BUILDING ENERGY CODES PROGRAM

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ANSI/ASHRAE/IES Standard 90.1-2019: Envelope

Prepared by Pacific Northwest National Laboratory for the U.S. Department of Energy

May 2020– PNNL-SA-153209

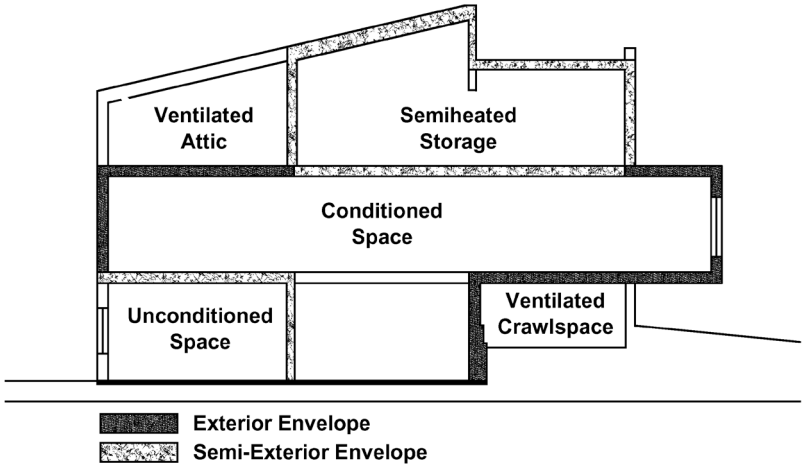
Acknowledgements

PNNL and DOE would like to thank ASHRAE Standing Standard Project Committee 90.1 for their contributions to the development of this presentation and their technical review of the content.

OVERVIEW OF CHANGES TO 90.1-2019

Overview

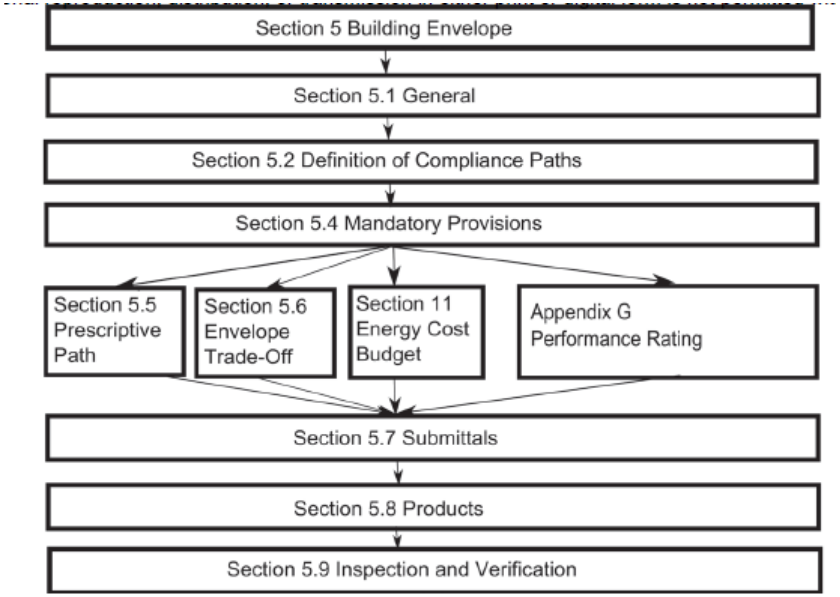
- Clean up type changes
  - References
  - Definitions
- Criteria changes
- Text re-arrangement type changes



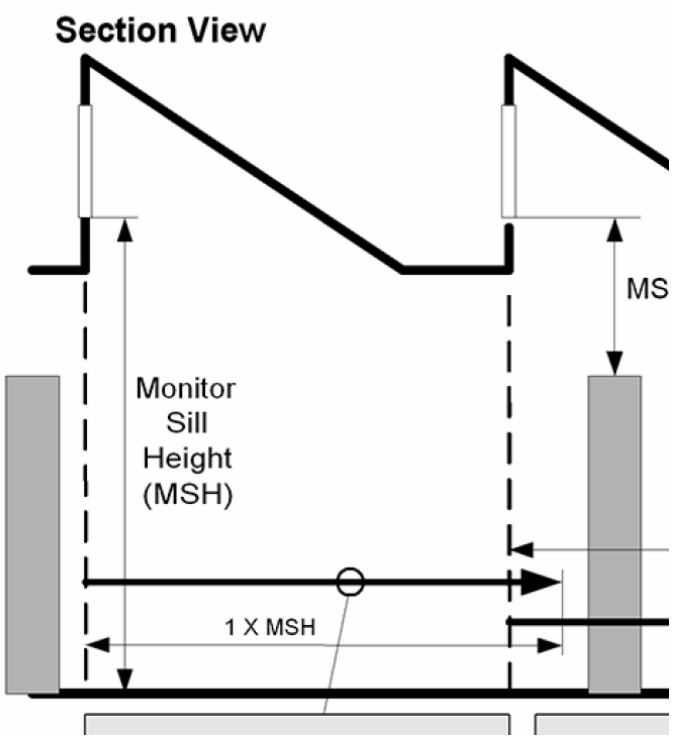
Compliance

1. Prescriptive Path
2. Envelope Trade Off
3. Energy Cost Budget
4. Performance Rating Method

Compliance with Sections 5.7, 5.8, & 5.9 is also required for all projects



References and Definitions



- Cool Roof Rating Standard from
  - CRRC -1 TO CRRC S100
- Added clarification in the definitions for ‘operable’ rooftop monitors
- Clarifications to the Definition of ‘door’ to help sort out confusion with revolving doors, garage doors, sectional garage doors, non-swinging doors, and glass doors

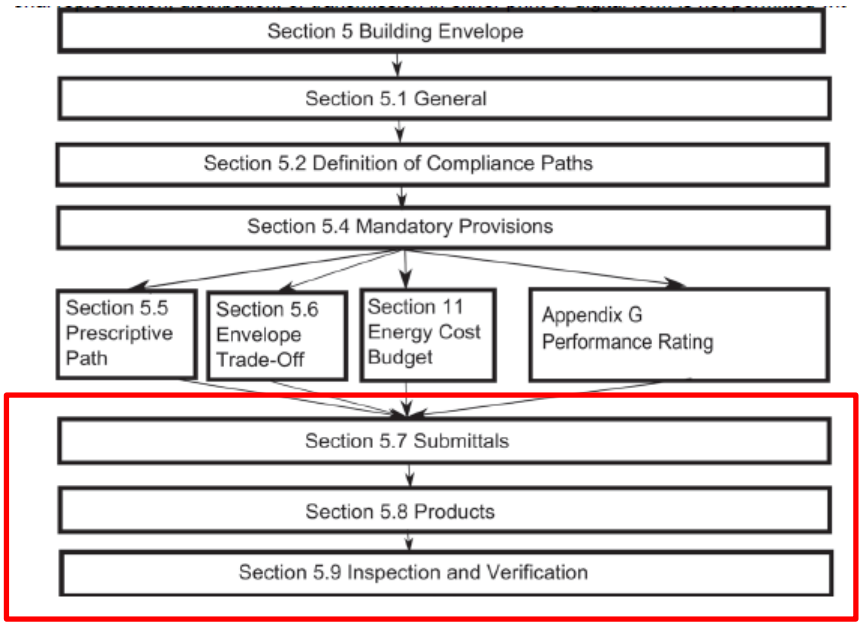
Criteria Changes

Section Re-organization and Alignment

The parts of Section 5 covering

- Submittals,
- Products, and
- Inspection and Verification

All underwent a general realignment so they are consistent with the same parts of Sections 6-10.



Language describing air-leakage requirements for materials, assemblies and the whole building was updated

Materials:
0.004 cfm/ft^2

Assemblies:
0.04 cfm/ft^2

Fenestration:
0.06 – 0.3 cfm/ft^2

Doors:
1.0 – 1.3 cfm/ft^2

Whole Building:
0.4 cfm/ft^2

Section 5.8.3.1

Section 5.4.3.1

Commissioning

Mandatory commissioning (Cx) requirements are now better organized and consistently addressed in Standard 90.1, including for the building envelope.

Section 4.2.5 Verification, Testing, and Commissioning outlines the general requirements while Sections 5-10 each have specific requirements under the heading Verification. Testing, Commissioning, and Inspections

Section 5.9 Verification. Testing, Commissioning, and Inspections

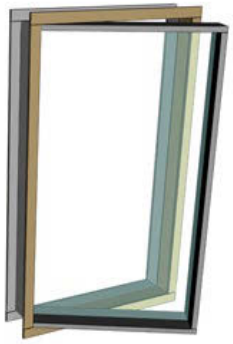
- 5.9.1 – Verification and Testing
- 5.9.2 – Commissioning **(New part of Section 5.9)**
- 5.9.3 – Inspections

Criteria Changes
Fenestration

Fenestration	Assembly Max. U	Assembly Max. *SHGC*	Assembly Min. *VT/SHGC*
Vertical Fenestration, 0% to 40% of *Wall*			
Fixed	0.36	0.36	1.10 (for all types)
Operable	0.45	0.33	
Entrance door	0.63	0.33	

Fenestration performance requirements are now based on fenestration type not on frame material.

