Low Slope Roofing Systems
The University of Wisconsin Madison
Madison, Wisconsin – December 2-3, 2025

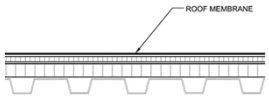
Roof insulation

presented by

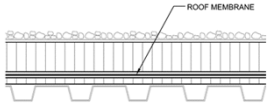
Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association
Rosemont, Illinois

1

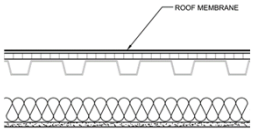
Roof assembly configurations



Conventional
Insulation above deck



Protected membrane
Insulation above membrane



Attic (or "other")
Insulation below deck

2

2

Purpose(s) for insulation

Low-slope roof systems

- Thermal performance
- Condensation control
- Smooth substrate
- Deck stability
  - Reduce temperature variations
  - Control thermal expansion and contraction
- Fire resistance
- Roof slope
  - Above-deck tapered insulation

3

3

Principles of thermal insulation

British thermal unit (Btu): the energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit (F).

4

4

Principles of thermal insulation

Thermal conductivity (k): the amount of heat is transmitted by conduction through 1 square foot of 1-inch-thick homogenous material in 1 hour where there is a difference of 1 degree Fahrenheit (F) across the two surfaces of the material.

$$k = Btu \bullet inch / ft^2 \bullet hr \bullet F$$

5

5

Principles of thermal insulation

Thermal conductance (C): the amount of heat is transmitted by conduction through 1 square foot of a specified thickness of material in 1 hour where there is a difference of 1 degree Fahrenheit (F) across the two surfaces of the material.

$$C = Btu / ft^2 \bullet hr \bullet F$$

6

6

Principles of thermal insulation

Thermal transmittance (U): the amount of heat is transmitted by conduction through 1 square foot of an assembly and its boundary layers in 1 hour where there is a difference of 1 degree Fahrenheit (F) across the two surfaces of the assembly.

$$U = Btu / ft^2 \bullet hr \bullet F$$

7

7

R-values of boundary layer air films

Applicable to the inside and outside surfaces of assemblies

Surface	Condition	Resistance
Outside air film (f_o)	15 mph wind (winter) 7.5 mph wind (summer)	0.17 °F•ft²•h/Btu 0.25 °F•ft²•h/Btu
Inside air film (f_i)	Still air—horizontal surface[3] Heat flow upward (winter) Heat flow downward (summer)	 0.61 °F•ft²•h/Btu 0.92 °F•ft²•h/Btu

1. Values derived from Table 1, *2001 ASHRAE Handbook—Fundamentals*, page 25.4.
2. Surface air films exist on every surface. They are invisible layers of air that cling to the surface on a material and have some resistance to heat flow. Outside air films vary in thickness according to wind velocity; inside air films vary in effectiveness according to the direction of heat flow.
3. Inside air film values listed are for horizontal inside surfaces only. If the inside surface being evaluated is sloping or vertical, other thermal resistance values may apply; refer to Table 1, *2001 ASHRAE Handbook—Fundamentals*, page 25.4.

Figure 3-1: Thermal resistance values for air films

8

8

Principles of thermal insulation

Thermal resistance: a relative measure of a material's or an assembly's resistance to heat flow; the reciprocal of the material's thermal conductance (C) or an assembly's thermal transmittance (U).

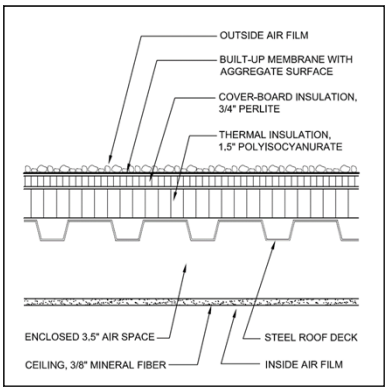
$$R = 1 / C \text{ or } R = 1 / U$$

R-values are readily additive (unlike k-values and C-values). Therefore $R_T = R_1 + R_2 + R_3 = \ldots$

9

9

R-value calculations



Component	Heating Condition R-value	Cooling Condition R-value
Outside air film	0.17	0.25
Built-up membrane, aggregate surfaced	0.33	0.33
Insulation cover board, ¾-inch perlite board	2.08	2.08
Primary insulation, 1½-inch polyisocyanurate	7.50	8.40
Roof deck, steel	0.00	0.00
Enclosed air space, 3½ inches	0.93	1.24
Ceiling, ¾-inch mineral fiber	1.56	1.56
Inside air film	0.61	0.92
Total (R_T):	13.18	14.78

10

10

R-values of enclosed spaces ("dead air")

Position of Air Space[3]	Condition[3]	Thickness of Air Space[4]	Thermal Resistance of Air Space[5]		
			Highly Reflective Roof Surface[6]	Moderately Reflective Roof Surface[7]	Non-Reflective Roof Surface[8]
Horizontal	Heat flow upward (winter)	0.75 inch 1.5 inches 3.5 inches	1.70°F•ft²•h/Btu 1.81°F•ft²•h/Btu 1.95°F•ft²•h/Btu	1.16°F•ft²•h/Btu 1.21°F•ft²•h/Btu 1.28°F•ft²•h/Btu	0.87°F•ft²•h/Btu 0.89°F•ft²•h/Btu 0.93°F•ft²•h/Btu
Horizontal	Heat flow downward (summer)	0.75 inch 1.5 inches 3.5 inches	2.41°F•ft²•h/Btu 3.27°F•ft²•h/Btu 4.09°F•ft²•h/Btu	1.45°F•ft²•h/Btu 1.73°F•ft²•h/Btu 1.93°F•ft²•h/Btu	1.02°F•ft²•h/Btu 1.15°F•ft²•h/Btu 1.24°F•ft²•h/Btu

