,630.

[7] Estimate Costs of 2015 IRC Code Changes

Report Reference No: FIR1

2018 IBC Code Sections: 706.1.1 Party walls

Summary of Code Change:

The code change adds a new exception specifying that a party wall between buildings does not have to be constructed as a fire wall when the lot line dividing two adjoining buildings is solely for ownership purposes and the building heights and areas for the adjoining buildings do not exceed the maximum height and area requirements in the IBC.

Cost Implication of the Code Change:

For this change, a two-hour fire-rated wall dividing two townhouses can be replaced by a one-hour rated wall. The two wall types differ in the gypsum details:

- A U301 wall (2 hour rating) has four layers of fire rated gypsum (two layers exterior and two layers interior of the studs)
- A U305 wall (1 hour rating) has two layers of fire rated gypsum (one layer exterior and one layer interior of the studs)

The bare material costs are below.

Component	Unit	Material	Labor	Total	w/O&P
5/8" thick fire rated gypsum, on walls, finish not included	SF	0.35	0.27	0.62	0.84

This change applies to two types of townhouses: an end-unit townhouse (one shared fire wall), and a middle-unit townhouse (two shared fire walls). We have the following values from the plans.

Type	Separation Wall Area
Mid unit (two fire walls)	3034 SF
End unit (one fire wall)	1517 SF

Table FIR1. Estimated Savings of Replacing a 2 Hour Rated Wall

Wall	Mid Unit	End Unit
2 hr rated	(10194)	(5097)
1 hr rated replacement	5097	2548
Savings	(5097)	(2548)

Report Reference No: OCC1

2018 IBC Code Sections: 406.3 Private garages and carports

Summary of Code Change:

The code change allows private garages (garages accessible only to tenants of the building) to be constructed to the requirements of public garages, in lieu of needing to be subdivided every 1000 square feet by 1-hour fire barrier walls with fire doors.

Cost Implication of the Code Change:

Because the garage in reference building 4 is Group S-2, this code change is not directly applicable to any of the reference buildings. For this cost analysis, a 2000 SF enclosed garage similar to the one found in reference building 4 will be compared in two scenarios: sprinkler system and ventilation vs. 1-hr fire barrier wall dividing the space in half.

Table OCC1. Estimated Savings from Public Garage Requirements

Component	Unit	Material	Labor	Total	Quantity	Cost
					Total for two 1000 SF garages	28,512
Light hazard wet pipe sprinkler system	SF	5.70	2.73	8.43	2000	16,860
Enclosed garage exhaust fan, 1640 CFM	Ea	689.99	98.50	922.50	1	923
Poured concrete wall, 10’ tall, 8” thick (previously separating two 1000 SF garages)	LF	52	110	162	(176)	(28,512)
					Total for 2000 SF garage	(10,730)

Report Reference No: OCC2

2018 IBC Code Sections: 406.6.2 Ventilation

Summary of Code Change:

The code change adds an exemption to providing mechanical ventilation for enclosed parking garages accessory to one- and two-family dwellings or townhouses (Group R-3 buildings). This change promotes consistency between dwellings constructed as Group R-3 under the IBC versus those constructed under the IRC, which does not require mechanical ventilation for an attached garage.

Cost Implication of the Code Change:

The change results in a material cost savings for a four-story townhouse that no longer needs mechanical ventilation and the associated ductwork in the attached garage.

Table OCC2. Estimated Additional Cost Savings of No Mechanical Ventilation in Garage

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Broan L200 exhaust fan	EA	152.44	--	152.44	167.68	1	168
Installation of ventilation fan	HR	--	42.4	--	70.85	2	142
Insulated flex duct, 6" diameter	LF	2.94	2.35	5.29	7.15	4	29
						Total	338

Report Reference No: HTS1

2018 IBC Code Sections: 503.1 General, 706.1 General

Summary of Code Change:

The code change clarifies that the building separation created by a fire wall provided in accordance with Section 706 applies only for determining height/area limits and construction types. It does not require all of the elements and systems on each side of the fire wall to be self-contained or self-supporting, except as required by Section 706. Only the gravity load-bearing elements on each side of the fire wall are required to be structurally independent.

Cost Implication of the Code Change:

This code change allows for the structural analysis of a row of townhomes under lateral wind and seismic loads as a complete building instead of as individual units. The primary difference is the bracing requirements for the front and rear walls of a town house, which typically have a large area of openings and a limited solid wall area for placing shear walls. If designed as a stand-alone unit, the townhouse would require a special engineering solution such as a steel moment frame to provide lateral bracing for the building. If the row of townhouses is designed as a complete building, the wind or seismic loads can be distributed between the adjacent units, leading to more optimized bracing solutions.

The analysis evaluates a wind scenario (115 mph wind speed) for cost impact on the reference four-story townhouse. This scenario is intended to represent a plausible structural solution for the specific set of conditions and is intended to demonstrate a range of cost implications. The cost for the shear panels were adopted from the previously published report (Estimated Costs of the 2009 IRC Code Changes, Home Innovation Research Labs, January 2015) and confirmed with current available web pricing from online suppliers. The cost for the moment frame was adopted from a quote provided by a supplier to a local home builder.

Table HTS1. Estimated Cost Savings for a 4-story Town House in 115 MPH Wind Speed Area

Townhouse Story/Level	Total estimated CS-WSP length	Individual Townhouse – Bracing Solution	A Row of Six Townhouses – Bracing Solution	Incremental Unit Cost of Proprietary Bracing Product	Total Cost Savings per Level
Level 4	6 ft	CS-WSP	CS-WSP	0	0
Level 3	11.5 ft	(3) Simpson Shear Panels – Front Wall CS-WSP and (1) Simpson Shear Panel – Back Wall	CS-PF – Front Wall CS-WSP – Back Wall	(565)	(3,200)
Level 2	17 ft	(3) Simpson Shear Walls per wall	CS-PF – Front Wall CS-WSP – Back Wall	(565)	(4,800)
Level 1 (ground level)	23 ft	(1) Simpson Moment Frame per wall	(2) Simpson Shear Walls per wall	(6,050) 565	(8,900)
				Total Savings	**(15,500)**

Report Reference No: CON1

2018 IBC Code Sections: Table 602 Fire resistance ratings for exterior walls based on fire separation distance

Summary of Code Change:

The code change adds a footnote to Table 602 exempting the adjacent exterior walls of Group R-3 buildings of Type IIB and Type VB construction from needing to be fire-rated where the fire separation distance between the buildings exceeds 5 feet. The change aligns the IBC requirements for Group R-3 dwellings with the IRC.

Cost Implication of the Code Change:

A U305 one-hour fire-rated wall consists of 2x4 wood studs and two layers of 5/8" fire-rated gypsum (one exterior and one interior of the studs). This change results in a material cost savings by exempting these walls from being fire-rated; i.e., standard gypsum can be used instead.

Component	Unit	Material	Labor	Total	w/O&P
5/8" thick fire rated gypsum, on walls, finish not included	SF	0.35	0.27	0.62	0.84
5/8" thick standard gypsum on walls, finish not included	SF	0.34	0.27	0.61	0.82

This applies to two types of townhomes: an end-unit townhouse, and a middle-unit townhouse. We have the following values from the plans.

Type	Gross exterior wall area	Fenestration area	Net exterior wall area
Middle unit (front and back exterior walls only)	1312 SF	384 SF	928 SF
End unit (front, back, side exterior wall)	2829 SF	570 SF	2259 SF

Table CON1. Estimated Cost Saving of U301 Wall

Wall	Middle Unit Townhouse	End Unit Townhouse
1 hr rated	1559	3795
Un-rated	1522	3705
Savings	37	90

Report Reference No: ELV1

2018 IBC Code Sections: 3001.2 Emergency elevator communication systems for the deaf, hard of hearing and speech impaired

Summary of Code Change:

The code change requires that every elevator in a building include a two-way video and text-based emergency communication system for deaf, hard of hearing, and speech impaired individuals. The requirement applies to all elevators in a building, whether they are accessible to the public (e.g. service elevators) or only serving private dwelling units. These systems are commonly known as video relay services and include a live video connection with an American Sign Language translator.

Cost Implication of the Code Change:

The change adds additional costs to the construction of reference buildings 1, 3 and 4, as they all have elevators. The proponent listed the cost of such systems as ranging from $2500 to $5000 per elevator and stated that this is not a significant additional costs because it “will be built into the design/build”. A survey of various VRS providers did not result in actual prices, but did call into question whether they even provide their service for video phones located inside an elevator.

Report Reference No: STR1

2018 IBC Code Sections: 1603.1 General, 1609.1.1 Determination of wind loads, 1609.3 Basic design wind speed

Summary of Code Change:

This code change updates wind maps to ASCE 7-16 including associated terminology and procedures and adopts by reference the wind load chapters of ASCE 7-16. The primary impact on construction methods is associated with a substantial increase in roof component and cladding (C&C) pressure coefficients for both “flat” roofs (roof angle less than or equal to 7 degrees) and low- or steep-slope roofs (roof angle exceeding 7 degrees). For large parts of the country, there is also a decrease in design wind speeds that partially offsets the C&C load increase. Two examples comparing C&C loads are provided below to demonstrate the range of impact.