Fenestration	Assembly Max. U	Assembly Max. *SHGC*	Assembly Min. *VT/SHGC*
Vertical Fenestration, 0% to 40% of *Wall*		(for all frame types)	
Nonmetal framing, all	0.31	0.36	1.10
Metal framing, fixed	0.38		
Metal framing, operable	0.46		
Metal framing, entrance door	0.68		



Criteria Changes
Fenestration Example

SHGC Change for a Fixed, Metal Framed Window									
SHGC	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2016	0.22	0.25	0.25	0.25	0.36	0.38	0.40	0.45	0.45
2019	0.22	**0.23**	0.25	0.25	0.36	**0.36**	**0.38**	**0.40**	**0.40**

U-Factor Change for a Fixed, Metal Framed Window									
U-factor	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2016	0.50	0.57	0.54	0.45	0.38	0.38	0.36	0.33	0.29
2019	0.50	**0.50**	**0.45**	**0.42**	**0.36**	**0.36**	**0.34**	**0.29**	**0.26**

Example of stringency improvements – *note this comparison is based on both a window type and frame material*

Air curtains allowed in lieu of vestibules for some building entrances

Requirements

- ANSI/AMCA 220 Compliant
- Design Jet Velocity of 6.6 ft/s
- Angle to door < 20 deg
- Commissioned
- Automatic controls

5.4.3.-43.3 Vestibule envelope. The exterior surfaces of both conditioned vestibules and unconditioned vestibules shall comply with the *continuous air barrier* requirements.

Exceptions to 5.4.3.3

1. *Doors* not intended to be used as a *building entrance*.
2. *Doors* opening directly from a *dwelling unit*.
3. *Building entrances* in *buildings* located in Climate Zone 1 or 2.
4. *Doors* opening into *semiheated spaces*.
5. Enclosed elevator lobbies for *building entrances* directly from parking garages.
6. *Building entrances* in *buildings* that are located in Climate Zone 3, where the *building* is less than four stories above *grade*, and less than 10,000 ft² (1000 m²) in *gross conditioned floor area*.
7. *Building entrances* in *buildings* that are located in Climate Zones 0, 4, 5, 6, 7, or 8 and the *building* is ~~are~~ less than 1000 ft² (100 m²) in *gross conditioned floor area*.
8. *Doors* that open directly from a *space* that is less than 3000 ft² (300 m²) in area and is separate from the *building entrance*.
9. Self-closing doors in buildings in Climate Zones 0, 3, and 4 that have an air curtain complying with Section 10.4.5.
10. Self-closing doors in buildings 15 stories or less in Climate Zones 5 thru 8 that have an air curtain complying with Section 10.4.5.

DETAILED INFORMATION

CHANGES TO 90.1-2019 SHOWN IN RED

Compliance Paths
Building Envelope

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building System

- **Envelope**
- HVAC
- SWH
- Power
- Lighting
- Other

Compliance Requirements

Mandatory Provisions
(required for each compliance path)

- **Prescriptive Path**
- **Envelope Trade Off**
- **Energy Cost Budget**
- **Simplified**
- **Performance Rating Method**

- **Submittal Requirements**
- **Information and Installation Requirements**
- **Verification, Testing, Inspection & Commissioning**

Energy Code Compliance

Section 5.1 General

- Scope
- Space-Conditioning Categories
- Envelope Alterations
- Climate

Section 5.2 Definition of Compliance Paths

Section 5.3 Simplified Building *(*Not Used)

Section 5.4 Mandatory Provisions

- Insulation
- Fenestration and Doors
- Air Leakage (continuous air barriers; loading dock weatherseals; vestibules **and revolving doors**)

Prescriptive Building Envelope Compliance Path *(Section 5.5)*

- Exterior Building Envelope
- Semiexterior Building Envelope
- Opaque Areas
- Fenestration

Building Envelope Trade-Off Option *(Section 5.6)*

Submittals *(Section 5.7)*

Product Information and Installation Requirements *(Section 5.8)*

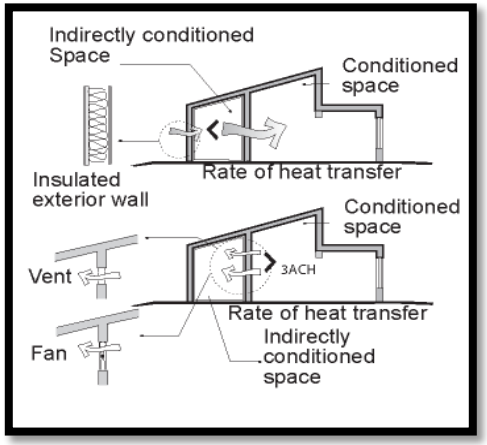
Verification, Testing, Commissioning, and Inspection *(Section 5.9)*

Space classifications used to determine Building Envelope Requirements

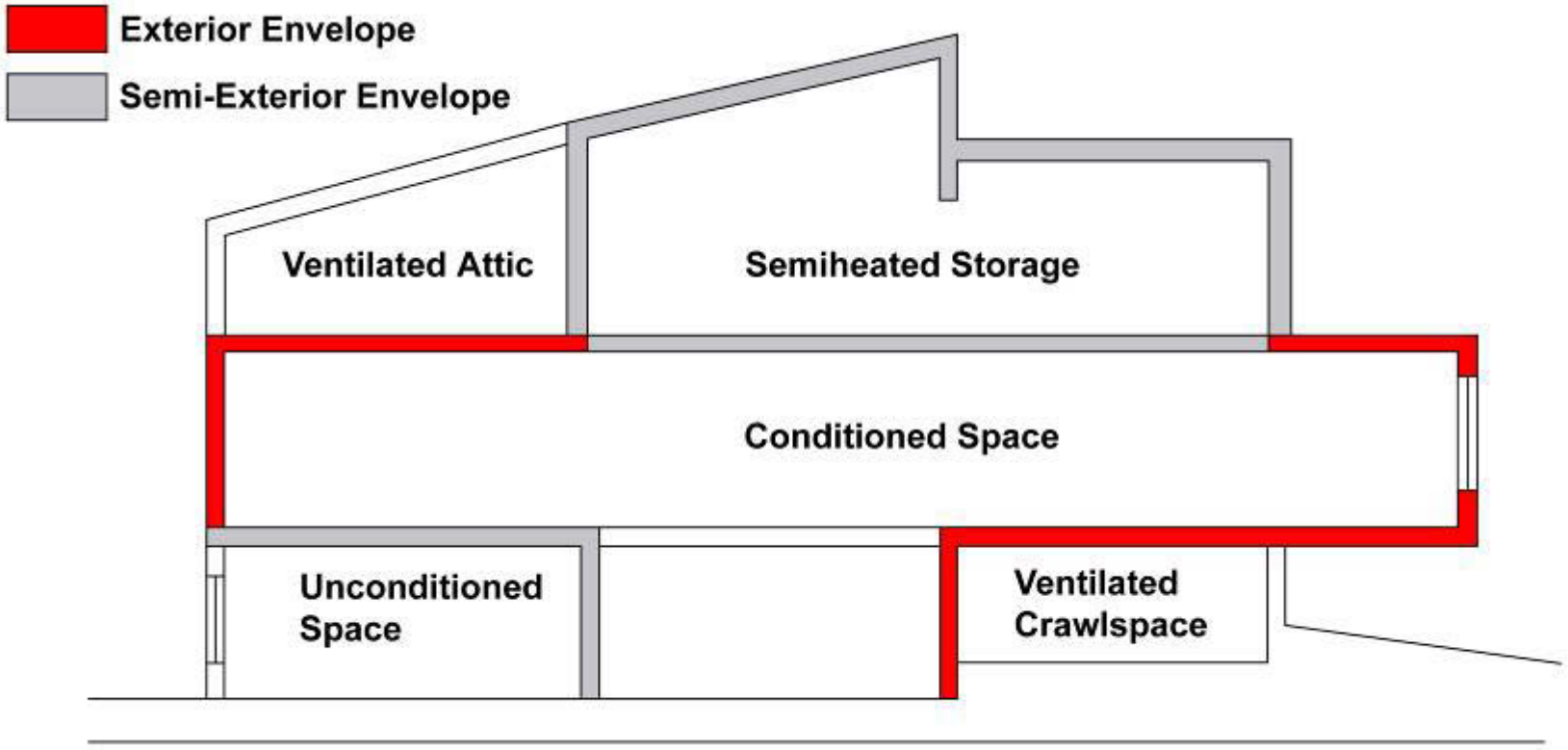
- Conditioned space
  - ***Cooled Space -*** any enclosed space served by a system with sensible cooling output capacity larger than 3.4 Btu/h·ft2
  - ***Heated Space*** - *an enclosed space* with a heating system output capacity larger than specified below
  - ***Indirectly conditioned space –*** see image.
- Semiheated space
  - *Enclosed space* with a heating *system* capacity ≥ 3.4 Btu/h·ft^2 but is not a conditioned space
- Unconditioned space
  - Any *enclosed space* that is not a conditioned or semiheated space. Attics, crawlspaces and parking garages are not considered enclosed spaces.

Heating Output, Btu/h·ft^2	Climate Zone
>5	0, 1, 2
>9	3A, 3B
>7	3C
>10	4A, 4B
>8	4C
>12	5
>14	6
>16	7
>19	8

Heated Space Capacity Criteria



Example of Indirectly Conditioned Spaces
User's Manual – 90.1-2013


Exterior Envelope
Semi-Exterior Envelope
Ventilated Attic
Semiheated Storage
Conditioned Space
Unconditioned Space
Ventilated Crawlspace

