CEPI-63-21 Part II

IECC®: R402.4.1.2

Proponents:

Lisa Rosenow, representing Self (lrosenow@evergreen-tech.net); Kevin Rose, representing Northwest Energy Efficiency Alliance (NEEA) (krose@neea.org)

2021 International Energy Conservation Code

Revise as follows:
R402.4.1.2 Testing.

The *building* or *dwelling unit* shall be tested for air leakage. The maximum air leakage rate for any *building* or *dwelling unit* under any compliance path shall not exceed 5.0 air changes per hour or 0.28 cubic feet per minute (CFM) per square foot [0.0079 $m^3/(s \times m^2)$] of dwelling unit enclosure area. Testing shall be conducted in accordance with ANSI/RESNET/ICC 380, ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). Where required by the *code official*, testing shall be conducted by an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope* have been sealed.

Exception: For heated, attached private garages and heated, detached private garages accessory to one- and two-family dwellings and townhouses not more than three stories above *grade plane* in height, building envelope tightness and insulation installation shall be considered acceptable where the items in Table R402.4.1.1, applicable to the method of construction, are field verified. Where required by the code official, an *approved* third party independent from the installer shall inspect both air barrier and insulation installation criteria. Heated, attached private garage space and heated, detached private garage space shall be thermally isolated from all other habitable, *conditioned spaces* in accordance with Sections R402.2.12 and R402.3.5, as applicable.

During testing:

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures.
2. Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures.
3. Interior doors, where installed at the time of the test, shall be open.
4. Exterior or interior terminations for continuous ventilation systems shall be sealed.
5. Heating and cooling systems, where installed at the time of the test, shall be turned off.
6. Supply and return registers, where installed at the time of the test, shall be fully open.

~~Exception~~ Exceptions:

1. When testing individual *dwelling units*, an air leakage rate not exceeding 0.30 cubic feet per minute per square foot [0.008 $m^3/(s \times m^2)$] of the dwelling unit enclosure area, tested in accordance with ANSI/RESNET/ICC 380, ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pa), shall be permitted in all climate zones for:

   ~~1~~ 1.1. Attached single-family and multiple-family building *dwelling units*.

~~2~~ 1.2. Buildings or *dwelling units* that are 1,500 square feet ($139.4\ m^2$) or smaller.
2. Multiple family buildings with dwelling units accessed directly from the outdoors, that comply with Section C402.5.3

Mechanical ventilation shall be provided in accordance with Section M1505 of the *International Residential Code* or Section 403.3.2 of the *International Mechanical Code*, as applicable, or with other *approved* means of ventilation.

Reason Statement:

Purpose of proposed changes is to clarify code intent.

In Section C402.5.1.2, compliance options are reorganized so the compliance option that applies to most buildings is listed first. The second requirement clarifies that it only applies to building occupancies with dwelling or sleeping units.

In Sections C402.5.2 and C402.5.3, additional language is added to provide better code intent clarity and metric units are corrected.

In Section R402.4.1.2, an exception is added that allows low-rise multifamily buildings to comply with the same testing criteria as mid-rise multifamily. This is consistent with the language in the original Exception 1, but in clearer terms.

Cost Impact:

The code change proposal will neither increase nor decrease the cost of construction.

The intent of this proposal is to improve code language clarity only.

CEPI-63-21 Part II

IRCEPI-1-21

IRC: N1102.2.6, TABLE N1102.2.6, Chapter 44 (New)

Proponents:

Jonathan Humble, representing American Iron and Steel Institute (Jhumble@steel.org)

THIS PROPOSAL WILL BE HEARD BY THE IECC-RESIDENTIAL COMMITTEE.

2021 International Residential Code

Revise as follows:

N1102.2.6 Steel-frame ceilings~~,~~ and walls~~, and floors~~.

Steel-frame ceilings~~,~~ and walls~~, and floors~~ shall comply with the ~~insulation requirements of Table N1102.2.6 or the~~ *U*-factor requirements of Table N1102.1.2. The ~~calculation of the~~ *U*-factor for a steel-frame envelope assembly shall ~~use a series-parallel path calculation method~~ be determined in accordance with AISI S250.