1. Values derived from Tables 2 and 3, *2001 ASHRAE Handbook—Fundamentals*, pages 25.2 and 25.4.
2. Any air space where the air is not ventilated or otherwise allowed to freely move has some thermal resistance to heat flow. If the air space is ventilated or if the space is used as a plenum, the thermal resistance of the space and inside air film must be considered zero.
3. The thermal resistance values listed are for horizontal air spaces with the direction of heat flow either in an upward (winter) or downward (summer) direction. If the air space being evaluated is oriented in a sloping or vertical direction, other thermal resistance values may apply; refer to Tables 2 and 3, *2001 ASHRAE Handbook—Fundamentals*, pages 25.2 and 25.4.
4. Interpolation and moderate extrapolation for air spaces other than those listed is permissible.
5. Thermal resistance values based on 50 F mean temperature and 10 F temperature difference.
6. Values based on an Effective Emittance (ϵ_{eff}) of 0.20 with one surface with a reflectivity of 75-84 percent and the other surface with ϵ=0.90 (e.g., foil-surfaced modified bitumen membrane, mill finish aluminum panels).
7. Values based on an ϵ_{eff} of 0.50 with one surface with a reflectivity of 30-70 percent and the other surface with ϵ=0.90 (e.g., white membranes, smooth-surfaced membrane with a reflective coating).
8. Values based on an ϵ_{eff} of 0.82 with surfaces with a reflectivity of 5-15 percent (e.g., most aggregate-surfaced roofs, smooth-surfaced built-up roofs).

Figure 3-2: Thermal resistance values for enclosed air spaces

11

11

Desirable properties for roof insulation

- Attachment capability
- Compatible with adhesives
- Compatible with other roof assembly components
- Compressive strength
- Dimensionally stable
- Fire resistant
- Impact resistance
- Moisture resistant
- Thermal resistant (low k-value or C-value/high R-value)
- Thermal resistance stability

12

12

So, what is the "ideal" roof insulation?

There is no "ideal" roof insulation…

roof insulation selection and use is a compromise

13

13

Roof insulation types

Rigid board insulation

- Cellular glass
- Expanded polystyrene (EPS)
- Extruded polystyrene (XPS)
- Faced gypsum
- Fiber-reinforced gypsum
- Mineral fiber (stone wool)
- Perlite
- Polyisocyanurate
- High-density polyisocyanurate
- Wood fiberboard
- Vacuum insulated panels

14

14

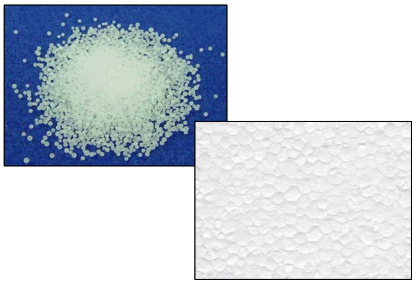
Cellular glass

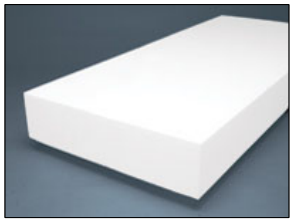
- Crushed glass and hydrogen sulfide gas heated to 950 F
- ASTM C552, Type IV
- 12” x 18”, 18” x 24” and 2’ x 4’
- 1½” to 6” and tapered
- R = 3.44 per inch

15

15

Expanded polystyrene (EPS)





- Polystyrene polymer, foaming agent and heat
- ASTM C578 (many types)
- 4’ x 4’ and 4’ and 8’
- ⅜” to 24”and tapered
- R = 3.1 to 4.3 per inch based upon density

16

16

EPS types

ASTM C578, Type __

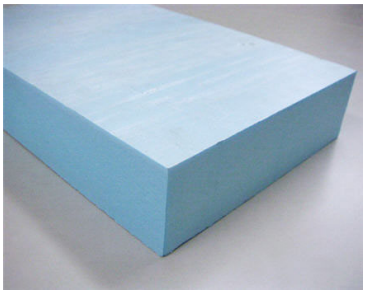
EPS type	Density, min. (pounds per cubic foot)	Compressive strength, min. (psi)	R-value
Type I*	0.90 (1.0 nominal)	10.0	3.6
Type II	1.35 (1.5 nominal)	15.0	4.0
Type VIII	1.15 (1.25 nominal)	13.0	3.8
Type IX	1.80 (2.0 nominal)	25.0	4.2
Type XI*	0.70 (0.75 nominal)	5.0	3.1
Type XIV	2.40 (2.5 nominal)	40.0	4.2
Type XV	2.85 (3.0 nominal)	60.0	4.3

* Type I and Type XI are generally not intended to be used in roofing applications

17

17

Extruded polystyrene (XPS)



- Polystyrene polymer is heated and extruded
- ASTM C578 (many types)
- 2’ x 4’ and 2’ x 8’
- 1”, 1½”, 2”, 2½”, 3” & 4”
- R = 4.6 to 5.0 per inch

18

18

XPS types

ASTM C578, Type __

XPS type	Density, min. (pounds per cubic foot)	Compressive strength, min. (psi)	R-value
Type IV	1.45	25.0	5.0
Type V	3.00	100.0	5.0
Type VI	1.80	40.0	5.0
Type VII	2.20	60.0	5.0
Type X	1.30	15.0	5.0
Type XII*	1.20	15.0	4.6
Type XIII*	1.60	20.0	3.9

* Type XII and Type XIII are generally not intended to be used in roofing applications

19

19

Faced gypsum

- Gypsum core between paper or fiberglass-mat facers
- ASTM C1396 (paper)
- ASTM C1177 (glass-mat)
- 4’ x 4’ and 4’ x 8’
- ¼”, ½” and ⅝” thick
- R = 1.12 per inch

20

20

Fiber-reinforced gypsum

- Cellulose-fiber reinforced gypsum
- ASTM C1278
- 4’ x 4’ and 4’ x 8’
- ¼”, ⅜”, ½” and ⅝” thick
- R = 1.0 per inch

21

21

Mineral fiber (stone wool)

- Rock, slag or glass heated and spun into fibers with a binding agent
- ASTM C726 or ASTM C612
- 4’ x 4’
- Up to 6” thick
- R = 4 per inch (10 pcf density)

22

22

Perlite

- Expanded volcanic minerals, organic fibers and binders
- ASTM C728 (various types)
- 2’ x 4’ and 4’ x 4’
- ½”, ¾”, 1”, 1½”, 2” and tapered
- R = 2.78 per inch