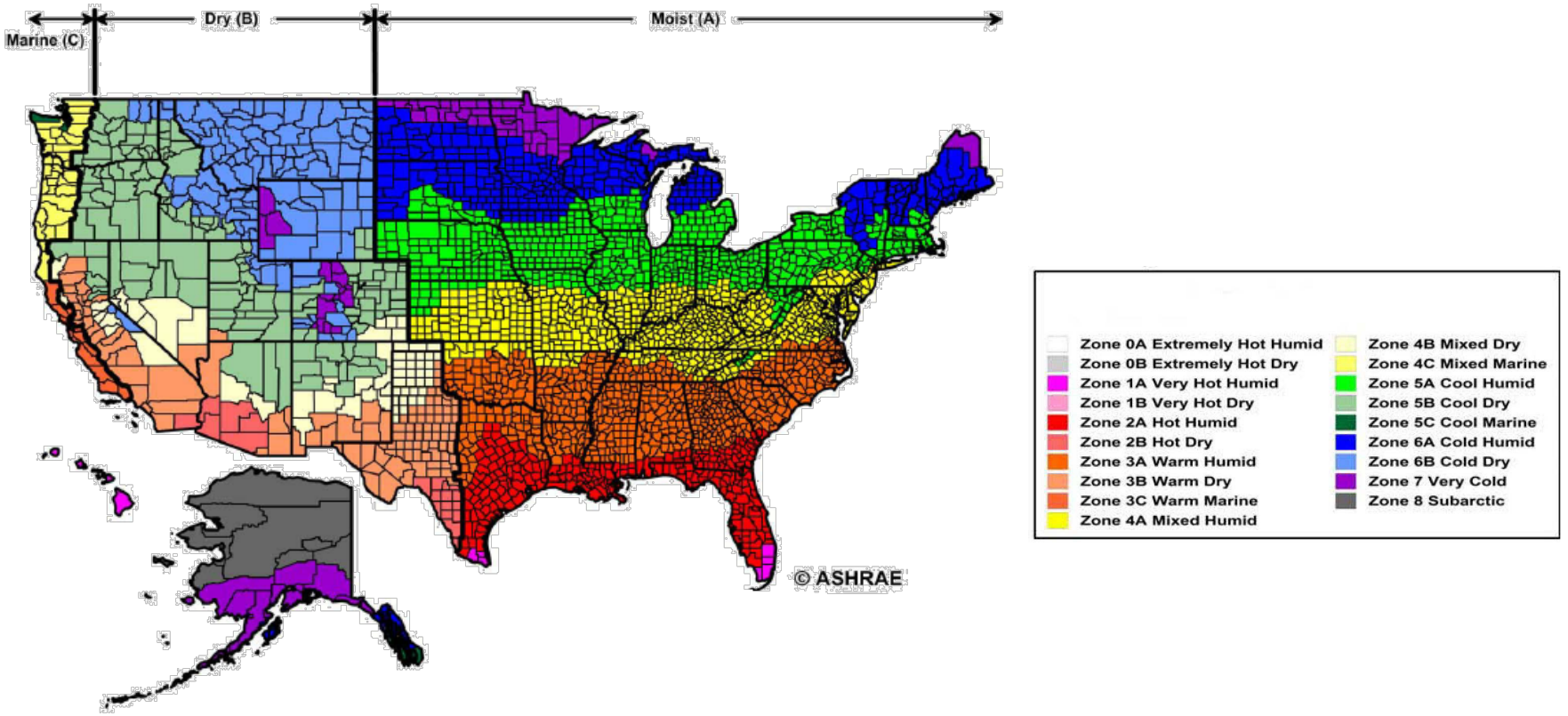
Spaces are assumed to be *conditioned space* and comply with requirements of *conditioned space* at time of *construction* regardless of whether the mechanical or electrical *equipment* is included in the building permit application or installed at that time

Exceptions:

- *Space* is designated as *semiheated* or *unconditioned* ***and***
- Approved as such by the building official

Allowed if they don't increase energy usage of building

- ✓ Installation of storm windows or glazing panels with low-emissivity coating
- ✓ Replacement of glazing in existing sash and frame provided *U-factor* and *SHGC* ≤ than previous glass
- ✓ *Alterations* to envelope cavities provided they are insulated to full depth with a nominal R-3.0 per in.
- ✓ *Wall* and *floor alterations* where no new cavities are created
- ✓ *Roof recovering*
- ✓ Removal and replacement of *roof* membranes
- ✓ Replacement of existing *doors* that separate *conditioned space* from exterior do not require a vestibule provided existing vestibule is not removed
- ✓ Replacement of existing fenestration, provided area of replacement is no more than 25% of total fenestration area provided *U-factor* and *SHGC* ≤ than previous fenestration



United States Locations – ASHRAE 90.1-2019 Table Annex1-1

Canadian Locations – ASHRAE 90.1-2019 Table Annex 1-2

International Locations – ASHRAE 90.1-2019 Table Annex 1-3

Compliance Paths
Building Envelope

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Building System

- **Envelope**
- HVAC
- SWH
- Power
- Lighting
- Other

Compliance Requirements

Mandatory Provisions
(required for each compliance path)

- Prescriptive Path
- Envelope Trade Off
- Energy Cost Budget
- Simplified
- Performance Rating Method

- Submittal Requirements
- Information and Installation Requirements
- Verification, Testing, Inspection & Commissioning

Energy Code Compliance

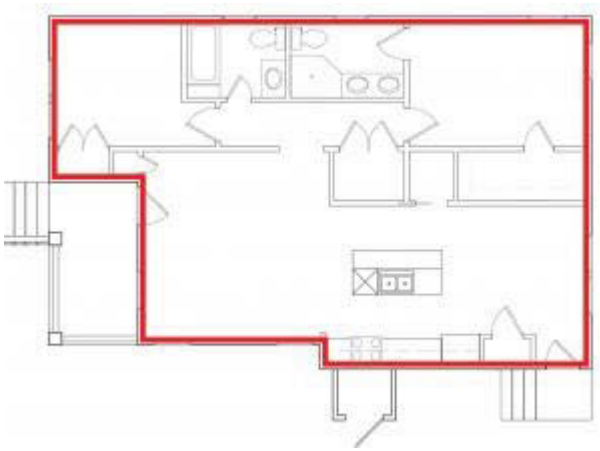
Insulation *(Section 5.4.1 refers to 5.8.1. through 5.8.1.10)*

- ✓ Labeling *(Section 5.8.1.1)*
- ✓ **Manufacturers' Installation Instructions *(Section 5.8.1.2)***
- ✓ Loose-Fill Insulation Limitation *(Section 5.8.1.3)*
- ✓ Baffles *(Section 5.8.1.4)*
- ✓ Substantial Contact *(Section 5.8.1.5)*
- ✓ Recessed Equipment *(Section 5.8.1.6)*
- ✓ Insulation Protection *(Section 5.8.1.7)*
- ✓ Location of Roof Insulation *(Section 5.8.1.8)*
- ✓ Extent of Insulation *(Section 5.8.1.9)*
- ✓ Joints in Rigid Insulation *(Section 5.8.1.10)*
- ✓ Insulation Installation Documentation *(Section 5.8.1.11)*

- ✓ Fenestration and *Doors (Section 5.4.2 that refers to 5.8.2)*
- ✓ Air Leakage *(Section 5.4.3)*

Photo courtesy of Ken Baker, K energy

Mandatory air-leakage requirements exist for



Continuous air barriers

Loading dock weather seals

Vestibules and revolving doors

Continuous air barrier required in all buildings covered by the Standard except:

- *Semiheated spaces* in climate zones 0-6
- Single wythe concrete masonry *buildings* in climate zone 2B

Measured whole building air-leakage rate not to exceed 0.40 cfm/ft^2 (at a pressure differ. of 0.3 in. of water)

- Normalized by above and below-grade building envelope area of both conditioned space and semiheated spaces.
- Testing conducted per ASTM E779 or ASTM E1827 by independent 3rd party

Section 5 – 5.4.3.1.1
Whole-Building Air Leakage – Exceptions

Buildings > 50,000 sf (exception)

May comply using partial testing if:

a) Test entire floor area of all stories with; any space under a roof, a building entrance or a loading dock.

b) Test representative above-grade wall sections totaling at least 25% of wall area enclosing remaining conditioned space, cannot include areas tested under (a)

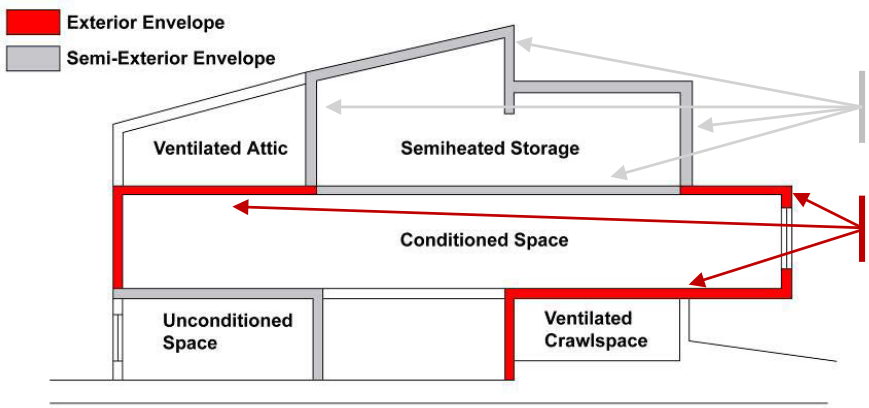
All Buildings

Comply by testing entire building

1. Building complies if measured air leakage rate is less than 0.40 cfm/ft^2 at 0.30 in. of water
2. If measured air leakage rate is greater than 0.40 cfm/ft^2 but less than 0.60 cfm/ft^2
   - Perform diagnostic evaluation (smoke tracer, infrared imaging, etc.) and seal identified leaks
   - Perform visual inspection of air barrier and seal identified leaks
   - Submit report to code official and building owner identifying corrective actions taken to seal leaks
3. Testing not required when meeting

When a building has both conditioned space and semiheated space, compliance can be demonstrated using one of two methods

1. Separately for each space condition type
   - *Air-leakage* of *conditioned space* normalized by *exterior building envelope* area
   - *Air-leakage* of *semiheated space* normalized by area of *semiexterior building envelope*
2. Both space conditioning types together,
   - Air-leakage rate for both *space* types normalized by sum of *exterior building envelope* area and *semiexterior building envelope* area minus *semiexterior building envelope* area separating conditioned and *semiheated* spaces



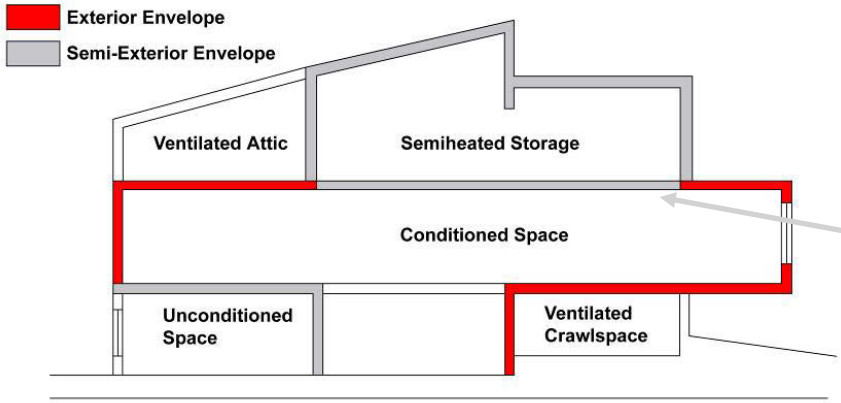
Option 1: Air-leakage calculated separately for each space.

