PRESCRIPTIVE R-VALUES, U-FACTOR EQUIVALENTS, AND TOTAL UA ANALYSIS



US Climate Zones







Prescriptive Wall R-values – Homes

2012 IECC Residential Wall R-value

Installation	Wood Fra			
Climate Zone	2009 IECC	2012 IECC	2015 IECC	
1	13	13		
2	13	13		
3	13	20 or 13+5**	lsama as	
4 exc. Marine	13	20 or 13+5	(3ame as 2012 IECC)	
4 Marine & 5	20 or 13+5	20 or 13+5		
6	20 or 13+5	20+5 or 13+10		
7 & 8	21	20+5 or 13+10		



Prescriptive Wall R-values – Commercial Buildings/Non-Res

Climate Zone	Wood Frame	Metal Frame	Metal Bldg	Mass
1	R13+R3.8ci or R-20	R13+ R5ci	R13+ R6.5ci	R5.7ci
2	R13+R3.8ci or R-20	R13+ R5ci	R13+ R6.5ci	R5.7ci
3	R13+ R3.8ci or R-20	R13+ R7.55ci	R13+R6.5ci	R7.6ci
4	R13+ R3.8ci or R-20	R13+ R7.5ci	R13+R13ci	R9.5ci
5/4 Marine	R13+ R3.8ci or R20	R13+ R7.5ci	R13+ <mark>R13ci</mark>	R11.4ci
6	R13+ <mark>R7.5ci</mark> or R20+ <mark>R3.8ci</mark>	R13+ R7.5ci	R13+ <mark>R13c</mark> i	R13.3ci
7	R13+R7.5ci or R20+ R3.8ci	R13+ R7.5ci	R13+R13ci	R15.2ci
8	R13+ <mark>R15.6ci</mark> or R20+ R10ci	R13+ R7.5ci	R13+R13ci	R25ci

2012 IECC Commercial Wall R-value

Note that the use of CI is featured in all climate zones for all building types.

Again, equivalent alternatives are possible through the U-factor approach.

Residential apartment/condo values may be slightly higher in some climate zones



2015 IECC – same as 2012 IECC

U-factors for Equivalent Alternatives to R-values

EQUIVALENT U-FACTORS ^a							
FENESTRATION U-FACTOR	SKYLIGHT U-FACTOR	CEILING U-FACTOR	FRAME WALL U-FACTOR	MASS WALL U-FACTOR ^b	FLOOR U-FACTOR	BASEMENT WALL U-FACTOR	CRAWL SPACE WALL U-FACTOR
0.50	0.75	0.035	0.084	0.197	0.064	0.360	0.477
0.40	0.65	0.030	0.084	0.165	0.064	0.360	0.477
0.35	0.55	0.030	0.060	0.098	0.047	0.091°	0.136
0.35	0.55	0.026	0.060	0.098	0.047	0.059	0.065
0.32	0.55	0.026	0.060	0.082	0.033	0.050	0.055
0.32	0.55	0.026	0.045	0.060	0.033	0.050	0.055
0.32	0.55	0.026	0.045	0.057	0.028	0.050	0.055
	FENESTRATION U-FACTOR 0.50 0.40 0.35 0.35 0.32 0.32 0.32	FENESTRATION U-FACTOR SKYLIGHT U-FACTOR 0.50 0.75 0.40 0.65 0.35 0.55 0.32 0.55 0.32 0.55 0.32 0.55 0.32 0.55	EQUIVAL FENESTRATION U-FACTOR SKYLIGHT U-FACTOR CEILING U-FACTOR 0.50 0.75 0.035 0.40 0.65 0.030 0.35 0.55 0.030 0.35 0.55 0.026 0.32 0.55 0.026 0.32 0.55 0.026	EQUIVALENT U-FACTOR FENESTRATION U-FACTOR SKYLIGHT U-FACTOR CEILING U-FACTOR FRAME WALL U-FACTOR 0.50 0.75 0.035 0.084 0.40 0.65 0.030 0.084 0.35 0.55 0.030 0.060 0.35 0.55 0.026 0.060 0.32 0.55 0.026 0.045 0.32 0.55 0.026 0.045 0.32 0.55 0.026 0.045	EQUIVALENT U-FACTORS ^a FENESTRATION U-FACTOR SKYLIGHT U-FACTOR CEILING U-FACTOR FRAME WALL U-FACTOR MASS WALL U-FACTOR ^b 0.50 0.75 0.035 0.084 0.197 0.40 0.65 0.030 0.084 0.197 0.35 0.55 0.030 0.060 0.098 0.35 0.55 0.026 0.060 0.098 0.32 0.55 0.026 0.045 0.060 0.32 0.55 0.026 0.045 0.060 0.32 0.55 0.026 0.045 0.060	FENESTRATION U-FACTOR SKYLIGHT U-FACTOR CEILING U-FACTOR FRAME WALL U-FACTOR MASS WALL U-FACTOR ^b FLOOR U-FACTOR 0.50 0.75 0.035 0.084 0.197 0.064 0.40 0.65 0.030 0.084 0.165 0.064 0.35 0.55 0.030 0.060 0.098 0.047 0.35 0.55 0.026 0.060 0.082 0.033 0.32 0.55 0.026 0.045 0.060 0.033 0.32 0.55 0.026 0.045 0.060 0.033 0.32 0.55 0.026 0.045 0.060 0.033 0.32 0.55 0.026 0.045 0.060 0.033	FENESTRATION UFACTOR SKYLIGHT UFACTOR CEILING UFACTOR FRAME WALL UFACTOR MASS WALL UFACTOR ^b FLOOR UFACTOR BASEMENT WALL UFACTOR 0.50 0.75 0.035 0.084 0.197 0.064 0.360 0.40 0.65 0.030 0.084 0.165 0.064 0.360 0.35 0.55 0.030 0.060 0.098 0.047 0.091° 0.35 0.55 0.026 0.060 0.098 0.047 0.059 0.32 0.55 0.026 0.060 0.082 0.033 0.050 0.32 0.55 0.026 0.045 0.060 0.033 0.050 0.32 0.55 0.026 0.045 0.057 0.028 0.050