Table STR1-1 provides an example of impact of ASCE 7-16 on the C&C loads for a 5/12 pitch roof in a 170 mph wind zone [Source: SBCA SRR No. 1601-08, 2017]. Depending on the roof zone, the impact varies between a 56 percent increase and -11 percent decrease. Based on the tributary area of the largest zone (Zone 1), the primary impact is a substantial increase.

Table STR1-1. ASCE7-10 vs. ASCE7-16 Wind Roof C&C Load Change for a 5/12 Pitch Roof

Zone	Change
1	56%
2e	-11%
2n	43%
2r	43%
3e	-4%
3r	36%

Table STR1-2 provides an example of impact of ASCE 7-16 on the C&C loads for a “flat” commercial roof in three geographical locations [Source: personal communications with SPRI staff]. Depending on the location and roof zone, the impact varies between a 45 percent increase in Jacksonville and 34 percent decrease in San Francisco.

Table STR1-2 ASCE 7-10 vs. ASCE 7-16 Wind Roof C&C Load Change for a Flat Roof

Roof Zone	Chicago 7-10	Chicago 7-16	% change	Jacksonville 7-10	Jacksonville 7-16	% change	San Francisco 7-10	San Francisco 7-16	% change
1’	29.0	23.5	-19.0	37.0	34.7	-6.2	26.5	17.4	-34.3
1	29.0	36.4	+25.5	37.0	53.8	+45.4	26.5	26.9	+1.5
2	44.0	46.1	+4.8	56.2	68.1	+21.2	40.2	34.1	-15.2
3	62.7	60.7	-3.2	80.1	89.6	+11.9	57.3	44.9	-21.6

Note: 40' roof height, Exposure C used in all calculations.

Cost Implication of the Code Change:

It is noted that the implications of this change have not been fully evaluated by the industry and corresponding solutions have not yet been developed. Because there is a lag between publication of model codes and their adoption at the local level, product manufacturers and the design community have time to make necessary adjustments to develop compliant solutions. Based on direct communications with various industry stakeholders, none of them could provide specific information regarding impact on roof construction for either sloped or flat roof systems at this point. Similarly, design software providers do not yet offer functionality for design to the new ASCE-7 loads.

The information included in this report is intended to provide an initial direction and to benchmark the potential range of costs rather than estimate impact on a specific project. The cost implications on the roof construction are evaluated for reference buildings 1, 2 and 3 for a wood-frame gable roof system with asphalt shingles and for building 4 for a single-ply commercial roof system.

Gable-roof building

Because shingle wind ratings are established directly based on wind pressure testing, the new C&C loads do not impact existing wind ratings of shingles. The possible impact is on sheathing, sheathing attachments, truss spacing, and truss attachment. Because the net impact on C&C can range from effectively neutral to a substantial increase, the analysis investigates a scenario with a maximum potential impact on roof construction at an Exposure C site. Based on review of the prescriptive provisions in the 2018 Wood Frame Construction Manual for Exposure C based on the new ASCE 7-16 wind provisions, the most likely scenario includes increase in the minimum OSB thickness from 3/8" to 7/16" or 15/32" and a decrease in sheathing nail spacing from 6/12 to 6/6 at interior zones and from 6/6 to 4/4 or 3/3 at perimeter zones (Table STR1-3(a)(b)).

Table STR1-3(a). Gable Roof Scenarios – Reference Buildings 1 & 2

	Roof sheathing thickness, inch	Roof sheathing nailing, inch on center (panel edges/panel field)
2015 IBC Exp C 115 mph	3/8	6/12 roof field 6/6 roof edges
2018 IBC Exp C 115 mph	7/16	6/6 roof field 4/4 roof edges
2018 IBC Exp C 130 mph	15/32	6/6 roof field 4/4 roof edges

Table STR1-3(b). Gable Roof Scenarios – Reference Building 3

	Roof sheathing thickness, inch	Roof sheathing nailing, inch on center (panel edges/panel field)
2015 IBC Exp C 115 mph	15/32	6/12 roof field 6/6 roof edges
2018 IBC Exp C 115 mph	19/32	6/6 roof field 4/4 roof edges
2018 IBC Exp C 130 mph	19/32	4/4 roof field 3/3 roof edges

The combined cost impact is listed in Tables STR1-4(a)-(c) ranging from $0.11 to $0.35 per square foot of roof.

Table STR1-4(a). Cost Impact of OSB and Nailing (Ref. Building 1)

Wind Loads Basis	Nail spacing, inch	Number of added nails per sf	Added unit cost per nail, $	Added cost of OSB, $/sf	Roof area, sf	Number of added nails	Total Added Cost, $	Total Added Cost, $/sf
2015 IBC Exp C 115 mph	6/12 oc 6/6 oc	0	0.16	n/a	10,988	0	**Baseline**	
2018 IBC Exp C 115 mph	6/6 oc 4/4 oc	0.375 0.625		0.03	6,536 4,452	2,451 2,783	**$1,167**	**0.11**
2018 IBC Exp C 130 mph	6/6 oc 4/4 oc	0.375 0.625		0.14	6,536 4,452	2,451 2,783	**$2,376**	**0.22**

Table STR1-4(b). Cost Impact of OSB and Nailing (Ref. Building 2)

Wind Loads Basis	Nail spacing, inch	Number of added nails per sf	Added unit cost per nail, $	Added cost of OSB, $/sf	Roof area, sf	Number of added nails	Total Added Cost, $	Total Added Cost, $/sf
2015 IBC Exp C 115 mph	6/12 oc 6/6 oc	0	0.16	n/a		0	**Baseline**	
2018 IBC Exp C 115 mph	6/6 oc 4/4 oc	0.375 0.625		0.03	10,800 8,836	4,045 5,522	**$2,120**	**0.11**
2018 IBC Exp C 130 mph	6/6 oc 4/4 oc	0.375 0.625		0.14	10,800 8,836	4,045 5,522	**$4,280**	**0.22**

Table STR1-4(c). Cost Impact of OSB and Nailing (Ref. Building 3)

Wind Loads Basis	Nail spacing, inch	Number of added nails per sf	Added unit cost per nail, $	Added cost of OSB, $/sf	Roof area, sf	Number of added nails	Total Added Cost, $	Total Added Cost, $/sf
2015 IBC Exp C 115 mph	6/12 oc 6/6 oc	0	0.16	n/a		0	**Baseline**	
2018 IBC Exp C 115 mph	6/6 oc 4/4 oc	0.375 0.625		0.17	4,800 5,200	1,800 3,250	**$2,207**	**0.22**
2018 IBC Exp C 130 mph	4/4 oc 3/3 oc	1.0 1.25		0.17	4,800 5,200	4,800 6,500	**$3,507**	**0.35**

It is also possible that for certain conditions the roof member spacing (rafter or trusses) would decrease (e.g., from 24 inches on center to 16 inches on center); this change would not be cumulative with the changes to nail spacing and OSB thickness described above. The cost implications of this change would be more significant – $1.76 per square foot of roof (Table STR1-7). It is noted that the truss manufacturer would likely attempt to redesign the truss before changing the spacing. Those types of scenarios can be evaluated after truss design software has been updated for ASCE 7-16.

Table STR1-5. Cost Impact of Truss Spacing and Wind Clips

Wind Loads Basis	Truss Spacing	Unit Cost of Trusses, $/sf	Number of Added Clips per lf	Cost per Clip, $	Total Added Cost, $/sf
2015 IBC	24" oc	3.70	Baseline	Baseline	Baseline
2018 IBC	16" oc	5.42	0.67	**4.71**	**1.76**

Low-slope commercial roof (Reference Building 4)

A mechanically-attached, single-ply roof system is specified for Reference Building 4. Analysis is conducted for three locations: Chicago, San Francisco, and Jacksonville. The summarized impacts on construction practices were obtained from a manufacturer of single-ply roof systems.

For Chicago and San Francisco, the 2018 IBC pressures in the field of the roof are less than the minimum acceptable uplift rated assembly of 60 lb/sf for 10-foot wide sheets. For the roof edges, ASCE 7-16 will require 5 perimeter rows at 5.5 feet (instead of 3 rows for 2015 IBC) increasing the total length of seams for the building by approximately 1,704 linear feet. The increase in seam length entails increase in the number of fasteners (screws and stress plates) and amount of labor. Table STR1-8 summarizes the cost results. The estimated cost impact is $12.95 per roof square (100 square feet).

For Jacksonville, in addition to the changes described for Chicago/San Francisco, the increase in field pressure will require the total length of the seams in the field of the roof to increase by 50 percent (the design example requires the sheets to be secured every 8 feet compared to 12 feet for a baseline scenario). The total additional length of seams for the entire roof including the edge zones and the field is 3,393 linear feet. Table STR1-9 summarizes the cost results. The estimated cost impact is $25.94 per roof square (100 square feet).