23

23

Perlite types

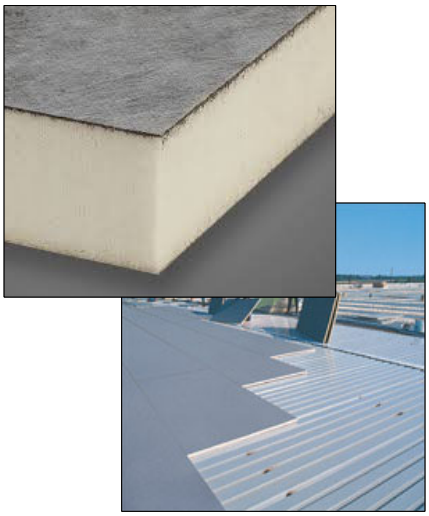
ASTM C728, Type __

- Type 1: Roof insulation board
- Type 2: Recover board
- Type 3: Recover board (higher physical properties)

24

24

Polyisocyanurate



- Polyisocyanurate foam and facers
- ASTM C1289 (multiple types, grades and classes)
- 4’ x 4’ and 4’ x 8’
- Thicknesses range from 1” to 4”
- R = 5.0-6.0 per inch
- LTTR = 5.6 to 5.9 per inch

25

25

Polyiso. type, grades and classes

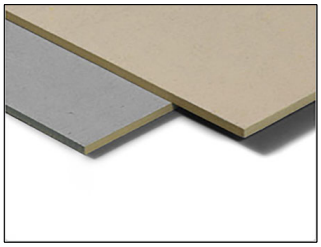
ASTM C1289, Type II, Class __, Grade __

- Type II:
  - Class 1: organic/glass facer:
    - Grade 1: 16 psi (min.) compressive strength
    - Grade 2: 20 psi (min.) compressive strength
    - Grade 3: 25 psi (min.) compressive strength
  - Class 2: coated glass facer
  - Class 3: uncoated glass facer

26

26

High density polyisocyanurate



- Polyisocyanurate foam and facers
- ASTM C1289, Type II, Class 4 (multiple grades)
- 4’ x 4’ and 4’ x 8’
- ¼” and ½” thick
- R = 1.0 for ¼” thick
  R = 2.0 for ½” thick

27

27

HD polyiso. type, class and grades

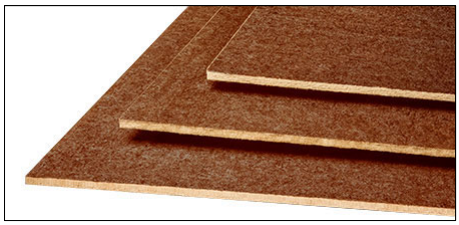
ASTM C1289, Type III, Class 4, Grade __

- Type II:
  - Class 4: coated or uncoated glass mats:
    - Grade 1: 80 psi (min.) compressive strength
    - Grade 2: 110 psi (min.) compressive strength
    - Grade 3: 140 psi (min.) compressive strength

28

28

Wood fiberboard



- Wood or cane fibers and binders; may be coated
- ASTM C208, Type II (two grades)
- 2’ x 4’, 4’ x 4’ and 4’ x 8’
- ½”, 1” and 2’ thick
- R = 2.78 per inch

29

29

Wood fiberboard grades

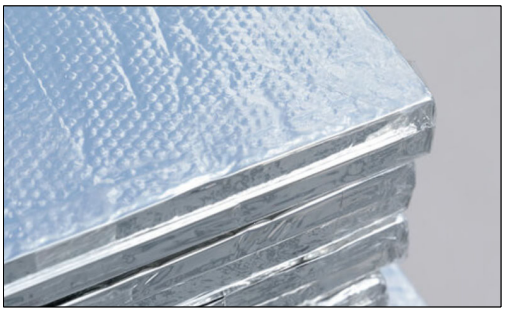
ASTM C208, Type II, Grade __

- ASTM C208, Type II:
  - Grade 1: For BUR and MB systems
  - Grade 2: For single-ply systems

30

30

Vacuum insulated panels



- Microporous core, which is evacuated, encased and sealed in a thin, gas–tight, foil envelope
- ASTM C1484
- 2’ x 2’ and 2’ x 4’
- ¾- to about 2-inch thick
- R=28 per inch
- Cannot be cut or penetrated

31

In-fill insulation

Vacuum insulated panels

Link to installation video

32

Composite boards

- EPS and plywood/OSB
- Polyiso. and perlite, wood fiberboard, plywood/OSB or glass-mat-faced gypsum

33

33

Board joints

Heat loss through gaps at the joints between insulation boards can represent up to a 10% reduction in effective R-value

A two-layer application rigid board insulation with staggered and offset board joints is recommended

34

34

Mechanical fasteners

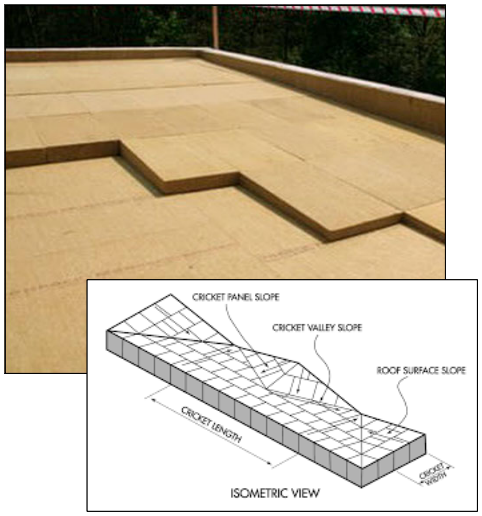
Mechanical fasteners through the cross-section of rigid board insulation can represent 3% to 8% losses in effective R-values.

Mechanically-attach the bottommost layer and adhere subsequent layers is preferred.