Semiheated Storage air-leakage normalized only using its semiexterior envelope area

Conditioned space air-leakage normalized using the exterior envelope area

When a building has both conditioned space and semiheated space, compliance can be demonstrated using one of two methods

1. Separately for each space condition type
   - *Air-leakage* of *conditioned space* normalized by *exterior building envelope* area
   - *Air-leakage* of *semiheated space* normalized by area of *semiexterior building envelope*
2. Both space conditioning types together,
   - Air-leakage rate for both *space* types normalized by sum of *exterior building envelope* area and *semiexterior building envelope* area minus *semiexterior building envelope* area separating conditioned and *semiheated* spaces



Option 2:
Air-leakage calculated for both spaces together, normalized based on total envelope area (red + grey) minus the area of exterior envelope between the spaces.

Continuous air barrier compliance requires:

- Component and component positions in envelope assemblies to be clearly identified on construction documents
- Joints, interconnections, and penetrations to be detailed on construction documents
- Extension over all surfaces of the *building envelope* and identified as continuous on construction documents
- A design that resists positive and negative pressures from wind, stack effect, and mechanical ventilation and allow for anticipated movements
- The following areas to be wrapped, sealed, caulked, gasketed, or taped in an approved manner
  - Joints around fenestration and door frames
  - Junctions between all wall, floor and roof assembly transitions including building corners
  - Penetrations through roofs, walls, and floors
  - Building assemblies used as ducts or plenums
  - Joints, seams, connections between planes, and other changes in air barrier materials

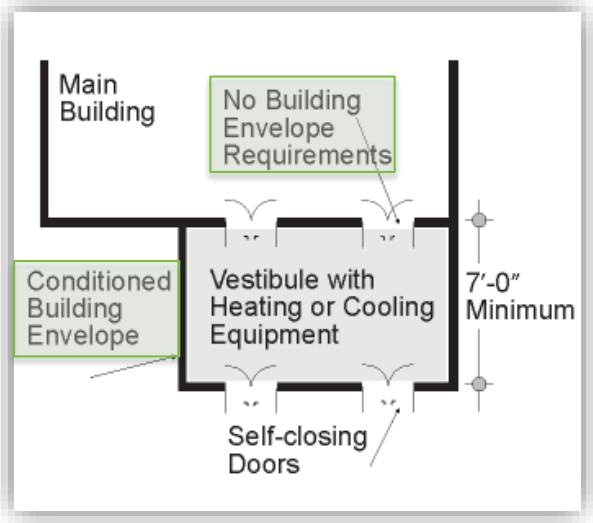
In climate zones 0 and 4-8

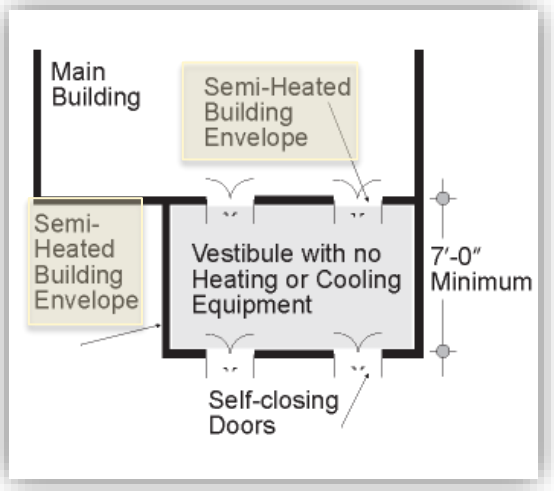
- Cargo doors and loading dock doors equipped with weatherseals
  - To restrict infiltration when vehicles are parked in the loading dock/doorway

Building entrances must have an enclosed vestibule with self-closing devices, revolving doors or a combination of the two

Vestibules and revolving doors

- Cannot have interior and exterior *doors* open at the same time
- Distance between interior and exterior *doors,* minimum 7 ft when closed
- *Floor* area < 50 ft^2 or 2% of the conditioned area of that building level
- Conditioned vestibule must comply with *conditioned building envelope*
- Unconditioned vestibule must comply with semi-heated building envelope





Exceptions to Vestibule Requirements

- Non-entrance *doors* or *doors* opening from *dwelling unit*
- *Building entrances* with revolving *doors*
- All *building entrances* in climate zones 1 and 2 **OR** in *buildings* < 4 stories and < 10,000 ft^2 in gross conditioned floor area in climate zone 3 **OR** in buildings < 1000 ft^2 in *gross conditioned floor area* in climate zones **0** and 4-8
- All *doors* that open from *spaces* < 3000 ft^2 and separate from *building entrance*
- Self-closing doors in climate zones 0, 3, and 4 OR in buildings < = 15 stories in climate zones 5-8 that have air curtains complying with 10.4.5

Vestibules opening into large *conditioned spaces* (large retail) shall have a minimum distance between the interior and exterior doors of not less than 16 ft.

Applies when vestibules:

- open into a *space* >= 40,000 ft^2 of *gross conditioned floor area* at the same building level.
- have doors equipped with automatic, electrically driven, self-closing devices on doors going both in and out.

Compliance Paths
Building Envelope

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Building System

- **Envelope**
- HVAC
- SWH
- Power
- Lighting
- Other

Compliance Requirements

Mandatory Provisions
(required for each compliance path)

- **Prescriptive Path**
- Envelope Trade Off
- Energy Cost Budget
- Simplified
- Performance Rating Method

- Submittal Requirements
- Information and Installation Requirements
- Verification, Testing, Inspection & Commissioning

Energy Code Compliance

Each envelope component must separately meet designated space conditioning requirements:

(*Nonresidential, Residential,* and/or *Semiheated)*

Opaque Areas (5.5.3)

Fenestration (5.5.4)

- WWR ≤ 40% of gross *wall* area
- *Skylight*-roof ratio ≤ 3% of *roof* area

Prescriptive requirements for each component specified by climate zone and space conditioning category (Tables 5.5-0 through 5.5-8)

- Insulation levels for *roofs, walls, floors* and *doors*
- Fenestration criteria for windows, glazed *doors* and *skylights*

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-10 c.i.
Metal building[a]	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.082	R-19
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Walls, above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-13
Steel-framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-13
Wood-framed and other	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13
Wall, below Grade						
Below-grade wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-6.3 c.i.
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
Slab-on-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

Fenestration	Assembly Max. U	Assembly Max. *SHGC*	Assembly Min. *VT/SHGC*	Assembly Max. U	Assembly Max. SHGC	Assembly Min. *VT/SHGC*	Assembly Max. U	Assembly Max. *SHGC*	Assembly Min. *VT/SHGC*
Vertical Fenestration, 0% to 40% of *Wall*									
Fixed	0.36	0.36	1.10 (for all types)	0.36	0.36	1.10 (for all types)	0.50	NR (for all types)	NR (for all types)
Operable	0.45	0.33		0.45	0.33		0.65		
Entrance door	0.63	0.33		0.63	0.33		0.77		
Skylight, 0% to 3% of *Roof*									
All types	0.50	0.40	NR	0.50	0.40	NR	0.75	NR	NR

Compliance

- ✓ Meet or exceed minimum *R-values* in table
  - Only *R-value* of insulation, not to include air films, etc.

OR

- ✓ Meet maximum *U-factor, C-factor,* or *F-factor* for the entire assembly (typical construction assemblies described in Appendix A)

OR

- ✓ Perform area-weighted average *U-factor, C-factor,* or *F-factor*
  - Only if there are multiple assemblies within a single class of construction for a single *space-conditioning* category

Table 5.5-0 *Building Envelope* Requirements for Climate Zone 0 (A,B)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.039	R-25 c.i.	U-0.032	R-30 c.i.	U-0.218	R-3.8 c.i.

Opaque Elements	*Nonresidential*		*Residential*		*Semiheated*	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.039	R-25 c.i.	U-0.032	R-30 c.i.	U-0.218	R-3.8 c.i.
Metal Building	U-0.041	R-10 + 19 FC	U-0.041	R-10 + 19 FC	U-0.115	R-10
Attic and Other	U-0.027	R-38	U-0.027	R-38	U-0.081	R-13

FC = filled cavity

Reference Table 5.5-0 on page 58 in 90.1-2019

Table 5.5-1 *Building Envelope* Requirements for Climate Zone 1 (A,B)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.048	R-20 c.i.	U-0.039	R-25 c.i.	U-0.218	R-3.8 c.i.
Metal building[a]	U-0.041	R-10 + R-19 FC	U-0.041	R-10 + R-19 FC	U-0.115	R-10
Attic and other	U-0.027	R-38	U-0.027	R-38	U-0.081	R-13
Floors						
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood-framed and other	U-0.282	NR	U-0.282	NR	U-0.282	NR

Opaque Elements	*Nonresidential*		*Residential*		*Semiheated*	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.048	R-20 c.i.	U-0.039	R-25 c.i.	U-0.218	R-3.8 c.i.
Metal Building	U-0.041	R-10 + 19 FC	U-0.041	R-10 + 19 FC	U-0.115	R-10
Attic and Other	U-0.027	R-38	U-0.027	R-38	U-0.081	R-13