Table STR1-8. Cost Impact in Chicago or San Francisco, Low-Slope Roof

Total additional length of seams, ft	Labor, $/ft of seam	Fasteners (based on 6" oc spacing), $/ft	Total Additional Cost, $/ft	Total Added Cost	Total Added Cost, $/Sq. (100 ft2)
1,704	1.13	3.80	4.93	**8,380**	**12.95**

Table STR1-9. Cost Impact in Jacksonville, Low-Slope Roof

Total additional length of seams, ft	Additional Labor, $/ft	Additional Fasteners (based on 6" oc spacing), $/ft	Total Additional Cost, $/ft	Total Added Cost	Total Added Cost, $/Sq. (100 ft2)
3,393	1.13	3.80	4.93	**16,724**	**25.84**

Report Reference No: STR2

2018 IBC Code Sections: Table 1607.1 Minimum uniformly distributed live loads

Summary of Code Change:

This code change increases the design live load for decks and balconies from 40 psf to 1.5 times the design live load for the adjoining area served, with a maximum of 100 psf. For a deck or balcony off the living room, dining room, or similar area of a house or dwelling unit the resulting live load becomes 60 psf rather than 40 psf as would be required under the IRC.

Cost Implication of the Code Change:

The cost implications include the increase in the size and/or number of the structural members and their connections. Footing sizes may also increase based on the balcony/deck size and building configuration.

Reference Building 2 has 12 feet by 6 feet balconies on the second and third floor and the Townhouse has a 14 feet by 5 feet optional deck. Two scenarios are evaluated for each reference buildings: joists running parallel to the building and joist running perpendicular to the building. The footings supporting the columns for Reference Building 2 increase because the balconies are stacked and support a roof [1,500 psf soil is assumed]. Because the deck size for the Townhouse is small, a nominal 12 inch by 12 inch footing is sufficient to support the increased load. Therefore, there is no expected cost impact on the footing for the reference Townhouse.

The cost increase for Reference Building 2 varies from $170 to $233 (Tables STR2-1 and STR2-2) per balcony. It’s noted that the units on the ground level of the three-story building do not have balconies. The cost increase for the Townhouse varies between $191 and $207 (Tables STR2-3 and STR2-4) per deck with a single optional deck included in the building design.

Table STR2-1 – Reference Building 2 with 12' by 6' Balconies (Joists Parallel to Building)

Component for 40 PSF	Unit	Material	Labor	Equip	Total	w/O&P	Qty	Cost
Joist: 2x10-19.2oc	LF	1.43	0.67		2.10	2.70	60	162
Beam: (2) 2x12	LF	4.06	1.16		5.22	6.40	12	77
Joist hanger, 2x10	EA	2.51				2.76	10	28
Post: 4x6	LF	2.06	2.03		4.09	5.95	40	238
Footing: concrete, hand mix	CF	3.96	1.74	1.22	6.92	8.60	2	17
Footing: place concrete	CF		0.77	0.09	0.86	1.37	2	3
Footing: excavate	CF		1.10		1.10	1.82	2	4
Total to builder (per 40 PSF deck)								**528**
Component for 60 PSF	**Unit**	**Material**	**Labor**	**Equip**	**Total**	**w/O&P**	**Qty**	**Cost**
Joist: 2x10-12oc	LF	1.43	0.67		2.10	2.70	84	227
Beam: (3) 2x12	LF	6.10	1.28		7.38	8.85	12	106
Joist hanger, 2x10	EA	2.51				2.76	14	39
Post: 8x8	LF	8.17	5.16		13.33	17.62	40	705
Footing: concrete, hand mix	CF	3.96	1.74	1.22	6.92	8.60	4	34
Footing: place concrete	CF		0.77	0.09	0.86	1.37	4	5
Footing: excavate	CF		1.10		1.10	1.82	4	7
Total to builder (per 60 PSF deck)								**1124**
Total difference to builder (per deck)								**596**

Table STR2-2 – Reference Building 2 with 12' by 6' Balconies (Joists Perpendicular to Building)

Component for 40 PSF	Unit	Material	Labor	Equip	Total	w/O&P	Qty	Cost
Joist: 2x6-24oc same as 60 PSF	LF							0
Beam: (3) 2x10	LF	4.29	1.21		5.50	6.75	24	162
Joist hanger: same as 60 PSF	EA							0
Post: 4x6	LF	2.06	2.21		4.27	5.95	40	238
Footing: concrete, hand mix	CF	3.96	1.74	1.22	6.92	8.60	2	17
Footing: place concrete	CF		0.77	0.09	0.86	1.37	2	3
Footing: excavate	CF		1.10		1.10	1.82	2	4
Total to builder (per 40 PSF deck)								**424**
Component for 60 PSF	**Unit**	**Material**	**Labor**	**Equip**	**Total**	**w/O&P**	**Qty**	**Cost**
Joist: same as 40 PSF	LF							0
Beam: (4) 2x10	LF	5.72	1.33		7.05	8.53	24	205
Joist hanger: same as 40 PSF	EA							0
Post: 8x8	LF	8.17	5.16		13.33	17.62	40	705
Footing: concrete, hand mix	CF	3.96	1.74	1.22	6.92	8.60	4	34
Footing: place concrete	CF		0.77	0.09	0.86	1.37	4	5
Footing: excavate	CF		1.10		1.10	1.82	4	7
Total to builder (per 60 PSF deck)								**957**
Total difference to builder (per deck)								**533**

Table STR2-3 – Townhouse with 14' by 5' Balconies (Joists Parallel to Building)

Component for 40 PSF	Unit	Material	Labor	Total	w/O&P	Qty	Cost
Joist: 2x10-16oc	LF	1.43	0.67	2.10	2.70	70	189
Beam: (3) 2x12	LF	6.10	1.28	7.38	8.85	10	89
Joist hanger, 2x10	EA	2.51			2.76	10	28
Post: 4x6	LF	2.06	2.21	4.27	5.95	48	286
Total to builder (per townhouse)							**591**
Component for 60 PSF	**Unit**	**Material**	**Labor**	**Total**	**w/O&P**	**Qty**	**Cost**
Joist: 2x12-16oc	LF	1.71	0.69	2.40	3.05	70	214
Beam: (4) 2x12	LF	8.14	1.40	9.54	11.30	10	113
Joist hanger, 2x12	EA	2.77			3.05	10	30
Post: 8x8	LF	8.17	5.16	13.33	17.62	48	846
Total to builder (per townhouse)							**1203**
Total difference to builder (per townhouse)							**612**

Table STR2-4 – Townhouse with 14' by 5' Balconies (Joists Perpendicular to Building)

Component for 40 PSF	Unit	Material	Labor	Total	w/O&P	Qty	Cost
Joist: 2x6-24oc same as 60 PSF	LF						0
Beam: (3) 2x12	LF	6.10	1.28	7.38	8.85	28	248
Joist hanger: same as 60 PSF	EA						0
Post: 4x6	LF	2.06	2.21	4.27	5.95	48	286
Total to builder (per townhouse)							**533**
Component for 60 PSF	**Unit**	**Material**	**Labor**	**Total**	**w/O&P**	**Qty**	**Cost**
Joist: same as 40 PSF	LF						0
Beam: (4) 2x12	LF	8.14	1.40	9.54	11.30	28	316
Joist hanger: same as 40 PSF	EA						0
Post: 8x8	LF	8.17	5.16	13.33	17.62	48	846
Total to builder (per townhouse)							**1162**
Total difference to builder (per townhouse)							**629**

Reference Building 4 has 37 pre-fabricated bolt-on balconies. During a phone conversation with a manufacturer of aluminum bolt-on balconies, it was determined that increasing the design live-load would primarily affect the connection hardware. An increase from 40 psf to 60 psf may not require different connection hardware, whereas an increase 40 psf to 100 psf would certainly require a more robust connection. The manufacturer representative estimated that the increase to a 100 psf live-load would result in a material price increase of $100 per balcony, or $3,700 increase for the building as a whole. It should be noted that bolt-on balconies are designed as a collaboration between the balcony manufacturer and the project structural engineers (custom design cost).

Report Reference No: STR3

2018 IBC Code Sections: 1613.2 Seismic ground motion values

Summary of Code Change:

The code change updates the seismic design maps and site factor tables to be consistent with those in the 2014 *NEHRP Recommended Seismic Provisions* and ASCE 7-16 *Minimum Design Loads for Buildings and Other Structures*.

The revisions represent an update of the previous maps based on a new analysis of earthquake faults conducted by the USGS and increases to the site amplification factors for stiff soils and soft rock. For some jurisdictions located at the boundaries between the adjacent seismic design categories, the result for many buildings will be a shift to a higher seismic design category (see Table STR3-1). It is noted that in some areas the change results in a downgrade of the seismic design hazard and lowering of assigned seismic design category.

Table STR3-1 – Summary of Changes to a Higher Seismic Design Category

SDC Change	Where impacted?	Impact
A → B	Multiple locations of limited geographical area around the country in non-seismic areas.	No impact on seismic force-resisting system as wind likely to govern the design. Some additional detailing for egress stairways.
B → C	A few locations around the country with low-to-moderate seismicity with rural or mountainous areas in Colorado, Wyoming, and Utah the primary areas impacted. Some areas in Oklahoma, New England (particularly New Hampshire) and around the New Madrid Seismic Zone are also impacted.	Moderate impact or no impact on seismic force-resisting system as wind likely to control design, egress stairway detailing and suspended ceilings.
B → D	Isolated areas in rural Colorado and Utah.	Substantial impact on seismic force-resisting system, egress stairway detailing and suspended ceilings.
C → D	Isolated areas around the country including eastern Tennessee, Arkansas, Oklahoma, and Utah.	Substantial impact on seismic force-resisting system, egress stairway detailing and suspended ceilings.