35

35

Tapered roof insulation



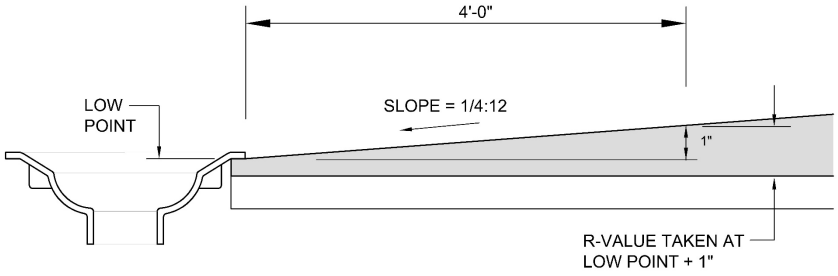
- Common materials:
  - EPS
  - XPS
  - Perlite
  - Polyisocyanurate
- Common slopes:
  - ⅛” per foot
  - ¼” per foot
  - ½” per foot

36

36

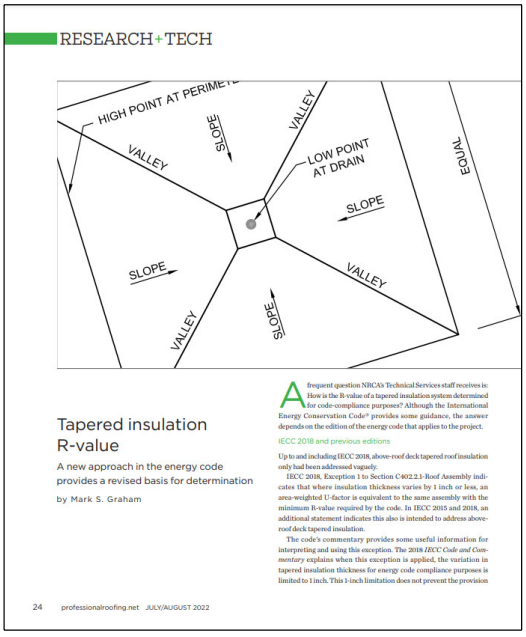
What is the R-value of tapered insulation…?

IBC 2018 and previous editions, Sec. C402.2-Roof Assembly , Exception 1 allows a 1-inch insulation thickness variation



37

37


RESEARCH+TECH

HIGH POINT AT PERIMETER
VALLEY
SLOPE
VALLEY
LOW POINT AT DRAIN
SLOPE
SLOPE
VALLEY
VALLEY
SLOPE
EQUAL

Tapered insulation R-value

A new approach in the energy code provides a revised basis for determination

by Mark S. Graham

A frequent question NRCA's Technical Services staff receives is: How is the R-value of a tapered insulation system determined for code-compliance purposes? Although the International Energy Conservation Code® provides some guidance, the answer depends on the edition of the energy code that applies to the project.

IECC 2018 and previous editions

Up to and including IECC 2018, above-roof deck tapered roof insulation only had been addressed vaguely.

IECC 2018, Exception 1 to Section C402.2.1-Roof Assembly indicates that where insulation thickness varies by 1 inch or less, an area-weighted U-factor is equivalent to the same assembly with the minimum R-value required by the code. In IECC 2015 and 2018, an additional statement indicates this also is intended to address above-roof deck tapered insulation.

The code's commentary provides some useful information for interpreting and using this exception. The 2018 *IECC Code and Commentary* explains when this exception is applied, the variation in tapered insulation thickness for energy code compliance purposes is limited to 1 inch. This 1-inch limitation does not prevent the provision

24 professionalroofing.net JULY/AUGUST 2022

Tapered insulation R-value

Professional Roofing, July/August 2022

Link

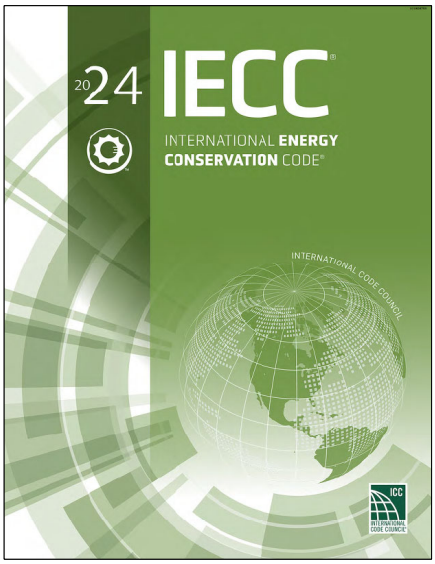
Link to article applicable IECC 2018 and previous editions

38

How much/what thickness of insulation is needed?

- Roof assembly's fire classification (Building Code)
- Energy Code's requirements