FC = filled cavity

Reference Table 5.5-1 on page 59 in 90.1-2019

Table 5.5-2 *Building Envelope* Requirements for Climate Zone 2 (A,B)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.039	R-25 c.i.	U-0.039	R-25 c.i.	U-0.173	R-5 c.i.
Floors						
Mass	U-0.107	R-6.3 c.i.	U-0.087	R-8.3 c.i.	U-0.322	NR
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.069	R-13
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.066	R-13

Opaque Elements	*Nonresidential*		*Residential*		*Semiheated*	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.039	R-25 c.i.	U-0.039	R-25 c.i.	U-0.173	R-5 c.i.
Metal Building	U-0.041	R-10+R-19 FC	U-0.041	R-10+R-19 FC	U-0.096	R-16
Attic and Other	U-0.027	R-38	U-0.027	R-38	U-0.053	R-19

Reference Table 5.5-2 on page 60 in 90.1-2019

Table 5.5-3 *Building Envelope* Requirements for Climate Zone 3 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.039	R-25 c.i.	U-0.039	R-25 c.i.	U-0.119	R-7.6 c.i.
Metal Building	U-0.041	R-10+R-19 FC	U-0.041	R-10+R-19 FC	U-0.096	R-16
Attic and Other	U-0.027	R-38	U-0.027	R-38	U-0.053	R-19
Wood-framed and other	U-0.089	R-13	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13
Wall, below Grade						
Below-grade wall	C-1.140	NR	C-1.140	NR	C-1.140	NR

Reference Table 5.5-3 on page 61 in 90.1-2019

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)

Opaque Elements	*Nonresidential*		*Residential*		*Semiheated*	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-10 c.i.
Metal Building	U-0.037	R-19+R-11 Ls or R-25+R-8 Ls	U-0.037	R-19+R-11 Ls or R-25+R-8 Ls	U-0.082	R-19
Attic and Other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
other		or R-20		or R-20		
Wall, below Grade						
Below-grade wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						

Reference Table 5.5-4 on page 62 in 90.1-2019

Table 5.5-5 *Building Envelope* Requirements for Climate Zone 5 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.063	R-15 c.i.
Metal Building	U-0.037	R-19+R-11 Ls or R-25+R-8 Ls	U-0.037	R-19+R-11 Ls or R-25+R-8 Ls	U-0.082	R-19
Attic and Other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Wood-framed and other	U-0.051	R-13 + R-7.5 c.i. or R-19 + R-5 c.i.	U-0.051	R-13 + R-7.5 c.i. or R-19 + R-5 c.i.	U-0.089	R-13
Wall, below Grade						
Below-grade wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR

Reference Table 5.5-5 on page 63 in 90.1-2019

Table 5.5-6 *Building Envelope* Requirements for Climate Zone 6 (A,B)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation entirely above deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.063	R-15 c.i.
Metal building	U-0.031	R-25+R-11 Ls	U-0.029	R-30+R-11 Ls	U-0.060	R-19+R-19
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Wood-framed and other	U-0.051	R-13 + R-7.5 c.i. or R-19 + R-5 c.i.	U-0.051	R-13 + R-7.5 c.i. or R-19 + R-5 c.i.	U-0.089	R-13
Wall, below Grade						
Below-grade wall	C-0.092	R-10 c.i.	C-0.063	R-15 c.i.	C-0.119	R-7.5 c.i
Floors						

Reference Table 5.5-6 on page 64 in 90.1-2019

Table 5.5-7 *Building Envelope* Requirements for Climate Zone 7*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.028	R-35 c.i.	U-0.028	R-35 c.i.	U-0.039	R-25 c.i.
Metal Building	U-0.029	R-30+R-11 Ls	U-0.029	R-30+R-11 Ls	U-0.037	R-19+R-11 Ls or R-25+R-8 Ls
Attic and Other	U-0.017	R-60	U-0.017	R-60	U-0.027	R-38
other		R-19 + R-5 c.i.		R-19 + R-5 c.i.		
Wall, below Grade						

Reference Table 5.5-7 on page 65 in 90.1-2019

Table 5.5-8 *Building Envelope* Requirements for Climate Zone 8*

Opaque Elements	*Nonresidential*		*Residential*		*Semiheated*	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Roofs						
Insulation Entirely above Deck	U-0.028	R-35 c.i.	U-0.028	R-35 c.i.	U-0.039	R-25 c.i.
Metal Building	U-0.026	R-25+R-11+ R-11 Ls	U-0.026	R-25+R-11+ R-11 Ls	U-0.037	R-19+R-11 Ls or R-25+R-8 Ls
Attic and Other	U-0.017	R-60	U-0.017	R-60	U-0.027	R-38
other						
Wall, below Grade						
Below-grade wall	C-0.063	R-15 c.i.	C-0.063	R-15 c.i.	C-0.119	R-7.5 c.i.
Floors						

Reference Table 5.5-8 on page 66 in 90.1-2019

Meet or exceed minimum R-value in table for climate zone

Skylight curbs insulated to level of *roofs* with insulation entirely above deck or R-5, whichever is less

Three types of *roofs* are defined

- ✓ *Roofs* with insulation entirely above deck
  - *R-value* is for continuous insulation
  - Exception: mechanical equipment framing and pads ≤ 1% of roof area
- ✓ *Metal building roofs*
  - First value is for insulation
    - draped over purlins and then compressed by metal spanning members or
    - hung between purlins provided a minimum 1" thermal break exists between purlins and metal spanning members
  - Second value is for double-layer installations with insulation installed parallel to the purlins
- ✓ *Attics and other roofs*
  - *R-value* is for insulation installed both inside and outside the roof or entirely inside the roof cavity

Insulation must be installed such that:

- ✓ The rated R-value is clearly identified by an identification mark applied by manufacturer to each piece of building envelope insulation

  Exception - provide documentation and one of the following:

  - ✓ **Batts/blankets** – rated R-value, length, width, thickness
  - ✓ **Boardstock** – rated R-value, length, width, thickness of boards in the package
  - ✓ **Loose-fill** – minimum settled thickness, initial installed thickness, max. net coverage area, number of bags/1000 sf and minimum weight per sf at R-values of 13, 19, 30, 38,and 49; package to state minimum net weight of insulation in the package
  - ✓ **Spray-applied polyurethane foam** – R-value of insulation at 1 in. thickness and additional inch increments up to max. thickness allowed

- ✓ Per manufacturer's installation instructions in a way that achieves the rated R-value
- ✓ No open-blown or poured loose-fill insulation when ceiling slope is > 3/12
- ✓ If eave air vents are installed, provide baffling to deflect incoming air above the surface of the insulation
  - Metal buildings Exception - if roof and wall insulation is compressed between roof or wall skin and the structure

Photos courtesy of MBMA

High Albedo Roofs Required in climate zones 0-3

Minimum three-year aged solar *reflectance* of 0.55 and minimum three-year aged thermal *emittance* of 0.75 (tested in accordance with **CRRC S100**)

OR

Minimum Solar Reflectance Index of 64, based on

- Three-year aged solar *reflectance*
- Three-year aged thermal *emittance*
  - Tested in accordance with **CRRC S100**

OR

Increase *roof* insulation levels in Table 5.5.3.1.1

Situations when High Albedo Roofs are not required:

- Ballasted *roofs* with minimum stone *ballast* of 17 lb/ft^2 or 23 lb/ft^2 pavers
- *Vegetated roof systems* containing minimum thickness of 2.5 in. of growing medium that covers minimum of 75% of roof area with durable plantings
- *Roofs*, where a minimum of 75% of the *roof* area is:
  1. shaded during peak sun angle on June 21 by permanent features of the *building*
  2. covered by on-site solar energy systems (ie: PV arrays) **OR**
  3. permitted to be interpolated using a combination of 1 and 2 above
- Steep-sloped *roofs*
- Low-sloped *metal building roofs* in climate zones 2-3
- *Roofs* over: ventilated attics, *semiheated spaces*, or *conditioned spaces* that aren't *cooled spaces*
- Asphaltic membranes in climate zones 2-3

Meet or exceed *R-value* specified for climate zone in appropriate table

When *wall* consists of both above-grade and below-grade portion, entire *wall* to be insulated on either exterior or interior or be integral

- If insulated on interior: a*bove-grade wall* insulation requirements apply
- If insulated on exterior or integral: below-grade wall portion to be insulated to the below-grade wall requirements and above-grade to above-grade wall requirements

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Walls, above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-13
Steel-framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-13
Wood-framed and other	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13

Above-grade East and West walls in climate zone 0 shall meet one of the following:

A. Minimum of 75% of the opaque wall area to have a minimum SRI 29
- glass spandrel areas a minimum solar reflectance of 29% determined in accordance with NFRC 300 or ISO 9050 is permitted
- Each wall is allowed to be considered separately

B. Minimum of 30% of the above-grade wall area be shaded
- Can demonstrate using shade-providing plants, manmade structures, existing buildings, hillsides, permanent building projections, on-site renewable energy systems, or combination
- Shade coverage calculated at 10 a.m. for east walls and 3 p.m. for west walls on summer solstice

The building is allowed to be rotated up to 45 degrees to the nearest cardinal orientation for compliance calculation purposes

Four types of above-grade walls

1. Mass walls,
2. Metal Building walls,
3. Steel Framed walls,
4. Non-metal walls.

Mass walls

- heat capacity (HC) determined from Table A3.1-2 or A3.1-3
- *Rated R-value* is for continuous insulation or when uninterrupted by framing other than metal clips no closer than 24 in. o.c. horizontally and 16 in. o.c. vertically

Exception

•Requirement of U-0.151

Metal building wall *R-value*

- for insulation compressed between metal wall panels and the steel structure

Steel-framed wall *R-value*

- for uncompressed insulation installed in the cavity between steel studs; also acceptable to be continuous insulation uninterrupted by studs

Wood-framed and other *R-value*

- for uncompressed insulation installed in the cavity between wood studs; also acceptable to be continuous insulation uninterrupted by studs

Meet or exceed values in appropriate table for climate zone

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Wall, below Grade						
Below-grade wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR

R-value is for continuous insulation and the maximum assembly *C-factor* is for framed assemblies with cavity insulation.