TABLE R402 1 4

Table R402.1.4

R402.1.4 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table R402.1.4 shall be permitted as an alternative to the *R*-value in Table R402.1.2.



Above table for homes. U-factors for commercial buildings will differ; See <u>IECC-C</u> and <u>ASHRAE 90.1</u>

Application of the U-factor

- Use this approach to:
 - Explore alternatives to the prescriptive wall insulation (more CI and less cavity R-value, etc.)
 - Determine U-factor input to energy model or energy rating programs
- Must use code-compliant insulation materials
- Must substantiate U-factor for assembly
- Must check moisture vapor control separately
- NOTE: U = $1/R_{act} \neq 1/R_{nom}$

Comparing R20, R25, and R20+5ci walls

	U-factor Comparison		
Wall Component	R20	R25	R20+5ci
Outside winter air	0.17	0.17	0.17
Siding	0.62	0.62	0.62
Continuous insulation	0	0	5
OSB - 7/16	0.62	0.62	0.62
SPF stud	6.875	6.875	6.875
SPF header	6.875	6.875	6.875
Cavity insulation	20	25	20
1/2 drywall	0.45	0.45	0.45
Inside air film	0.68	0.68	0.68
R-value stud path	9.42	9.42	14.42
R-value header path	9.42	9.42	14.42
R-value cavity path	22.54	27.54	27.54
Framing factor - studs	21%	21%	21%
Framing factor -header	4%	4%	4%
Framing factor - cavity	75%	75%	75%
U-factor	0.060	0.054	0.045
Effective R of wall	17	19	22

The R2O+5ci wall is 15% more efficient than the R-25 wall. This is because the R-5ci creates a thermal break at the stud and header locations.

According to the U-factor compliance table, the R2O+5ci will work in any climate zone for thermal performance. Moisture control performance is addressed later as a separate check. The R-25 and R-20 walls are suitable for climate zones 5 or less.

Continuous insulation is very important to thermal performance of steel framing

C402.1.4.1 Thermal resistance of cold-formed steel walls. *U*-factors of walls with cold-formed steel studs shall be permitted to be determined in accordance with Equation 4-1:

 $U = 1/[R_s + (ER)]$

(Equation 4-1)

where:

•

- R_s = The cumulative *R*-value of the wall components along the path of heat transfer, excluding the cavity insulation and steel studs.
- ER = The effective R-value of the cavity insulation with steel studs.