Cost Implication of the Code Change:

Reference Buildings 1 and 2 are included in the scope of this analysis. Reference Buildings 3 and 4 and Reference Townhouse are not analyzed as part of STR3; the types of cost implications indicated for Reference Buildings 1 and 2 would apply for these buildings, as well as additional implications are possible.

In seismic design categories A-C, the design of the lateral-force resisting system is expected to be primarily controlled by wind. The impact of changing from SDC C to D is evaluated. The summary of potential changes to the lateral-force resisting system includes:

1) Blocking at the eaves of the roof diaphragm

2) Foundation anchors
3) Shear wall length
4) Suspended Ceilings
5) Anchorage for stairways

It is noted that this summary is intended to provide a range of the types of changes that are expected. These changes do not represent a specific building design.

1. Blocking at roof eave

The height of blocking will depend on the height of the truss heel. For this analysis 2x4 and 2x8 blocking is evaluated. It's assumed blocking is installed in every bay. It is assumed no additional blocking is installed at interior walls. Depending on the specific loads calculated for the building, the design may specify blocking at an interval such as every other bay; the cost would be directly proportional to the length of blocking required. The unit costs are adopted from the report titled "Estimated Cost of the 2009 IRC Code Changes" (Home Innovation Research Labs, 2015).

Table STR3-2. Incremental Blocking

Unit Cost of Blocking		Reference Building 1		Reference Building 2	
		Total length of blocking	Cost	Total length of blocking	Cost
2x4 blocking	$1.44 per ft	324 ft	467	526 ft	757
2x8 blocking	$2.72 per ft		881		1,431

2. Foundation anchors

For reference building 1, it is estimated that using 1/2-inch anchor bolts the spacing will change from 48 inches on center to 32 inches on center. In addition to exterior walls, it is assumed that two interior walls are used as braced walls in the north-south direction.

For reference building 2, it's estimated that using 5/8-inch anchor bolts the spacing will change from 60 inches on center to 32 inches on center. In addition to exterior walls, it is assumed that three interior walls are used as braced walls in the north-south direction.

The unit costs are adopted from the report titled "Estimated Cost of the 2009 IRC Code Changes" (Home Innovation Research Labs, 2015). Plate washers are used with all bolts.

Table STR3-3. Incremental Bolt Increase

	Bolt	Unit Cost	Total perimeter of anchored wall	Total Incremental Bolt Increase	Total Cost Increase
Reference Building 1	1/2" with plate washer	$6.00	564 ft	71 bolts	341
Reference Building 2	5/8" with plate washer	$7.00	836 ft	167 bolts	1,170

3. Shear walls

For wind speed 115 mph Exposure B or Seismic Design Category C, the available wall area is expected to be sufficient to accommodate standard shear walls solutions for Reference Buildings 1 and 2. For

Seismic Design Category D, the required amount of shear walls approximately doubles requiring additional measures. The following scenarios are analyzed for the two reference buildings:

Reference Building 1: Interior shear walls are added at ground level in each direction so that the spacing between shear walls does not exceed 30 feet.

Table STR3-4. Incremental Shear Walls

Total Length of Additional Wood Shear Walls	Total Square Footage of Additional Shear Walls	Unit Cost Installed Wood Structural Panels	Reinforced Footing (12"x16") Unit Cost	Additional Number of Hold-Downs	Additional Hold-Down Cost	Total Cost for Reference Building 1
342 lf	3,078 sq ft	$1.07 / sq ft	$26.49 / lf	12	$39.18 each	12,823

Reference Building 2: Prefabricated shear wall panels are used for the ground level at the front and back walls.

Table STR3-5. Incremental Prefabricated Shear Wall Panels

Total Additional Wood Shear Panels	Incremental Unit Cost of Installed Wood Shear Panel	Total Cost for Reference Building 2
72	565.71	40,731

4. Suspended Ceilings

Additional requirements apply for installation of suspended ceilings in seismic areas. The estimated cost implications range from $0.25 to $1.02 per square foot of ceiling depending on the shape of the space. The unit costs are higher for narrow spaces such as halls because of the higher relative length of the ceiling-wall interface. (It’s noted that for spaces larger than 2,500 square feet further additional requirements apply. Those types of spaces are not common in typical multifamily buildings and are not addressed in this report.)

Table STR3-6. Incremental Suspended Ceiling Increase for a 6x60 Foot Hall

Component	Unit	Material	Labor	Total	w/O&P	Qty	Cost
Seismic clips at attached walls	EA	1.09	1.68	2.77	4.02	33	133
Perimeter support wires within 8"	EA	0.06	1.01	1.07	1.76	66	116
7/8" wall molding	LF	0.82			0.90	(132)	(119)
2" wall molding	LF	1.64			1.81	132	239
Total to builder							**369**
Total to builder, cost per SF							**1**

Table STR3-7. Incremental Suspended Ceiling Increase for a 50x40 Foot Room

Component	Unit	Material	Labor	Total	w/O&P	Qty	Cost
Seismic clips at attached walls	EA	1.09	1.68	2.77	4.02	45	181
Perimeter support wires within 8"	EA	0.06	1.01	1.07	1.76	90	158
7/8" wall molding	LF	0.82			0.90	(180)	(162)
2" wall molding	LF	1.64			1.81	180	326
Total to builder							**503**
Total to builder, cost per SF							**0.25**

For Reference Building 1, if suspended ceiling is used in the common halls on the first and second level, the cost to upgrade the system is estimated at $2,493 for both levels. Areas used in the calculation include one hallway on each floor that runs the length of the building (6' x 162') and an additional 500 SF that includes the entrance and stairway halls.

5. Anchorage of stairways

To provide a positive connection for stairways in seismic design category D, tension ties are specified for each landing to fasten the system to the building. In addition, the upper end of each stair stringer is attached to the landing platform with a metal angle.

Table STR3-8. Estimated Additional Cost of Stairway Anchorage

Component	Unit	Material	Labor	Total	w/O&P	Qty	Cost
Deck/landing tension tie (two-pack)	EA	16.71	16.05	32.76	55.00	2	110
Threaded rod	EA	5.00		5.00	5.50	2	11
Angle bracket: top of stair	EA	0.82			0.90	2	2
Angle bracket connectors	Box	12.69		12.69	13.96	0.33	5
Total to builder per stair/landing						**1**	**127**
Total for Reference Building 1						**3**	**382**
Total for Reference Building 2						**12**	**1529**

The total estimated costs for this change are summarized below.

Table STR3-9. Seismic Loads Additional Cost Summary

Cost	Building 1		Building 2	
	Low	High	Low	High
Blocking at roof eave	467	881	757	1431
Foundation anchors	341		1,170	
Shear walls	12,823		40,731	
Suspended ceilings	2,493		--	
Anchorage at stairways	382		1,529	
Total	**16,506**	**16,920**	**44,187**	**44,861**

Report Reference No: WOD1

2018 IBC Code Sections: 2304.12.2.6 Ventilation beneath balcony or elevated walking surfaces

Summary of Code Change:

The code change requires openings to provide cross-ventilation for enclosed wood-framed balconies with moisture-permeable toppings such as concrete or masonry toppings. The net free area of ventilation openings shall be at least 1/150 of the area of each enclosed space.

Cost Implication of the Code Change:

This change increases the cost of construction for reference building 2 due to the addition of ventilation openings in the balcony framing. This building has 12 balconies measuring 14 feet long by 5 feet deep. The simplest method to comply with the cross ventilation requirement is to install is to install two rows of soffit vents as shown below.

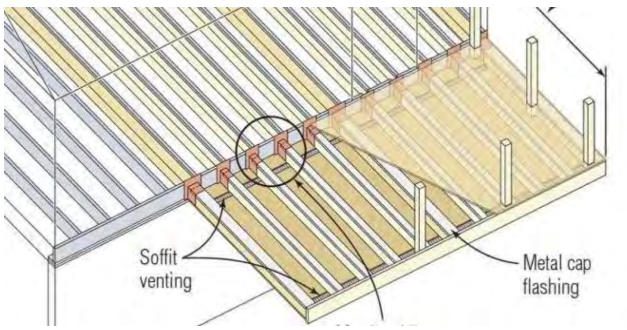


Table WOD1-1. Estimated Additional Cost of Balcony Ventilation

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost/Balcony
soffit/eave vent, 2-1/2" wide	LF	0.46	1.4	1.86	2.85	28	80

Where balconies or elevated walking surfaces are required to be fire rated, vents are not permitted, so the builder would need to extend the sprinkler system out to the balcony.

Table WOD1-2. Estimated Additional Cost of Balcony Sprinkler

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost/Balcony
Type M copper tubing, 1/2"	LF	3.21	4.17	7.38	10.45	5	52
Sprinkler head	Ea	16	21.50	37.50	53	1	53
						Total	105

This code change ranges from $960 to $1,263 for the entire building.

Report Reference No: WOD2

2018 IBC Code Sections: 2304.12.2.5 Supporting members for permeable floors and roofs

Summary of Code Change:

The code change requires that the moisture barrier system separating the naturally durable or preservative-treated wood structure of a balcony from a moisture-permeable floor topping above (e.g. a concrete or masonry slab) provide positive drainage of water from incidental water penetration.