Photo courtesy of Dow Building Solutions

Table A4.2.1 Assembly *C-Factors* for *Below-Grade Walls*

Framing Type and Depth	*Rated R-Value of Insulation* Alone	Specified *C-Factors* (*Wall* Only, without Soil and Air Films)
No framing	R-0	C-1.140
Exterior Insulation, Continuous and Uninterrupted by Framing		
No framing	R-5.0	C-0.170
No framing	R-7.5	C-0.119
No framing	R-10.0	C-0.092
No framing	R-50.0	C-0.020
Continuous *Metal Framing* at 24 in. on Center Horizontally		

Exterior floors over unconditioned space must meet or exceed insulation values in appropriate table for climate zone

The 3 classes of exterior floor are:

Mass floors

- *R-value* is for continuous insulation
- If framing is used, compliance is based on maximum assembly *U-factor*

Steel-joist floors

- *R-value* is for uncompressed insulation or spray-on insulation, but is also acceptable for continuous insulation

Wood-framed and others

- *R-value* is for uncompressed insulation, but is also acceptable for continuous insulation

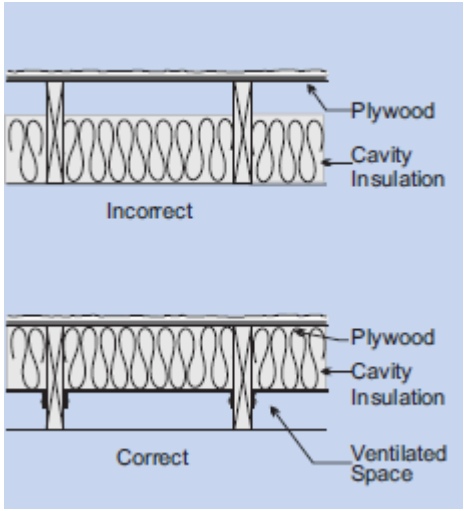


Table describes the *rated R-value* of insulation to be installed around the perimeter of the slab-on-grade floor to the distance specified or comply with F-factor requirement based on Appendix A.

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Slab-on-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.

Installing Insulation:

- **Inside foundation *wall*** – extend downward from top of slab a minimum distance specified or to the top of the footing, whichever is less
- **Outside foundation *wall*** – extend from top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum distance specified
- In all climate zones, the horizontal insulation extending outside of the foundation to be covered by pavement or by soil a minimum of 10 in. thick

Exception: monolithic *slab-on-grade floor*, insulation to extend from the top of the *slab-on-grade* to the bottom of the footing.

U-factor not greater than specified for climate zone in appropriate table

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*
Opaque Doors						
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

Criteria apply to *fenestration*, including windows, glass *doors*, glass block, plastic panels, and *skylights*

- specified by fenestration type and by climate zone

Compliance with values in Tables 5.5-0 through 5.5-8

- *U-factor* not greater than specified
- *SHGC* not greater than specified
- Meet or exceed minimum *VT/SHGC*
- Use NFRC ratings or default values in Appendix A

Exceptions:

- Area weighting allowed within same class of construction and space-conditioning categories
- Vertical fenestration can only be area-weighted across a single space conditioning category (ie: conditioned vs unconditioned spaces)

Total *vertical fenestration area* to be smaller than specified values in Tables 5.5-0 through 5.5-8 (40% for all climate zones)

- Including both fixed and operable *vertical fenestration*
- Exception: street-level *vertical fenestration* (5.5.4.4.1)

Total *skylight* area smaller than specified in Tables 5.5-0 through 5.5-8 (3% of roof area for all climate zones)

- Permitted to be no greater than 6% of *gross roof area* provided criteria in exception 1 to *skylight SHGC* requirements are met (5.5.4.4.2) and *daylight area under skylights* is more than or equal to half the *floor* area of the *space*

Minimum *skylight* area must be provided in *enclosed spaces* that are ≥ 2,500 ft^2 with ceiling height > 15 ft and the following use type:

- Office
- Lobby
- Atrium
- Concourse
- Corridor
- Storage (incl. nonrefrigerated warehouse)
- Gymnasium/fitness /exercise area
- Playing area
- Gymnasium seating area
- Convention exhibit/event space
- Courtroom
- Automotive service
- Fire station engine room
- Manufacturing
- Corridor/transition and bay areas
- Retail
- Library reading and stack areas
- Distribution/sorting area
- Transportation
- Baggage and seating areas
- Workshop

When spaces require skylights, the *skylight* area must *daylight* a minimum of half the floor area be designed to provide either:

- A minimum ratio of 3% of *skylight* area to *daylight area* with a *skylight VLT* at least 0.40, or
- a minimum *skylight effective aperture* of at least 1%

Minimum skylight areas are not required

- *For enclosed spaces* in climate zones 6-8
- *For enclosed spaces* under shaded *roofs* (beam sunlight blocked for more than 1500 daytime hours between 8 a.m. and 4 p.m.)
- *For daylight area* under rooftop monitors are > 50% of floor area
- When documented that 90% of *skylight* area is shaded on June 21 (Northern Hemisphere)/December 21 (Southern Hemisphere) at noon by permanent features
- When total *space* area minus the *primary and secondary sidelighted area*(s) is < 2,500 ft and where lighting is controlled according to sidelighting requirements of Section 9.4.1

Fenestration U-factor shall not be greater than specified in Tables 5.5-0 through 5.5-8

Exception:

- *U-factor* for *skylights* allowed to be increased no greater than
  - 0.90 Btu/h•ft^2 °F in climate zone 0-3
  - 0.75 Btu/h•ft^2 °F in climate zone 4-8

  Provided they have a measured haze value >90%, skylight VT> 90% and lighting under the skylight has multilevel photocontrols per Section 9.4.1.1 (f)

Fenestration and Door U-Factors shall be calculated accordance with NFRC 100 and *Skylight U-Factors* shall be based on a slope of 20° above the horizontal

Exceptions

- U-Factors from Appendix A are used; A8.1 for skylights, A8.2 for vertical fenestration, and A7 for opaque doors
- ANSI/DASMA 105 acceptable for sectional garage doors and metal coiling doors

Vertical fenestration (5.5.4.4.1)

- *SHGC* values < Assembly Maximum SHGC in Tables 5.5-0 to 5.5-

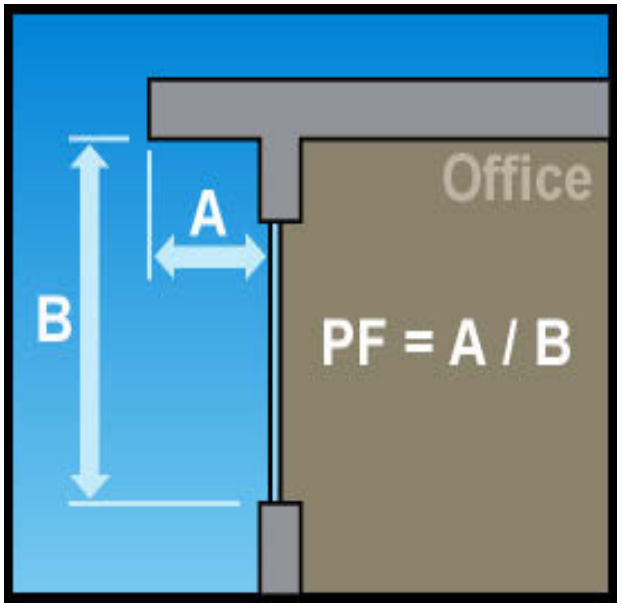
Exceptions

- For south, east, or west-oriented *vertical fenestration* only, the *SHGC* in the proposed *building* can be reduced by using the multipliers in Table 5.5.4.4.1 for *fenestration* shaded by permanent projections that will last as long as the building itself
- For south, east, or west-oriented *vertical fenestration* shaded by partially *opaque* permanent projections that will last as long as the building itself, can reduce the PF by multiplying by values in Table 5.5.4.4.1
- Street-level exception only applies when using the prescriptive compliance option
- *Dynamic glazing* cannot be area-weighted with other fenestration and minimum *SHGC* of *dynamic glazing* shall be used to show compliance for *dynamic glazing*
- North-oriented *vertical fenestration* allowed to have *SHGC* equal to or less than the area-weighted average *SHGC* of the south, east, and west-oriented *vertical fenestration* before any reductions made for permanent projections in Exception 1 and 2 of Section 5.5.4.4.1

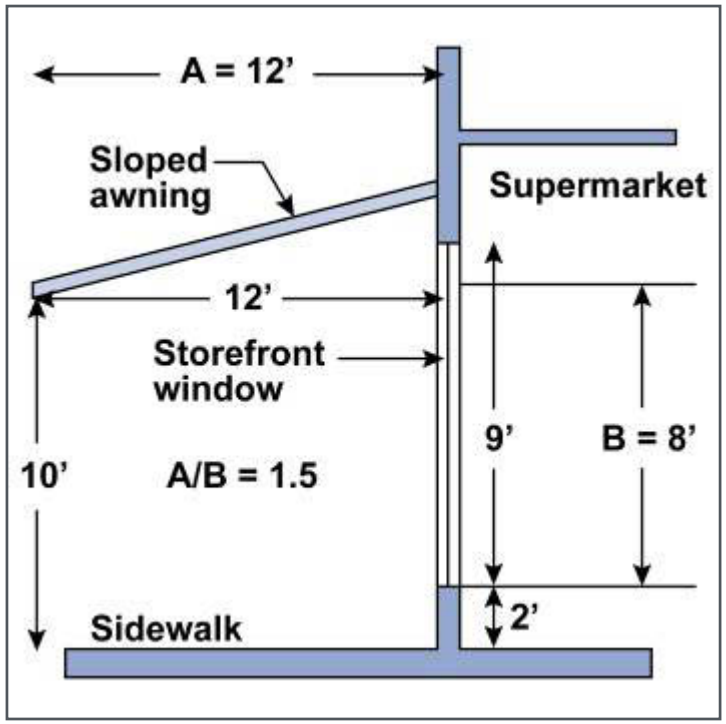
Information – Overhangs

Standard 90.1 credits permanent overhangs by adjustment to *SHGC*

Size of overhang is determined by projection factor



Projection Factor Ratio



Calculating Projection Factor Ratio

Fenestration SHGC shall be determined in accordance with NFRC 200

Exceptions

- *Shading Coefficient (SC)* x 0.86 is acceptable for overall *fenestration* area (NFRC 300)
- *SHGC* of center-of-glass is acceptable (NFRC 300) for overall fenestration area
- *SHGC* from A8.1 for *skylights* is an acceptable alternative for determining compliance
- *SHGC* from A8.2 for *vertical fenestration* is an acceptable alternative for determining compliance