39

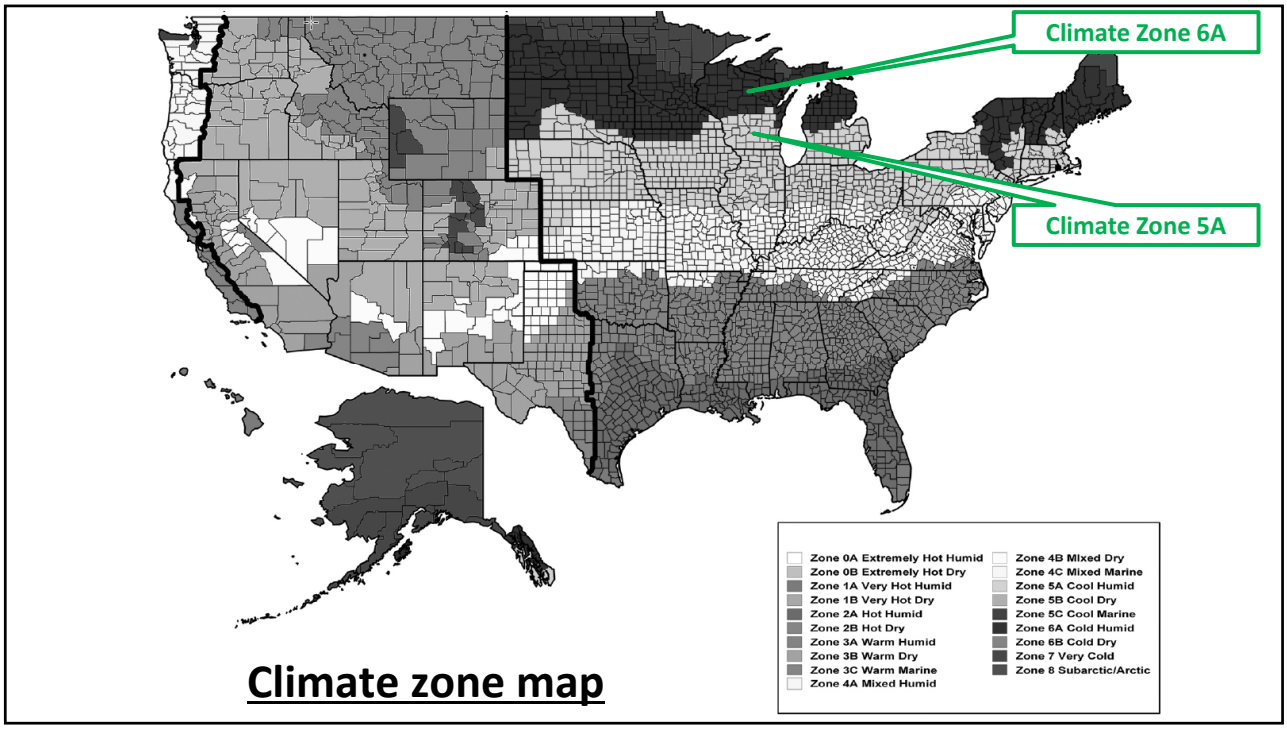


Roof requirements:

- Thermal efficiency
  - Multiple compliance paths
- Roof reflectivity (Commercial only)
- Air leakage
  - Multiple compliance paths

Separate requirements for Commercial (C) and Residential (R) buildings

40



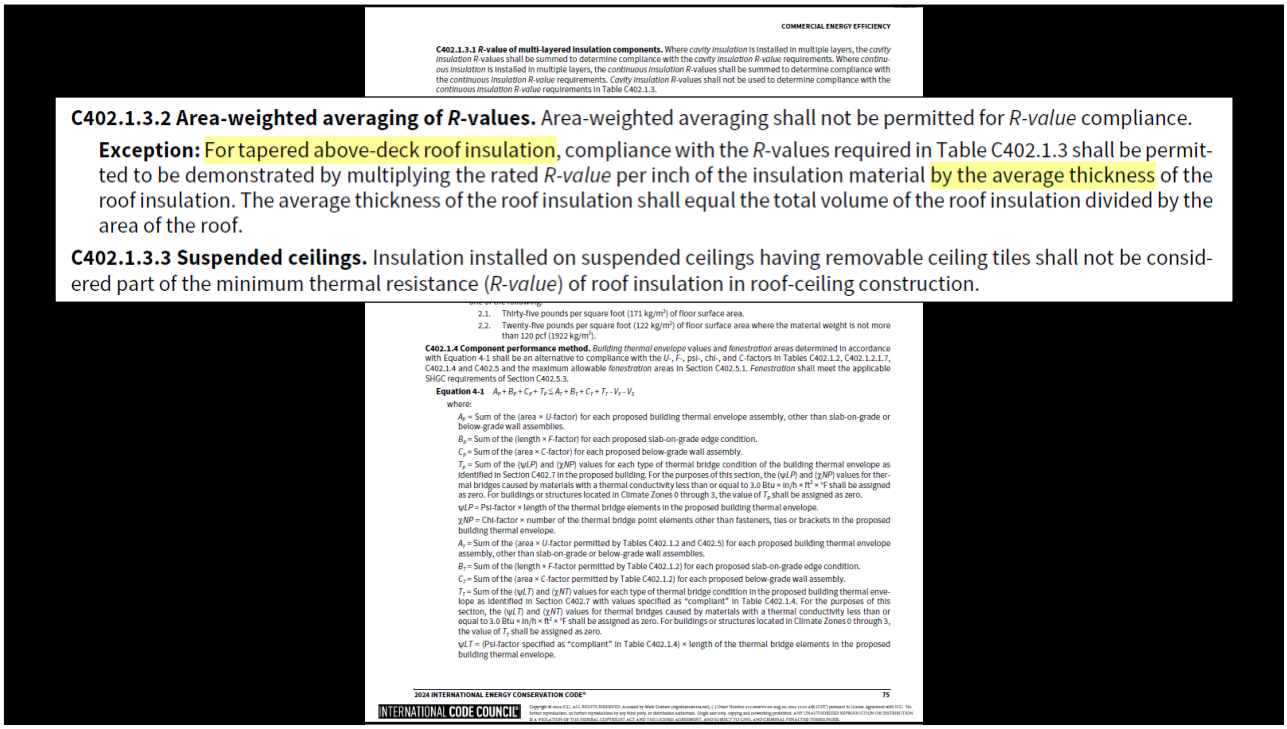
Climate zone map

41

TABLE C402.1.3—OPAQUE BUILDING THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
Roofs																
Insulation entirely above roof deck	R-20ci	R-25ci	R-25ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-35ci	R-35ci	R-35ci	R-35ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-25 + R-11 + R-11 LS	R-25 + R-11 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49	R-49	R-49	R-49	R-60	R-60	R-60	R-60
Metal framed	R-5ci or R-20 + R-3.8ci	R-5ci or R-20 + R-3.8ci	R-5ci or R-20 + R-3.8ci	R-7.5ci or R-20 + R-6.3ci	R-7.5ci or R-20 + R-6.3ci	R-7.5ci or R-20 + R-6.3ci	R-7.5ci or R-20 + R-6.3ci	R-10ci or R-20 + R-9ci	R-10ci or R-20 + R-9ci	R-12.5ci or R-20 + R-11ci	R-12.5ci or R-20 + R-11ci	R-12.5ci or R-20 + R-11ci	R-15.6ci or R-20 + R-14.3ci	R-18.8ci or R-20 + R-17.5ci	R-18.8ci or R-20 + R-17.5ci	
Wood framed and other[h,i]	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-12ci or R-13 + R-3.8ci or R-20	R-0 + R-16ci or R-13 + R-7.5ci or R20 + R3.8ci or R-27	R-0 + R-16ci or R-13 + R-7.5ci or R-20 + R-3.8ci or R-27	R-0 + R-16ci or R-13 + R-7.5ci or R-20 + R-3.8ci or R-27	R-0 + R-16ci or R-13 + R-7.5ci or R-20 + R-3.8ci or R-27	R-0 + R-16ci or R-13 + R-7.5ci or R-20 + R-3.8ci or R-27	R-0 + R-16ci or R-13 + R-7.5ci or R-20 + R-3.8ci or R-27	R-0 + R-27.5ci or R-13 + R-18.8ci or R-20 + R-14ci	R-0 + R-27.5ci or R-13 + R-18.8ci or R-20 + R-14ci
Walls, below grade																
Below-grade wall[f]	NR	NR	NR	NR	NR	NR	R-7.5ci	R-10ci	R-7.5ci	R-10ci	R-10ci	R-15ci	R-15ci	R-15ci	R-15ci	R-15ci
Floors																
Mass[e]	NR	NR	R-6.3ci	R-8.3ci	R-10ci	R-10ci	R-14.6ci	R-16.7ci	R-14.6ci	R-16.7ci	R-16.7ci	R-16.7ci	R-20.9ci	R-20.9ci	R-23ci	R-23ci
Joist/framing	R-13	R-13	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-38	R-38	R-38	R-38	R-38	R-38
Slab-on-grade floors																
Unheated slabs	NR	NR	NR	NR	NR	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-20 for 24" below	R-20 for 24" below	R-20 for 48" below	R-20 for 24" below	R-20 for 48" below	R-20 for 48" below	R-25 for 48" below
Heated slabs[g]	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-7.5 for 12" below + R-5 full slab	R-10 for 24" below + R-5 full slab	R-10 for 24" below + R-5 full slab	R-15 for 24" below + R-5 full slab	R-15 for 24" below + R-5 full slab	R-15 for 36" below + R-5 full slab	R-15 for 36" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab	R-20 for 48" below + R-5 full slab