Cost Implication of the Code Change:

The change increases the cost of construction for reference building 2, which has 12 wood framed balconies measuring 14 long x 5 deep, as a drainage mat must be installed prior to pouring the concrete for the balcony. Suitable mat products include the following (prices will vary by supplier):

Component	Unit	Material	Labor	Total	w/O&P
Tremco TREMDrain 1000	SF	1.12	0.29	1.41	1.55
SUPERSEAL dimpled foundation membrane	SF	0.54	0.29	0.83	0.91
SuperSeal subfloor membrane	SF	0.65	0.29	0.94	1.03
Delta MS foundation waterproofing	SF	0.53	0.29	0.82	0.90
CertainTeed Platon plastic subfloor for concrete	SF	0.55	0.29	0.84	0.92
J Board	SF	0.73	0.29	1.02	1.12
J Drain 420	SF	0.66	0.29	0.95	1.05
Note: labor cost is for floor underlayment.					

In addition to the drainage mat, drip edges are also installed around the perimeter (three sides) of balcony to shed water from the drainage mat. Flashing and WRB details remain unchanged.

Table WOD2. Estimated Additional Cost of Positive Drainage for Balcony

Component	Unit	Mat	Labor	Total	w/O&P	Quant.	Cost
SUPERSEAL dimpled foundation membrane	SF	0.54	0.29	0.83	0.91	840	767
Aluminum drip edge	LF	0.57	0.68	1.25	1.77	288	510
						Low Cost	**1,277**
Tremco TREMDrain 1000	SF	1.12	0.29	1.41	1.55	840	1,303
Aluminum drip edge	LF	0.57	0.68	1.25	1.77	288	510
						High Cost	**1,813**

Report Reference No: WOD3

2018 IBC Code Sections: 2308.5.5.1 Openings in exterior bearing walls

Summary of Code Change:

The code change added a prescriptive span table for 2x (dimension lumber) single-ply headers in exterior bearing walls. Previous codes provided prescriptive options only for multi-ply headers. Single member header spans range from less than 3 feet to over 8 feet based on the number of stories, building configuration, and the header size and material.

Cost Implication of the Code Change:

With roof spans exceeding 50 feet, the multifamily reference buildings are not expected to be able to take advantage of single-ply dimensional lumber header applications for most practical design scenarios. In the reference Townhouse unit, the roof and floor members are supported on the side walls. Because all openings are in non-loadbearing front and back walls, there is no opportunity for savings from using single headers. Cost savings for single-family dwellings can be found in the 2012 Home Innovation report titled "Estimated Costs of the 2012 IRC Code Changes" (www.homeinnovation.com) and range between $111 and $241 per house. Based on this report, savings where a single header insulated with foam sheathing can be used in lieu of a double member ranged between $3.0 and $4.5 per linear foot of opening width. Similar per foot savings can be expected for townhomes or smaller multi-family buildings where the building configuration allows the use of single-ply headers.

Appendix A-IECC: International Energy Conservation Code

Report Reference No: COM1

2018 IECC Code Sections: C403.7.4 Energy recovery ventilation systems

Summary of Code Change:

The code change revises Tables C403.7.4.1(1) and C403.7.4.2(2), which trigger the need for an energy recovery ventilator depending on the climate zone and percentage of outdoor air. If a fan system supply CFM exceeds the values in the tables, an ERV is required; i.e., where the table previously contained a zero, an ERV was always required. By replacing the zeros with a small value, it exempts those locations from needing an ERV if the HVAC system fan is small enough.

Cost Implication of the Code Change:

From the building plans we know the following:

Reference Building	HVAC System	Location	Notes
1	Building boiler servicing in-unit radiators; ductless mini-splits in common areas.	Rochester, NY (CZ 5A)	No forced air system
2	Split system air conditioner only (outdoor condenser, in-unit air handler)	Osceola, FL (CZ 2A)	Bathroom exhaust
3	Split system Heat pump (roof condenser, in-unit air handler) ERV on roof	Bridgeport, CT (CZ 5A)	ERV already provided
4	Split system heat pump (roof condenser, in-unit air handler)	Pittsburgh, PA (3A)	Whole-building ventilation
TH	Outdoor condenser, indoor furnace	Bethesda, MD (4A)	Various exhaust fans

This change is not applicable to any of the reference buildings because building 1 does not have a forced air system, and the design supply airflow rate of the systems in the other buildings all exceed 200 CFM. A previous analysis conducted by Home Innovation[8] found that the cost savings for not installing an ERV was approximately $2,045; depending on the model the savings could be less ($1749).

[8] Cost Analysis of Proposed Group A Code Changes

Report Reference No: COM2

2018 IECC Code Sections: C405.2.6 Exterior lighting controls

Summary of Code Change:

The code change adds a new section for exterior lighting controls that prohibits the use of mechanical exterior time switches for the control of exterior lighting. Exterior lighting control systems must have a daylight shutoff, decorative lighting shutoff, lighting setback, or exterior time-switch control functions.

Cost Implication of the Code Change:

The cost of this change will depend on the façade, landscape, and parking lighting. The exterior lighting at each of the reference buildings varies widely as summarized below. None of the projects uses mechanical time switches and are generally in compliance with the new provisions of the code [Note: information unavailable for parking lights for reference building 2].

Table COM2-1. Existing Lighting for Reference Buildings

Reference Building	Existing		
	Facade	**Landscape**	**Parking**
1	Minimal.	None; near highway.	Circuit photocells at parking lot.
2	Wall packs on exterior with individual photocells.	None.	Not specified.
3	Time clock; first floor apartments have mechanical switches.	Street lights.	
4	One photocell for entire project with wireless gateway, router and control software.		Not applicable; underground garage not exterior lot.
TH	Minimal.	Street lights.	Not applicable; attached garage.

The table below presents options for meeting the requirement; prices come from online retailers. Installation cost is a uniform $88 for each unit (two hours for one electrician per RS Means).

Table COM2-2. Lighting Options

Price Range	Equipment	Cost
Low	Photocell that can be wired to existing lighting	$8 - $13
Medium	Light package with built-in controls	$58 - $159
High	Engineered system with wireless sensors, gateway/routers, and software.	Custom

The table below presents the range in price for multifamily projects that do not currently meet the new exterior lighting controls for a small and a large building (townhouse and building 3 respectively).

Table COM2-3. Exterior Lighting Scenarios

Reference Building	Low		High	
	Description	Cost	Description	Cost
Townhouse	Photocell for sconce at door	96	Wall pack with built-in photocell	247
Building 3	Four wall packs at egress	584	Four wall packs at egress and 8 photocells for streetlamps.	1796

Appendix A-IFC: International Fire Code

Report Reference No: SYS1

2018 IFC Code Sections: 903.3.1.2.3 Attics

Summary of Code Change:

This code change requires that an attic sprinkler system be provided in attics used for living or storage space, or attics in Type III, Type IV or Type V podium buildings with attics located more than 55 feet above the lowest level fire department vehicle access. For podium buildings, the attic can be constructed of non-combustible materials or fire-retardant treated wood, or be filled with noncombustible insulation in lieu of providing sprinklers.

Cost Implication of the Code Change:

This code change is not directly applicable to any of the reference buildings as none have an attic located more than 55 feet above grade. However, the following would be the cost incurred for a building similar to reference building 3 if it had one additional floor, or taller floor heights, which would elevate the attic to a height that would trigger the requirements in this change. The building has three separate attic sections separated by portions of flat roof. The costs include piping to the attic sections and the sprinkler heads.

Table SYS1-1. Estimated Additional Cost of Attic Sprinkler System

Component	Unit	Material	Labor	Total w/O&P	Quantity	Cost
Wet pipe sprinkler system, each additional floor (attic)	SF	0.8	1.504	2.304	8322	19,174

As an alternative, the roof trusses could be built from fire-retardant treated wood (FRTW) instead of non-treated wood. The material cost difference between non-treated 2x6s used in roof framing ($0.61/LF) and FRTW ($0.77/LF) is roughly 25%. In total, the three attic sections use 73 trusses spaced 2 feet oc, and each truss has 181.5 LF of wood. Assuming no other change (labor, equipment, etc.) using FRTW would increase the cost for this building by $2,120 ($10,202 compared to $8,082). This applies only to material costs; pre-built trusses large enough for this attic (57 foot span) would be special order and incur delivery charges. For reference, a 40 foot truss can be purchased online for roughly $300.

A third alternative is to blanket the attic floor with blown-in fiberglass insulation. The cost to provide R38 insulation for the attics is $18,142 ($2.18/SF for 8322 SF).

Report Reference No: SYS2

2018 IFC Code Sections: 905.3.1 Height

Summary of Code Change:

This code change now requires a Class III standpipe system be provided for buildings that are four or more stories above or below grade plane, regardless of the elevation of the highest or lowest story relative to fire department vehicle access. Previously, a Class III standpipe was only required if the floor elevation of the highest story was more than 30 feet above the lowest level of fire department vehicle access.

Cost Implication of the Code Change:

Reference buildings 3 and 4 are four or more stories in height, but the elevation of the highest floor exceeds 30 feet above grade, and is presumably more than 30 feet above the lowest level of fire department vehicle access. Thus, standpipes were already required for both buildings. The Townhouse is four stories, but Group R-3 buildings are exempt from the standpipe requirement. If the townhouse were classified as Group R-2, a standpipe would be required.