2015 IECC

- Cavity insulation alone is a poor solution for steel framing.
- The addition of R-10 CI more than doubles this wall's insulating power



	TABLE C402.1.4.1 EFFECTIVE <i>R</i> -VALUES FOR STEEL STUD WALL ASSEMBLIES					
	NOMINAL STUD DEPTH (inches)	SPACING OF FRAMING (inches)	CAVITY <i>R</i> -VALUE (insulation)	CORRECTION FACTOR (F _c)	EFFECTIVE <i>R</i> -VALUE (ER) (Cavity <i>R</i> -Value $\times F_c$)	
	21/	16	13	0.46	5.98	
	572		15	0.43	6.45	
	21/	24	13	0.55	7.15	
	572		15	0.52	7.80	
	6	16	19	0.37	7.03	
	0		21	0.35	7.35	
	6	24	19	0.45	8.55	
	0		21	0.43	9.03	
	8	16	25	0.31	7.75	
		24	25	0.38	9.50	

Total UA Envelope Trade-offs

R402.1.5 Total UA alternative. If the total *building thermal envelope* UA (sum of *U*-factor times assembly area) is less than or equal to the total UA resulting from using the *U*-factors in Table R402.1.4 (multiplied by the same assembly area as in the proposed building), the building shall be considered in compliance with Table R402.1.2. The UA calculation shall be done using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. The SHGC requirements shall be met in addition to UA compliance.



U-factor and UA-Analysis Resources

- <u>ABTG U-factor calculator</u>
 - Specifically tailored to support U-factor analysis of CI assemblies
- <u>ResCheck</u>
 - U-factor and UA analysis
- <u>ComCheck</u>
 - U-factor and UA analysis



Building Performance Path

 Use this approach to make full use of trade-offs or demonstrate whole-building compliance, but requires approved energy modeling (software) and comparative analysis procedures.

> **R405.3 Performance-based compliance.** Compliance based on simulated energy performance requires that a proposed residence (*proposed design*) be shown to have an annual energy cost that is less than or equal to the annual energy cost of the *standard reference design*. Energy prices shall be taken from a source *approved* by the *code official*, such as the Department of Energy, Energy Information Administration's *State Energy Price and Expenditure Report. Code officials* shall be permitted to require time-of-use pricing in energy cost calculations.



IECC 2012 R405.3

Energy Rating Index (ERI) Path New in 2015 IECC

SECTION R406 ENERGY RATING INDEX COMPLIANCE ALTERNATIVE

R406.1 Scope. This section establishes criteria for compliance using an Energy Rating Index (ERI) analysis.

CLIMATE ZONE	ENERGY RATING INDEX		
1	52		
2	52		
3	51		
4	54		
5	55		
6	54		
7	53		
8	53		

TABLE R406.4 MAXIMUM ENERGY RATING INDE

- The ERI is a score of 100 (equivalent to the 2006 IECC) to 0 (no net energy use). Same as HERs.
- The ERI values in the table are evaluated by DOE and others to ensure equivalency to the other compliance paths in the 2015 code.
- Local amendments may attempt to raise these values to ease compliance and reduce insulation requirements
- This would create a compliance advantage for the ERI path that is not equivalent to other paths.



Coordinate with Building Code Vapor Retarder Requirements

- Regardless of a given assembly's compliance with the energy code, the 2015 IECC requires it to be checked for compliance with vapor control requirements in the building code.
- This check is important...more later.

R402.1.1 Vapor retarder. Wall assemblies in the *build-ing thermal envelope* shall comply with the vapor retarder requirements of Section R702.7 of the *International Residential Code* or Section 1405.3 of the *International Build-ing Code*, as applicable.



Not a fair trade: Long term benefit of CI vs. shorter term equipment efficiencies

- Some builders are using the performance or ERI paths to take equipment efficiency trade-offs
 - This can come at the expense of CI and long term wall performance
- Unfortunately, some federal mandates contain outdated minimum equipment efficiencies for trade-off purposes
 - Because it is an issue of federal law, this can't be dealt with through the model or local code development process.
- This creates a loophole where wall CI can be traded off for unequal equipment efficiencies, reducing the overall performance of the building



CI vs Thermal bridging: a game changer



Poor thermal bridges include:

- Uninsulated slab edges or balcony projections
- 2. Concrete wall/floor intersections with no exterior insulation
- Window/wall transitions (thru-wall metal flashings, etc.)
- Furring and shelf angles penetrating continuous insulation.

Stand-Off Shelf Angle

Thermally Broken Concrete Slab Extension Exte

Exterior Insulated Structural Steel Floor



Poor (top left) to enhanced thermal bridging details (Source: Morrison Hershfield, SOLUTIONS, 2012, Issue 3)

CI vs Thermal bridging: a game changer



Thermal bridging can increase heat flow up to 3x - but the energy codes do not address these details.

For additional information and design guidance refer to the <u>Building Envelope Thermal</u> <u>Analysis (BETA) Guide</u>.

Figure 4.7: Additional building energy use based on thermal performance of the building wall assembly for varying amounts of nominal exterior insulation for a mid-rise MURB in Edmonton (overall assembly thermal resistance in ft².°F · h/Btu also given)



Source: Cianfrone, Roppel, and Norris (2012)