42



COMMERCIAL ENERGY EFFICIENCY

C402.1.3.1 *R*-value of multi-layered insulation components. Where *cavity insulation* is installed in multiple layers, the *cavity insulation R-values* shall be summed to determine compliance with the *cavity insulation R-value* requirements. Where *continuous insulation* is installed in multiple layers, the *continuous insulation R-values* shall be summed to determine compliance with the *continuous insulation R-value* requirements. *Cavity insulation R-values* shall not be used to determine compliance with the *continuous insulation R-value* requirements in Table C402.1.3.

C402.1.3.2 Area-weighted averaging of *R*-values. Area-weighted averaging shall not be permitted for *R-value* compliance.

Exception: For tapered above-deck roof insulation, compliance with the *R*-values required in Table C402.1.3 shall be permitted to be demonstrated by multiplying the rated *R-value* per inch of the insulation material by the average thickness of the roof insulation. The average thickness of the roof insulation shall equal the total volume of the roof insulation divided by the area of the roof.

C402.1.3.3 Suspended ceilings. Insulation installed on suspended ceilings having removable ceiling tiles shall not be considered part of the minimum thermal resistance (*R-value*) of roof insulation in roof-ceiling construction.

2.1. Thirty-five pounds per square foot (171 kg/m²) of floor surface area.
2.2. Twenty-five pounds per square foot (122 kg/m²) of floor surface area where the material weight is not more than 120 pcf (1922 kg/m³).

C402.1.4 Component performance method. *Building thermal envelope* values and *fenestration* areas determined in accordance with Equation 4-1 shall be an alternative to compliance with the *U*-, *F*-, psi-, chi-, and *C*-factors in Tables C402.1.2, C402.1.2.1.7, C402.1.4 and C402.5 and the maximum allowable *fenestration* areas in Section C402.5.1. *Fenestration* shall meet the applicable SHGC requirements of Section C402.5.3.

Equation 4-1 $A_P + B_P + C_P + T_P \le A_T + B_T + C_T + T_T - V_T - V_S$

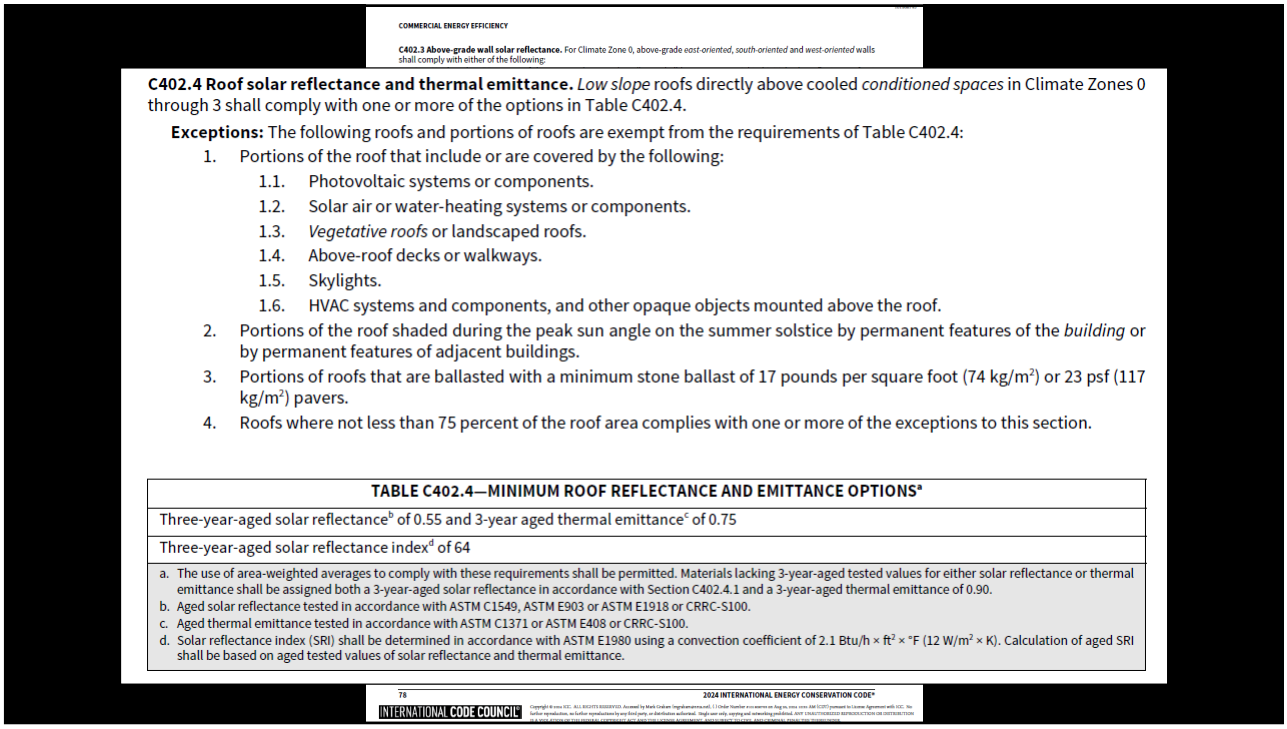
where:

A_P = Sum of the (area × *U*-factor) for each proposed building thermal envelope assembly, other than slab-on-grade or below-grade wall assemblies.
B_P = Sum of the (length × *F*-factor) for each proposed slab-on-grade edge condition.
C_P = Sum of the (area × *C*-factor) for each proposed below-grade wall assembly.
T_P = Sum of the (ψLP) and (χNP) values for each type of thermal bridge condition of the building thermal envelope as identified in Section C402.7 in the proposed building. For the purposes of this section, the (ψLP) and (χNP) values for thermal bridges caused by materials with a thermal conductivity less than or equal to 3.0 Btu × in/h × ft² × °F shall be assigned as zero. For buildings or structures located in Climate Zones 0 through 3, the value of T_P shall be assigned as zero.
ψLP = Psi-factor × length of the thermal bridge elements in the proposed building thermal envelope.
χNP = Chi-factor × number of the thermal bridge point elements other than fasteners, ties or brackets in the proposed building thermal envelope.
A_T = Sum of the (area × *U*-factor permitted by Tables C402.1.2 and C402.5) for each proposed building thermal envelope assembly, other than slab-on-grade or below-grade wall assemblies.
B_T = Sum of the (length × *F*-factor permitted by Table C402.1.2) for each proposed slab-on-grade edge condition.
C_T = Sum of the (area × *C*-factor permitted by Table C402.1.2) for each proposed below-grade wall assembly.
T_T = Sum of the (ψLT) and (χNT) values for each type of thermal bridge condition in the proposed building thermal envelope as identified in Section C402.7 with values specified as "compliant" in Table C402.1.4. For the purposes of this section, the (ψLT) and (χNT) values for thermal bridges caused by materials with a thermal conductivity less than or equal to 3.0 Btu × in/h × ft² × °F shall be assigned as zero. For buildings or structures located in Climate Zones 0 through 3, the value of T_T shall be assigned as zero.
ψLT = (Psi-factor specified as "compliant" in Table C402.1.4) × length of the thermal bridge elements in the proposed building thermal envelope.

2024 INTERNATIONAL ENERGY CONSERVATION CODE® 75

INTERNATIONAL CODE COUNCIL

43



COMMERCIAL ENERGY EFFICIENCY

C402.3 Above-grade wall solar reflectance. For Climate Zone 0, above-grade *east-oriented*, *south-oriented* and *west-oriented* walls shall comply with either of the following:

C402.4 Roof solar reflectance and thermal emittance. *Low slope* roofs directly above cooled *conditioned spaces* in Climate Zones 0 through 3 shall comply with one or more of the options in Table C402.4.

Exceptions: The following roofs and portions of roofs are exempt from the requirements of Table C402.4:

1. Portions of the roof that include or are covered by the following:
   1.1. Photovoltaic systems or components.
   1.2. Solar air or water-heating systems or components.
   1.3. *Vegetative roofs* or landscaped roofs.
   1.4. Above-roof decks or walkways.
   1.5. Skylights.
   1.6. HVAC systems and components, and other opaque objects mounted above the roof.
2. Portions of the roof shaded during the peak sun angle on the summer solstice by permanent features of the *building* or by permanent features of adjacent buildings.
3. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot (74 kg/m²) or 23 psf (117 kg/m²) pavers.
4. Roofs where not less than 75 percent of the roof area complies with one or more of the exceptions to this section.

TABLE C402.4—MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS[a]

Three-year-aged solar reflectance[b] of 0.55 and 3-year aged thermal emittance[c] of 0.75
Three-year-aged solar reflectance index[d] of 64

a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for either solar reflectance or thermal emittance shall be assigned both a 3-year-aged solar reflectance in accordance with Section C402.4.1 and a 3-year-aged thermal emittance of 0.90.
b. Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-S100.
c. Aged thermal emittance tested in accordance with ASTM C1371 or ASTM E408 or CRRC-S100.
d. Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h × ft² × °F (12 W/m² × K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.

78 2024 INTERNATIONAL ENERGY CONSERVATION CODE®

INTERNATIONAL CODE COUNCIL

44

Definitions

Solar reflectance: The fraction of solar flux reflected by a surface expressed within the range of 0.00 and 1.00.

Thermal emittance: The ratio of radiant heat flux emitted by a surface to that emitted by a black body radiator at the same temperature expressed within a range of 0.00 to 1.00.

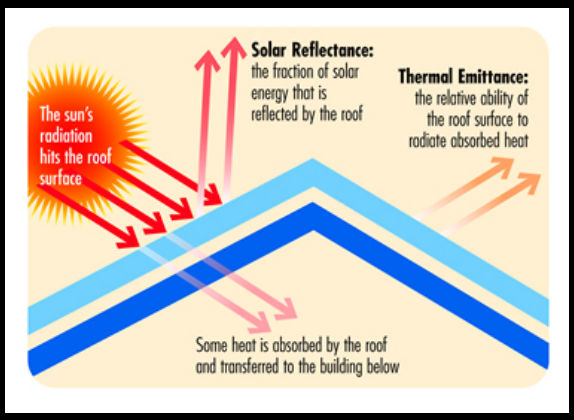
45

Definitions – cont.

Solar reflectance index (SRI): The relative steady-state surface temperature of a surface with respect to the standard white (SRI = 100) and standard black (SRI = 0) under standard solar and ambient conditions.