Component	Unit	Material	Labor	Total
Wet standpipe risers, Class III, 4" diameter pipe	floor	5,925	2,875	8,800
additional floors	floor	1,300	745	2,045
Total for four floors		9,825	5,110	14,935

The additional cost of a standpipe system for each stairway in a four-story building is estimated at $14,935.

Report Reference No: SAF1

2018 IFC Code Sections: 3304.5 Fire watch, 3308.1 Program development and maintenance, 3308.2 Program superintendent, 3308.4 Training, 3308.5 Fire protection devices, 3309.1 Emergency telephone

Summary of Code Change:

This code change provides the fire official the authority to require a fire watch during building demolition, while a building is being temporarily heated during construction or hot work is being performed, and as otherwise required by the fire official. The fire watch must cover the full construction site, fire extinguishing equipment must be made available to them, the equipment must be inspected on a daily basis, and the personnel may also provide security services. The fire watch plan must be made available to the code official upon request, written inspection logs must be kept, and fire watch instruction must be posted in approved locations.

Cost Implication of the Code Change:

The cost of this change will vary depending on the existing personnel. For projects that were already providing site security personnel, this change requires that security be trained to also serve as the fire watch and that the project manager develop the training plan, written instructions, maintain logs. For projects that were not previously providing site security, additional personnel costs are added.

These requirements apply when temporary heating is provided, which covers the drywall installation and painting prior to turning on the HVAC equipment, or when hot work activities such as welding or placement of asphalt built-up roofing (hot-mopped roofing) are performed. The costs will vary depending on the climate (i.e., day and night heating or night-only) and duration of the drywall/painting or roofing phase, or duration of welding activities.

Scenario	Assumptions
Low	- Security personnel already provided (no new labor cost) - Project manager spends half day to develop plan + written docs - Half day training of security personnel - Night-only temporary heating (12 hours)
Medium	- New personnel for fire watch (general labor) - Project manager spends half day to develop plan + written docs - Half day training of security personnel - Night-only temporary heating (12 hours)
High	- New personnel for fire watch - Project manager spends one day to develop plan + written docs - Half day training fire watch - 24 hour temporary heating
Hourly rates are as follows: - Dedicated fire watch personnel is $60/hr including O&P. - Project manager is $92.50/hr including O&P.	

Ref. Building	Duration of Temporary Heating
1	7 days
2	7 days
3	14 days
4	21 days
TH	2 days

Table SAF1. Estimated Additional Cost of Fire Watch during Temporary Heating

Estimate	Ref. Building			
	1 & 2	3	4	TH
Low	740	740	740	740
Medium	5,410	10,450	15,490	1,810
High	10,820	20,900	30,980	3,620

[Note: The cost estimate above applies where a fire watch was not previously required. A builder's commercial general liability insurance policy may already require a fire watch be provided.]

Report Reference No: SAF2

2018 IFC Code Sections: 3304.5.1 Fire watch during construction

Summary of Code Change:

This change provides the fire code official with the authority to require that a fire watch be provided during non-working hours for construction exceeding 40 feet in height.

Cost Implication of the Code Change:

For reference buildings 3, 4 and the Townhouse, the cost of a fire watch consists of the personnel watch only and is applied twelve hours a day for the duration of construction.

Ref. Building	Average Duration of Construction (weeks) Based On Region				
	North East	Midwest	South	West	National
3&4	76	54	56	65	60
TH	52	36	35	41	44
Source: US Census Bureau 2016 Survey of Construction (https://www.census.gov/construction/nrc/lengthoftime.html) For TH above, duration of construction corresponds to a row of 4 individual townhouses in the Census Bureau survey.					

Hourly rate for dedicated fire watch is $60/hr including O&P. The analysis uses 12 non-working hours per day, six days a week for the duration of construction.

Table SAF2. Estimated Additional Cost of Fire Watch for Construction Exceeding 40 Feet in Height

Ref. Building	Cost Based On Region				
	NE	MW	S	W	National
3&4	328,320	233,280	241,920	280,800	259,200
TH	224,640	155,520	151,200	177,120	190,080

Note that the estimated cost for the reference townhouse is for up to 4 individual townhouses. The individual cost could be as little as $37,800 per townhouse in the south ($151,200 spread over four townhouses) and as high as $56,160 per townhouse in the northeast ($224,640 spread over four townhouses).

[Note: The cost estimate above applies where a fire watch was not previously required. A builder's commercial general liability insurance policy may already require a fire watch be provided.]

Report Reference No: SAF3

2018 IFC Code Sections: 3308.7.1 Smoke detectors and smoke alarms

Summary of Code Change:

This change requires that smoke detectors and smoke alarms be covered or removed if dust is being produced during construction. Afterwards, the detectors and alarms must be replaced or inspected and cleaned if they were simply covered.

Cost Implication of the Code Change:

The code change applies primarily to an existing building undergoing remodeling, unless there is need to work on portions of a new building after the smoke detectors and smoke alarms are installed. The simplest way to comply with this requirement is to cover each smoke detector with 1 SF of polyethylene sheet. A visual inspection is conducted when the sheet is removed. One smoke detector is installed outside of each bedroom or sleeping area (den) and on each floor of the townhouse.

Component	Unit	Material	Labor	Total	w/O&P
4 mil polyethylene sheet	SF	0.0258	0.0635	0.0893	0.135

Table SAF3. Estimated Additional Cost of Covering Smoke Detectors

Reference Building	Smoke Detectors	Cost
1	28	4
2	84	11
3	64	9
4	221	30
TH	5	1

Appendix A-IMC: International Mechanical Code

Report Reference No: DCT1

2018 IMC Code Sections: 602.1 General

Summary of Code Change:

The code change allows the use of stud wall cavities and the spaces between solid floor joists as return air plenums.

Cost Implication of the Code Change:

The change can result in cost savings where a builder employs the stud and joist space plenums instead of installing sheet metal return ducts. This change will only affect reference building 3.

Reference Building	Return Air
1	Not applicable; no forced air system.
2	Concrete floors; short duct to return grill on wall shared with living room.
3	Ducted return.
4	Rated ceiling; short return duct to return grill above mechanical closest door.
TH	Furnace located in mechanical room adjacent to garage therefor return air duct to floor above remains unchanged.

For a 600 CFM unit, a 14x8 rectangular return duct weighs 5.5 lbs/SF. A 6 ft. long return duct in each unit weighs a total of 33 lbs. The installed cost of 24 gauge sheet metal is $6.74/lb. Using a return plenum results in a savings of $222 per apartment or $10,676 for the building.

Report Reference No: DCT2

2018 IMC Code Sections: 603.9 Joints, seams and connections

Summary of Code Change:

The code change exempts ducts located in conditioned space from mandatory air sealing requirements, allowing the use of snap-lock and button lock seams in metallic ducts where such ducts are located in conditioned space.

Cost Implication of the Code Change:

This change will not affect reference building 1 which does not have a forced air system. The table below indicates the savings from not sealing snap-lock seams with mastic (assumed to be performed by a sheet metal apprentice at 125 LF/hr).

Table DCT2. Estimated Cost Savings of Not Sealing Longitudinal Seams

Component	**Reference Building**			
	2	**3**	**4**	**TH**
Ducts in conditioned space, LF	90	75	120	200
Cost to seal duct, LF	0.56	0.56	0.56	0.56
Saving per apartment	(50.4)	(42)	(67.2)	(140)
Units	36	48	167	1
Total savings per building	**(1814)**	**(2,016)**	**(11,222)**	**(140)**