Skylights

- *SHGC* values < Table value for appropriate total *skylight* area

Exceptions

1. If *skylights*
   - Have a glazing material or diffuser with measured haze value > 90% when tested according to ASTM D1003, **and**
   - Have a *skylight* VT > 0.40, **and**
   - Have all general lighting in daylight area under *skylights* controlled by multilevel photocontrols per Section 9.4.1.1 (f)

2. Dynamic Glazing

- Minimum *SHGC* is used to demonstrate compliance
- Considered separately from other *vertical fenestration*
- Area-weighted averaging with other *vertical fenestration* that isn't *dynamic glazing* isn't allowed

Two options to comply for *vertical fenestration*:

Option 1 – Area Method

East & West fenestration areas are each less than 25% of building total

For climate zones 0 - 8

$A_W \leq (A_T)/4$ *and* $A_E \leq (A_t)/4$

Option 2 – SHGC Weighted Method

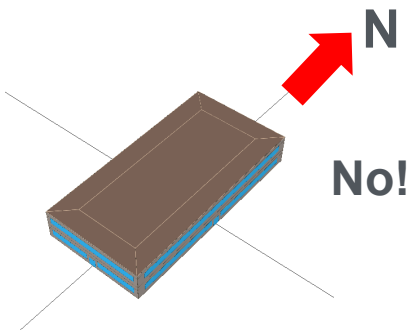
East & West area weighted SHGC is each less than average area weighted SHGC.

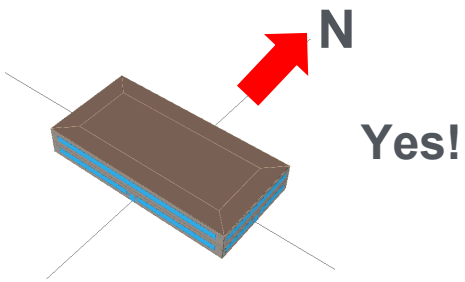
For climate zones 0 – 3

$A_W \times SHGC_W \leq (A_T \times SHGC_C)/4$ *and*
$A_E \times SHGC_E \leq (A_T \times SHGC_C)/4$

For climate zones 4 – 8

$A_W \times SHGC_W \leq (A_T \times SHGC_C)/5$ *and*
$A_E \times SHGC_E \leq (A_T \times SHGC_C)/5$





Where,
A_W and $SHGC_W$ = west-oriented *vertical fenestration area* and SHGC
A_E and $SHGC_E$ = east-oriented *vertical fenestration area* and SHGC
A_T = total *vertical fenestration area*
$SHGC_C$ = SHGC criteria in Tables 5.5-0 through 5.5-8

Exceptions

Complies with Exception 3 of Section 5.5.4.4.1
Buildings with shade on 75% of the west and east
Alterations and additions that don't increase *vertical fenestration area*
Buildings where west- and east-oriented *vertical fenestration area* < 20% of *gross wall area* for each of those facades and SHGC on those facades < 90% of $SHGC_c$
Buildings in climate zone 8

When *automatic daylighting controls* are required per 9.4.1.1 (e) or (f), *fenestration* in all climate zones shall have a VT/SHGC ratio that is no less than 1.1.

Exceptions

- Use of *light-to-solar-gain ratio* (LSG)
  - *Fenestration can have a LSG ratio of not less than 1.25 if center-of-glass SHGC and VT determined per NFRC 300 and NFRC 301 by independent lab*
- *Fenestration* not covered in scope of NFRC 200
- In enclosed spaces where:
  - *daylight area under rooftop monitors* is > 50% of *floor area and*
  - *skylights* comply with 5.5.4.2.3 and
  - *sidelighting effective aperture* is ≥ 0.15
- *Dynamic glazing*
  - *VT/SHGC* ratio and *LSG* determined using maximum *VT* and maximum *SHGC*
  - Considered separately from other *fenestration;* cannot include *dynamic glazing* with other fenestration for area-weighted averaging

Compliance Paths
Building Envelope

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Building System

- **Envelope**
- HVAC
- SWH
- Power
- Lighting
- Other

Compliance Requirements

Mandatory Provisions
(required for each compliance path)

- Prescriptive Path
- **Envelope Trade Off**
- Energy Cost Budget
- Simplified
- Performance Rating Method

- Submittal Requirements
- Information and Installation Requirements
- Verification, Testing, Inspection & Commissioning

Energy Code Compliance

Proposed design must comply with Sections 5.1, 5.4, 5.7, 5.8, and 5.9

Proposed envelope performance factor (EPF) of *proposed design* is less than or equal to the *proposed envelope performance factor* of the *base design*

- All *building envelope* components shown on drawings or installed in *existing buildings* to be included in proposed building design
- Fenestration and *opaque* envelope types and area used in simulation model to be consistent with design documents
- Don't need to separately describe any envelope assembly covering < 5% of total area of that assembly
  - as long as it's similar to an assembly being modeled
  - if not separately described, add the area of that assembly to an assembly with same orientation and thermal properties

Limitations of the Envelope Trade-off Approach

- If the building permit application applies to less than the whole building, then all parameters relating to unmodified existing conditions or future building components shall be identical when calculating the proposed EPF and base EPF.
- Any future components must meet prescriptive requirements of Section 5.5

Compliance Paths
Building Envelope

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Energy Code Compliance

Compliance documentation and supplemental information per 4.2.2

Permit Application Documentation shall include:

1. Type and rated R-value of each insulation product
2. Opaque door schedule showing U-factors
3. Fenestration schedule showing manufacturer, model number, orientation, area, U-factor, SHGC, and VT
4. air barrier details.
5. Clear labeling of space conditioning categories on permit drawings
6. Clear labeling of daylight areas on permit drawings including
   - *Primary sidelighted areas*
   - *Secondary sidelighted areas*
   - *Daylight area under skylights*
   - *Daylight areas under roof monitor*
7. Completion Requirements including record documents and Owner Manuals

Compliance Paths
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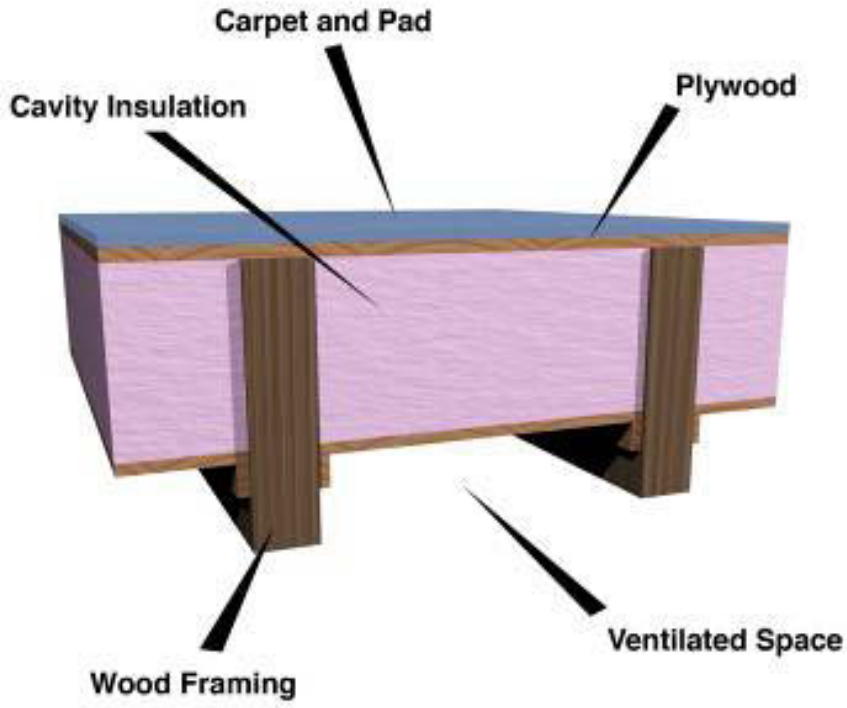
Energy Code Compliance

Building Envelope Assemblies must meet all of the information and Installation requirements in Section 5.8.

- ✓ Labeling of Building Envelope Insulation *(Section 5.8.1.1)*
- ✓ Manufacturers' Installation Instructions *(Section 5.8.1.2)*
- ✓ Loose-Fill Insulation Limitation *(Section 5.8.1.3)*
- ✓ Baffles *(Section 5.8.1.4)*
- ✓ Substantial Contact *(Section 5.8.1.5)*
- ✓ Recessed Equipment *(Section 5.8.1.6)*
- ✓ Insulation Protection *(Section 5.8.1.7)*
- ✓ Location of Roof Insulation *(Section 5.8.1.8)*
- ✓ Extent of Insulation *(Section 5.8.1.9)*
- ✓ Joints in Rigid Insulation *(Section 5.8.1.10)*
- ✓ Insulation Installation Documentation *(Section 5.8.1.11)*

Install insulation in a permanent manner in substantial contact with inside surface

Flexible batt insulation in *floor* cavities must be supported in a permanent manner by supports no more than 24 in. on center (o.c.)