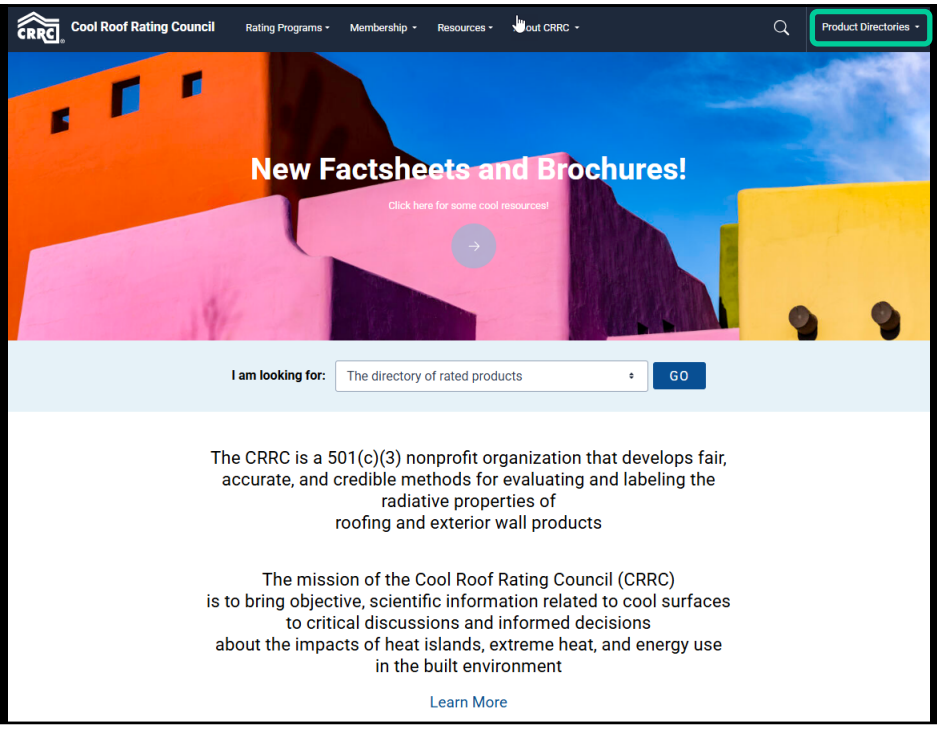
--ASTM E 1980

46

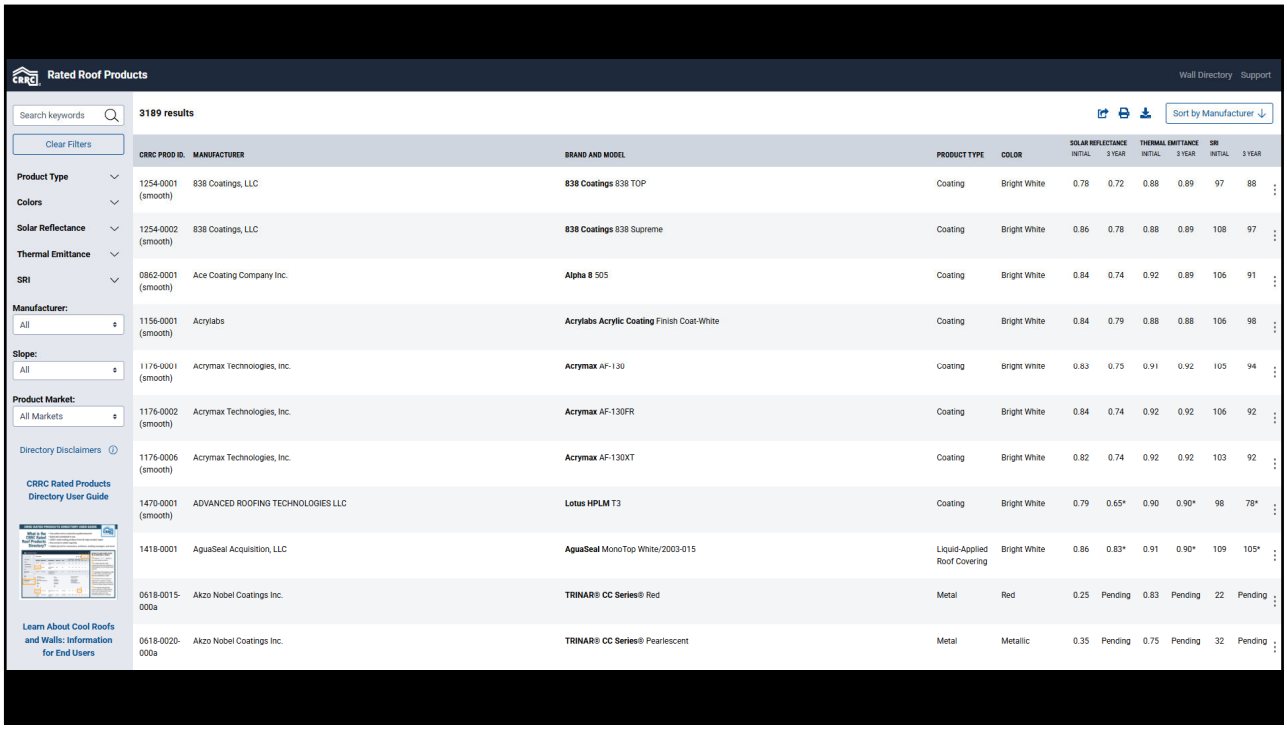


Courtesy of the Cool Roofs Rating Council

47



48



49

The Energy Code seems to be getting incrementally more stringent with each edition

50

R-value comparison of IECC's various editions

Commercial Buildings (Above-deck insulation)

Climate Zone	IECC 2003	IECC 2006	IECC 2009	IECC 2012*	IECC 2015*	IECC 2018*	IECC 2021*
1	R-12 ci	R-15 ci	R-15 ci	R-20 ci	R-20 ci	R-20 ci	R-20 ci
2	R-14 ci		R-20 ci		R-25 ci	R-25 ci	R-25 ci
3	R-10 ci						
4	R-12 ci			R-25 ci	R-30 ci	R-30 ci	R-30 ci
5	R-15 ci	R-20 ci					
6	R-11 ci						
7	R-15 ci	R-25 ci	R-25 ci	R-30 ci	R-35 ci	R-35 ci	R-35 ci
8							

* Applies to roof replacement projects
ci = continuous insulation

51

Questions

Roof insulation

52

52

Mark S. Graham
Vice President, Technical Services
National Roofing Contractors Association
Two Pierce Place, Suite 1200
Itasca, Illinois 60143

(847) 299-9070
mgraham@nrca.net
www.nrca.net

Personal website: www.MarkGrahamNRCA.com
LinkedIn: linkedin.com/in/MarkGrahamNRCA

53