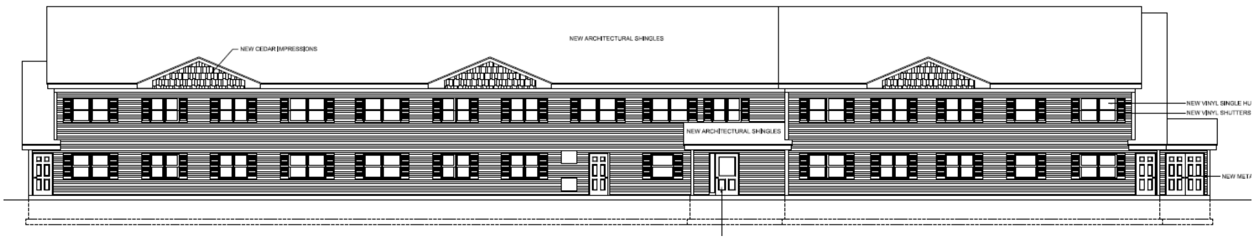
APPENDIX B: LOCATION ADJUSTMENT FACTORS

State	City	Cost Adjustment Factor	State	City	Cost Adjustment Factor
Alabama	Birmingham	0.84	Montana	Billings	0.88
Alabama	Mobile	0.84	Nebraska	Omaha	0.89
Alaska	Fairbanks	1.27	Nevada	Las Vegas	1.01
Arizona	Phoenix	0.85	New Hampshire	Portsmouth	0.95
Arizona	Tucson	0.84	New Jersey	Jersey City	1.19
Arkansas	Little Rock	0.80	New Mexico	Albuquerque	0.83
California	Alhambra	1.16	New York	Long Island City	1.41
California	Los Angeles	1.15	New York	Syracuse	1.01
California	Riverside	1.14	North Carolina	Charlotte	0.96
California	Stockton	1.19	North Carolina	Greensboro	0.96
Colorado	Boulder	0.91	North Carolina	Raleigh	0.94
Colorado	Colorado Springs	0.84	North Dakota	Fargo	0.88
Colorado	Denver	0.87	Ohio	Columbus	0.91
Connecticut	New Haven	1.11	Oklahoma	Oklahoma City	0.82
Delaware	Dover	1.02	Oklahoma	Tulsa	0.82
District of Columbia	Washington, D.C.	0.90	Oregon	Bend	1.00
Florida	Fort Meyers	0.80	Pennsylvania	Norristown	1.10
Florida	Miami	0.81	Pennsylvania	State College	0.93
Florida	Orlando	0.83	Rhode Island	Providence	1.08
Florida	Tampa	0.83	South Carolina	Greenville	0.94
Georgia	Atlanta	0.89	South Dakota	Sioux Falls	0.82
Hawaii	Honolulu	1.21	Tennessee	Memphis	0.84
Idaho	Boise	0.90	Texas	Austin	0.79
Illinois	Carbondale	1.01	Texas	Dallas	0.84
Indiana	Indianapolis	0.92	Texas	Houston	0.82
Iowa	Des Moines	0.92	Texas	San Antonio	0.81
Kansas	Wichita	0.84	Utah	Ogden	0.80
Kentucky	Louisville	0.87	Utah	Provo	0.81
Louisiana	Baton Rouge	0.86	Utah	Salt Lake City	0.82
Maine	Portland	0.91	Vermont	Burlington	0.93
Maryland	Baltimore	0.92	Virginia	Fairfax	1.01
Massachusetts	Boston	1.19	Virginia	Winchester	1.02
Michigan	Ann Arbor	1.00	Washington	Tacoma	1.02
Minnesota	St. Paul	1.05	West Virginia	Charleston	0.95
Mississippi	Biloxi	0.84	Wisconsin	La Crosse	0.98
Missouri	Springfield	0.89	Wyoming	Casper	0.81

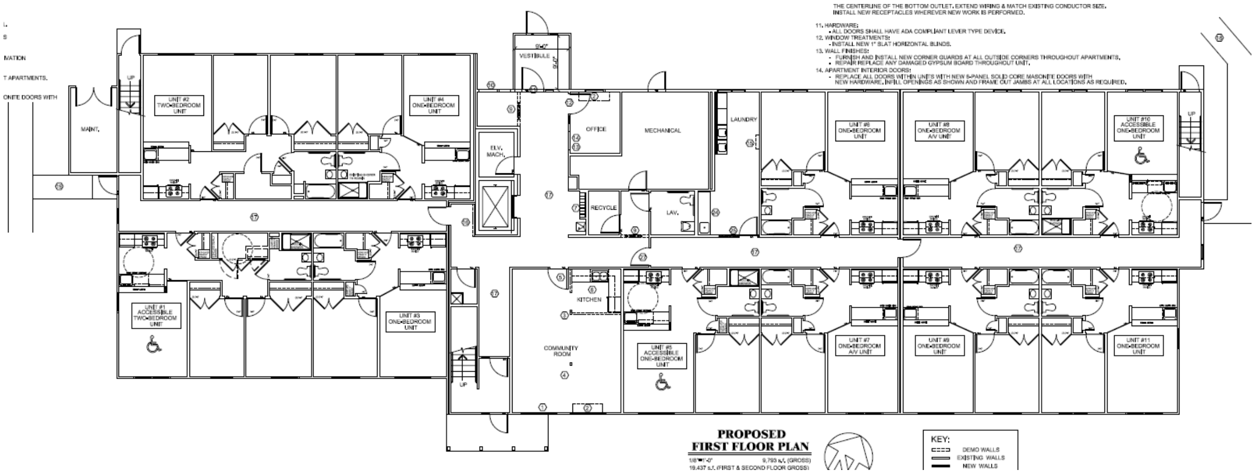
*Source: RSMeans *Residential Cost Data 2017*. Sample cities are listed in this table; check RSMeans for additional locations.

APPENDIX C: REFERENCE BUILDING 1

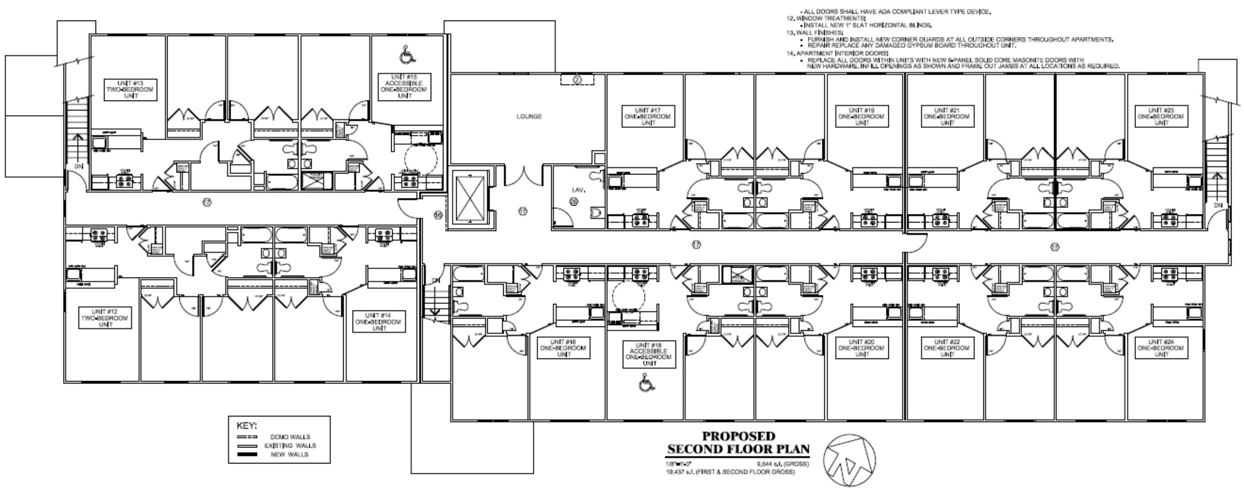
Two-Story Apartment Building, 24 Units



[ELEVATION]



[FIRST FLOOR PLAN]

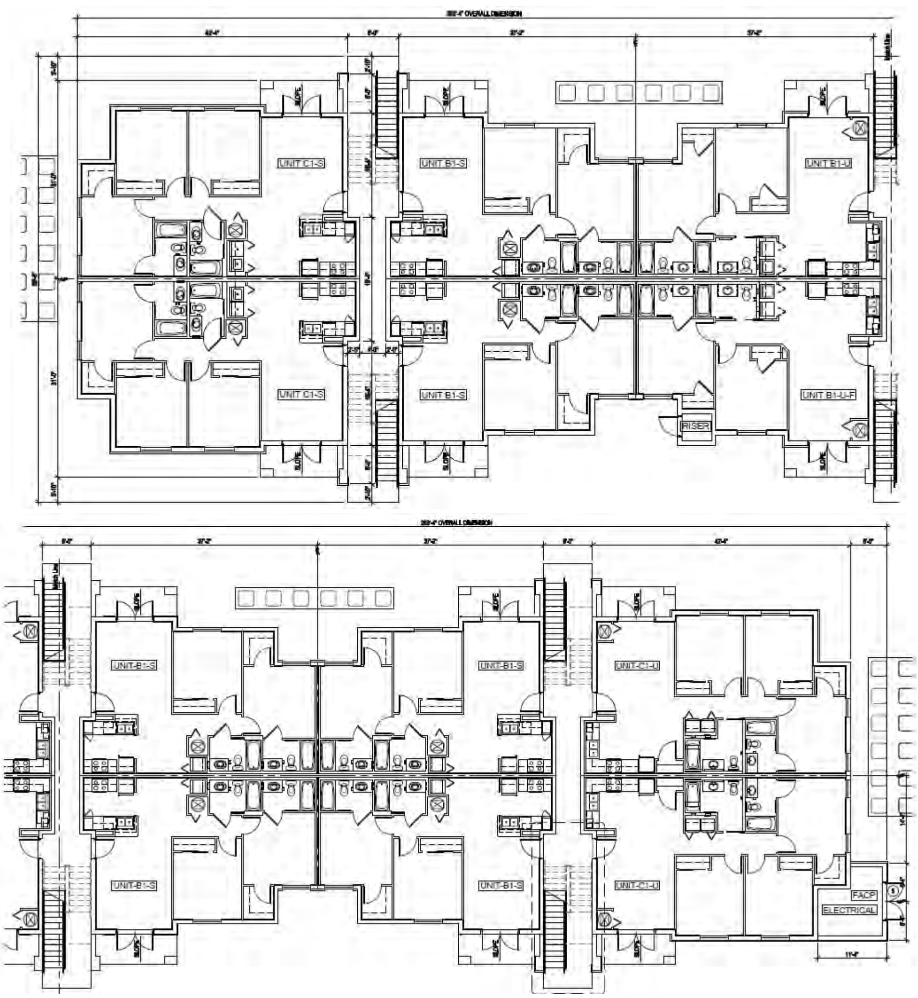


[SECOND FLOOR PLAN]