Recessed *equipment* should not affect insulation thickness

- Lighting fixtures
- HVAC *equipment* (includes *wall* heaters, ducts, and plenums)
- Other

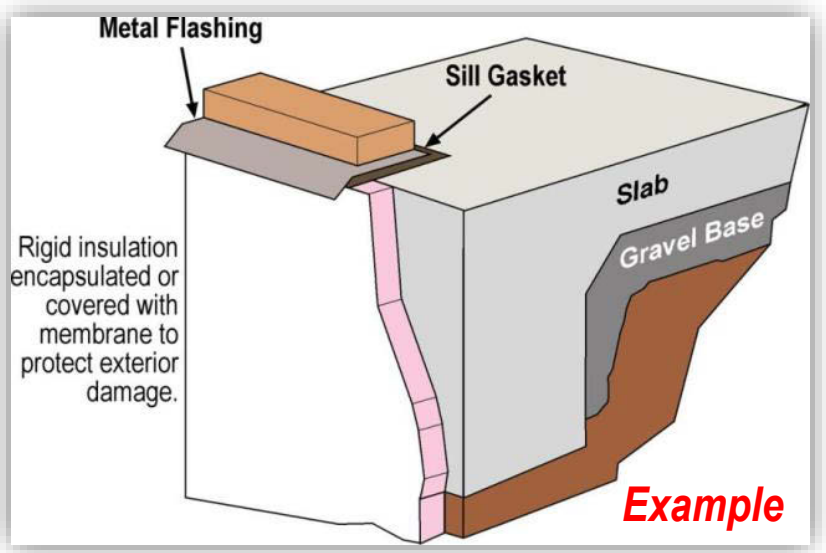
Except when

- Total combined area affected (include necessary clearances) is < 1% of *opaque* area of the assembly, **OR**
- Entire *roof, wall,* or *floor* is covered with insulation to the full depth required, **OR**
- Effects of reduced insulation are included in area-weighted calculations and compressed insulation values from Table A9.4.3

In all cases, air leakage to be limited through or around recessed *equipment* to the *conditioned space* in accordance with Section 5.4.3 (Air leakage)

Insulation Protection

- Cover exterior insulation to protect from
  - Sunlight
  - Moisture
  - Landscaping operations
  - *Equipment* maintenance
  - Wind
- Ensure access to attics and mechanical rooms without damaging or compressing insulation
- Any insulation materials in ground contact shall have a water absorption rate ≤ 0.3% *(ASTM C272)*



Roof Insulation

- Not installed on a suspended ceiling with removable ceiling panels
- Non-compliant

Section 5 – 5.8.1.9 Extent of Insulation

Insulation should extend over the full component area to the required *insulation rating R-value, U-factor, C-factor or F-factor*

Section 5 – 5.8.1.10 Joints in Rigid Insulation

Where two or more layers of rigid insulation board are used in a *construction* assembly the edge joints between each layer of boards to be staggered

Air leakage requirements for materials, assemblies, fenestration and doors is now in Section 5.8.3.1

Materials:
0.004 cfm/ft^2

Assemblies:
0.04 cfm/ft^2

Fenestration:
0.06 – 0.3 cfm/ft^2

Doors:
1.0 – 1.3 cfm/ft^2

Material air-leakage compliance – new table in Section 5.8

Table 5.8.3.1 Maximum Air Leakage for Materials and Assemblies

Continuous Air Barrier	Maximum Air Leakage, cfm/ft^2	Minimum Test Pressure, psf	Test Method
Materials [a]	0.004	1.57	ASTM E2178
Assemblies [b]	0.04	1.57	ASTM E2357, ASTM E1677, ASTM E1680, ASTM E283

The following materials meet the requirements of Table 5.8.3.1:

1. Plywood, minimum 3/8 in.
2. Oriented strand board, minimum 3/8 in.
3. Extruded polystyrene insulation board, minimum 1/2 in.
4. Foil-faced polyisocyanurate insulation board, minimum 1/2 in.
5. Exterior gypsum sheathing or interior gypsum board, minimum 1/2 in.
6. Cement board, minimum 1/2 in.
7. Built-up roofing membrane
8. Modified bituminous roof membrane
9. Single-ply roof membrane
10. A Portland cement/sand parge, stucco, or gypsum plaster, minimum 1/2 in. thick
11. Cast-in-place and precast concrete
12. Sheet metal
13. Closed-cell 2 lb/ft3 nominal density spray polyurethane foam, minimum 1 in.

Assembly air-leakage compliance – new table in Section 5.8

Table 5.8.3.1 Maximum Air Leakage for Materials and Assemblies

Continuous Air Barrier	Maximum Air Leakage, cfm/ft^2	Minimum Test Pressure, psf	Test Method
Materials [a]	0.004	1.57	ASTM E2178
Assemblies [b]	0.04	1.57	ASTM E2357, ASTM E1677, ASTM E1680, ASTM E283

The following assemblies meet the requirements of Table 5.8.3.1:

- Fully grouted concrete masonry walls
- Concrete masonry walls painted to fill the pores
- Shale or clay masonry units assembled as a solid wall (without weeps, with nominal width of 4in. or more, and with Type S mortar)

Table 5.8.3.2 Maximum Air Leakage for *Fenestration* and *Doors*

Fenestration and *Door* Products	Maximum Air Leakage, cfm/ft^2	Minimum Test Pressure, psf	Test Methods
Glazed swinging *entrance doors*, glazed power-operating sliding *entrance doors*, glazed power-operated folding *entrance doors*, and revolving *doors*	1.0	1.57	AAMA/WDMA/CSA 101/I.S.2/A440, NFRC 400, or ASTM E283;
Curtainwall and storefront glazing	0.06	1.57	NRFC 400 or ASTM 283
Unit *skylights* having condensation weepage openings	0.3	1.57	AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400
	OR		
	0.5	6.24	AAMA/WDMA/CSA 101/I.S.2/A440
Nonswinging doors intended for vehicular access and material transportation, with a minimum opening rate of 32 in./s	1.3	1.57	ANSI/DASMA 105, NFRC 400, or ASTM E283
Other *opaque nonswinging doors*, glazed *sectional garage doors*, and upward acting glazed *nonswinging*	0.4	1.57	ANSI/DASMA 105, NFRC 400, or ASTM E283
All other products	0.2	1.57	AAMA/WDMA/CSA 101/I.S.2/A440 or NFRC 400
	OR		
	0.3	6.24	AAMA/WDMA/CSA 101/I.S.2/A440

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Mandatory Provisions
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- Performance Rating Method

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- Information and Installation Requirements
- **Verification, Testing, Inspection & Commissioning**

Energy Code Compliance

Verification of:

- Building envelope performance
- Design and installation of continuous air barrier
  1. Design review to assess compliance with Sections 5.4.3 and 5.8.3.2
  2. Periodic field inspection during construction to view assemblies while still accessible, confirm *repairs* and verify compliance with Sections 5.4.1.2 and 5.8.3
  3. Reporting in compliance with Section 4.2.5.1.2

Commissioning

- Energy performance of building envelope

Required Inspections:

- *Fenestration* and *doors*
  - Air leakage testing conducted by independent third party, when applicable
  - Operation of *door* and operating mechanism for conformance with the *manufacturer's* instructions
  - Seals or gaskets installed per *manufacturer's* instructions
- Loading dock weatherseals to ensure proper installation and condition

Opaque building envelope air tightness

- *Opaque roof, above-grade walls*, and *below-grade walls*, and *floors* subject to the following inspections:
  - Use of compliant materials and assemblies per Section 5.8.3.1
  - Integration with adjoining *fenestration* and *continuous air barrier* elements

Fenestration Commissioning items

- Skylights size and location in relation to designed *primary sidelighted area* and *secondary lighted area* below
- *Roof monitor* size and location in relation to designed *primary sidelighted area* and *secondary lighted area* below
- *Dynamic glazing* with *SHGC* and *U-factor* per Section 5.5.4.4.1 and 5.5.4.4.2 and testing of the operation of conformance per *manufacturer's* instructions
- Permanent *fenestration* projections installation and performance per Section 5.5.4.4.1 and *construction documents*

Referenced 5.9 testing and commissioning refers to 4.2.5
New in 2019: Central FPT & Commissioning requirements

4.2.5.2 Commissioning & 90.1 compliance verification	• 4.2.5.2.1 Cx Plan • 4.2.5.2.2 Cx Reporting • Any added Cx: 5.9.2 thru 10.9.2
4.2.5.1 Verification & Testing (FPT)	• 4.2.5.1.1 V&T providers • FPT provision in Const. Docs • 4.2.5.1.2 V&T Documentation
Verification & Functional Performance Testing Details	• Specific for each discipline/path • 5.9.1, 6.9.1, 7.9.1, 8.9.1, • 9.9.1, 10.9.1, 11.2(d), G1.21(c)

Referenced 5.9 testing and commissioning refers to 4.2.5

4.2.5 Verification, Testing, and Commissioning

4.2.5.1 Verification and Testing (V&T)

- V&T provider qualifications
- V&T requirements in construction documents
- Functional Performance Testing (FPT) & Verification Documentation

4.2.5.2 Commissioning (Cx) (unless Excepted)

- Cx provider qualifications
- Cx plan, design review, requirements in construction documents
- Preliminary and Final Cx report includes FPT & verification

Where to FPT & Cx requirements apply

	Simple buildings (<10k conditioned ft², warehouse, or Simple HVAC path < 25k ft²)	Complex Buildings < 25,000 ft²	All Buildings ≥ 50,000 ft² Except Warehouse
Verification, FPT	Required	Required	Required
Pre- & Design phase Cx	NR	Required	Required
Construction Phase Cx	NR	Required	Required

- 80% of US buildings are exempt from commissioning requirements
- Verification and functional performance testing (FPT) required throughout
- Pre- & design-phase Cx saves energy and cost by catching issues early
- 90.1 Cx requirements only apply to 90.1 standard requirements
- Verification that the design substantially meets 90.1 included