APPENDIX D: REFERENCE BUILDING 2

Three-Story Garden Style Building, 36 Units

[ELEVATION]

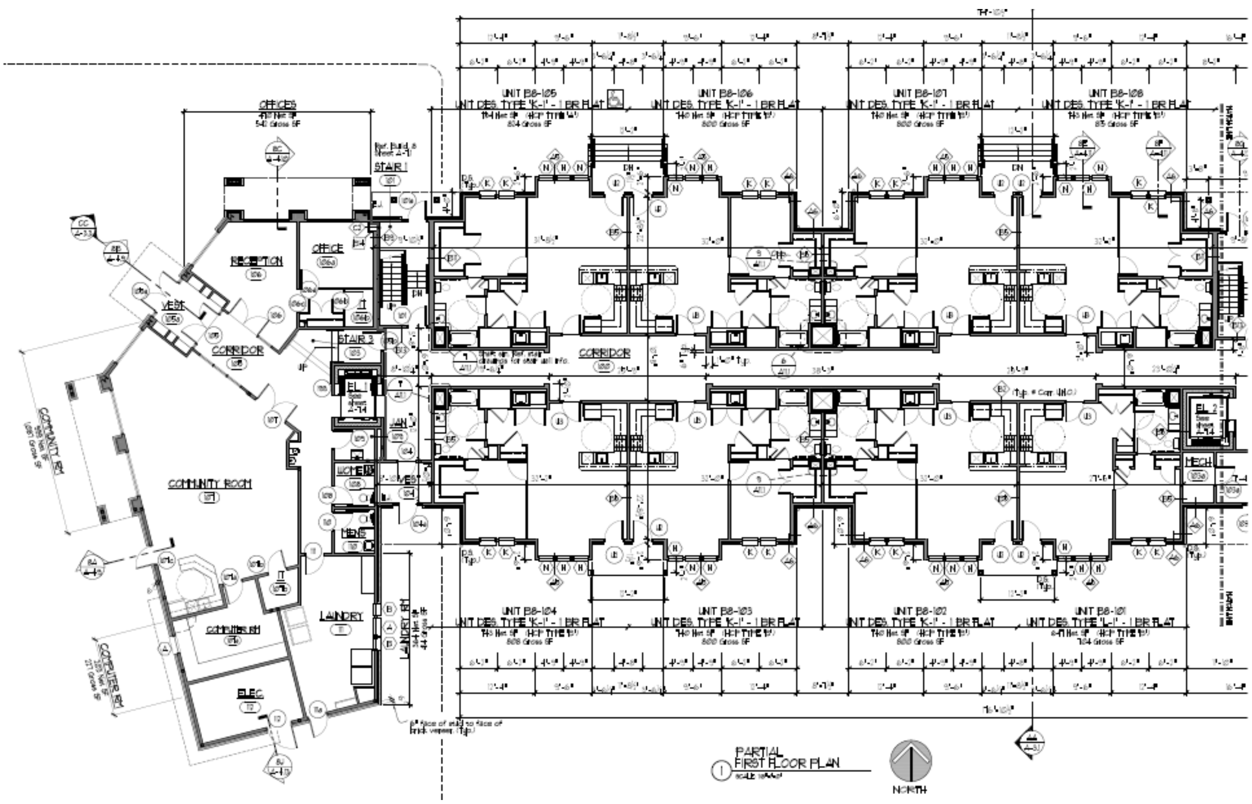


[FIRST FLOOR PLAN]

APPENDIX E: REFERENCE BUILDING 3

Four-Story Building on Grade, 48 Units & Common Areas

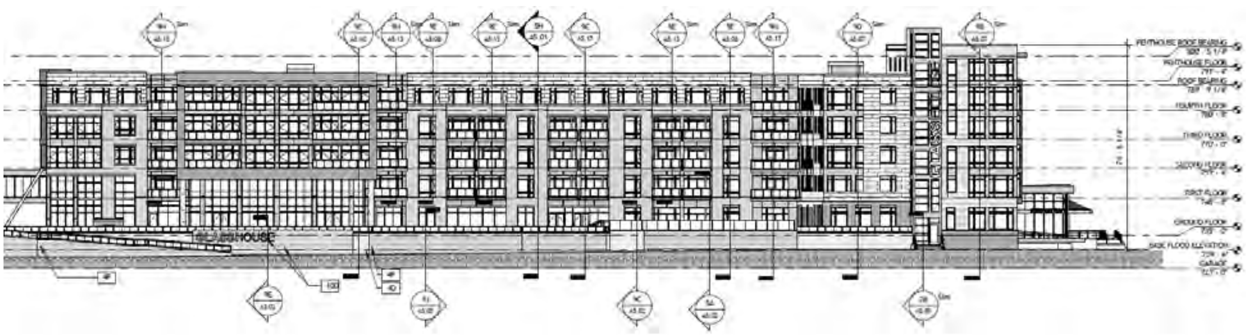
[ELEVATION]



[PARTIAL FIRST FLOOR PLAN]

APPENDIX F: REFERENCE BUILDING 4

Five-Story Building on Two-Story Podium, 167 Units



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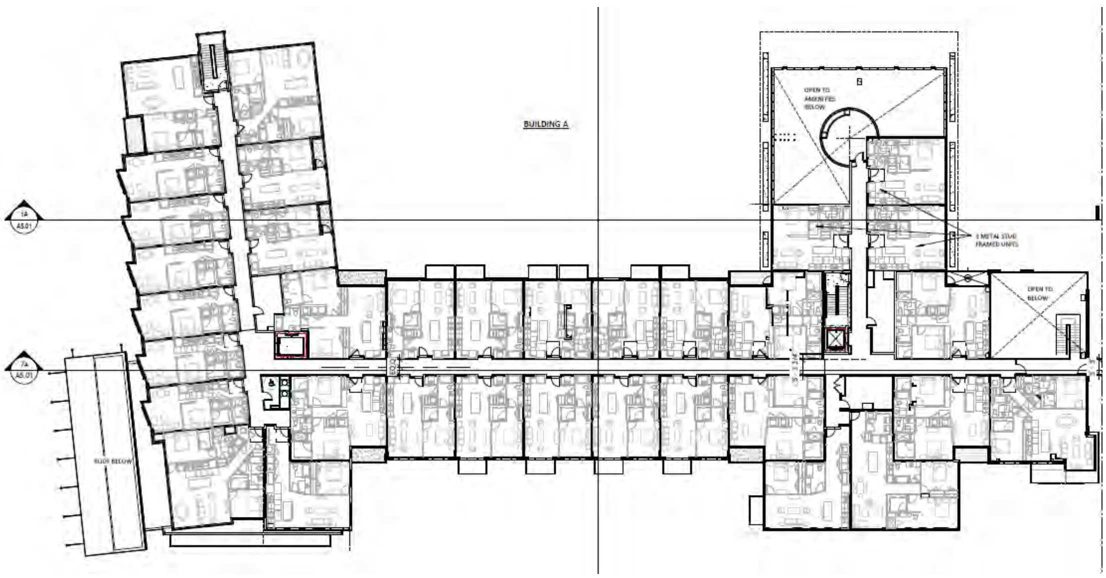
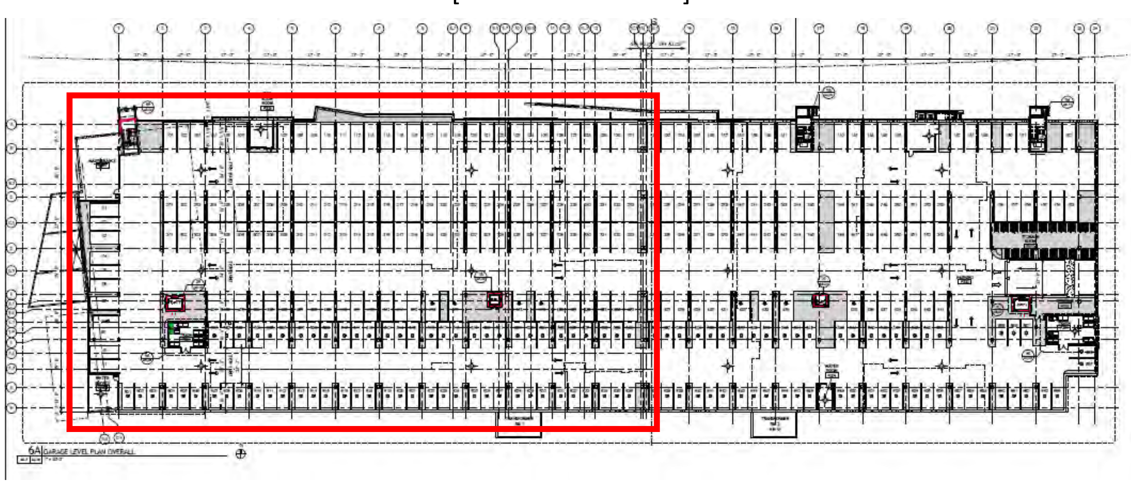


[FIRST FLOOR PLAN]



[GARAGE PLAN]

APPENDIX G: REFERENCE TOWNHOUSE

Four-Story Townhouse

[ELEVATION]

[FLOOR PLANS]

APPENDIX H: REFERENCES

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