~~TABLE N1102.2.6 STEEL-FRAME CEILING, WALL AND FLOOR INSULATION R-VALUES~~

~~**WOOD FRAME *R*-VALUE REQUIREMENT**~~	~~**COLD-FORMED STEEL-FRAME EQUIVALENT *R*-VALUE[a]**~~
~~**Steel Truss Ceilings[b]**~~	
~~R-30~~	~~R-38 or R-30 + 3 or R-26 + 5~~
~~R-38~~	~~R-49 or R-38 + 3~~
~~R-49~~	~~R-38 + 5~~
~~**Steel Joist Ceilings[b]**~~	
~~R-30~~	~~R-38 in 2 × 4 or 2 × 6 or 2 × 8 R-49 in any framing~~
~~R-38~~	~~R-49 in 2 × 4 or 2 × 6 or 2 × 8 or 2 × 10~~
~~**Steel-frame Wall, 16 inches on center**~~	
~~R-13~~	~~R-13 + 4.2 or R-21 + 2.8 or R-0 + 9.3 or R-15 + 3.8 or R-21 + 3.1~~
~~R-13 + 5~~	~~R-0 + 15 or R-13 + 9 or R-15 + 8.5 or R-19 + 8 or R-21 + 7~~
~~R-13 + 10~~	~~R-0 + 20 or R-13 + 15 or R-15 + 14 or R-19 + 13 or R-21 + 13~~
~~R-20~~	~~R-0 + 14.0 or R-13 + 8.9 or R-15 + 8.5 or R-19 + 7.8 or R-21 + 7.5~~
~~R-20 + 5~~	~~R-13 + 12.7 or R-15 + 12.3 or R-19 + 11.6 or R-21 + 11.3 or R-25 + 10.9~~
~~R-21~~	~~R-0 + 14.6 or R-13 + 9.5 or R-15 + 9.1 or R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7~~
~~**Steel-frame Wall, 24 inches on center**~~	
~~R-13~~	~~R-0 + 9.3 or R-13 + 3.0 or R-15 + 2.4~~
~~R-13 + 5~~	~~R-0 + 15 or R-13 + 7.5 or R-15 + 7 or R-19 + 6 or R-21 + 6~~
~~R-13 + 10~~	~~R-0 + 20 or R-13 + 13 or R-15 + 12 or R-19 + 11 or R-21 + 11~~
~~R-20~~	~~R-0 + 14.0 or R-13 + 7.7 or R-15 + 7.1 or R-19 + 6.3 or R-21 + 5.9~~
~~R-20 + 5~~	~~R-13 + 11.5 or R-15 + 10.9 or R-19 + 10.1 or R-21 + 9.7 or R-25 + 9.1~~
~~R-21~~	~~R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9~~
~~**Steel Joist Floor**~~	
~~R-13~~	~~R-19 in 2 × 6, or R-19 + 6 in 2 × 8 or 2 × 10~~
~~R-19~~	~~R-19 + 6 in 2 × 6, or R-19 + 12 in 2 × 8 or 2 × 10~~

For SI: 1 inch = 25.4 mm.

~~a. The first value is cavity insulation *R*-value; the second value is continuous insulation *R*-value. Therefore, for example, "R-30 + 3" means R-30 cavity insulation plus R-3 continuous insulation.~~

~~b. Insulation exceeding the height of the framing shall cover the framing.~~

Add new text as follows:
Chapter 44 Referenced Standards.

AISI

American Iron and Steel Institute

25 Massachusetts Avenue, NW, Suite 800

Washington, DC 20001

AISI S250-21

North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing

Section N1102.2.6

Attached Files

- **AISI_CFSD-Report-RP20-2-Final.pdf**
  http://localhost/proposal/157/863/files/download/31/
- **AISI S250-21&S250-21-C_s.pdf**
  http://localhost/proposal/157/863/files/download/30/

Reason Statement:

The purpose of this proposal is to address the issue of having to submit to the code official a request to use the alternative means and methods provisions for cold-formed steel framing designs that are not shown in the IECC. For example, Section C402.1.4.2 addresses only wall framing spacing for 16 and 24 inch on center spacing and is limited to cavity plus continuous insulation options only, whereas, in the market there are many more framing spacing and insulation options used.

This proposal recommends that the Section be modified to recognize the ANSI/AISI/COFS S250 standard. This standard covers cold-formed steel wall framing spacings from 6 inches to 24 inches on center, covers member sizes from 3.5 inches to 12 inches wide, and covers member thicknesses from 0.033 inches thick to 0.064 inches thick. This standard will provide greater latitude for the user of the IECC by mitigating the necessity of having to submit for approval under alternate means and methods provisions. Further, this standard also includes provisions for evaluation of wall assemblies where all the insulation is located outside the wall cavity, which is an option the IECC does not cover.

This standard also contains provisions for calculating ceiling assemblies constructed of cold-formed steel framing with either conventional c-shape framing members, or truss construction with insulation in the attic and with additional continuous insulation below the truss framing. Previous to this proposal we found users applying the 2003 IECC provisions, which contained the calculation procedures, as part of the alternative means and methods submission process to demonstrate compliance. This proposal is intended to mitigate that additional step.

The ANSI/AISI/COFS S250 was approved and published in September 2021.

As part of AISI's effort to make this document user friendly, an excel spread sheet containing all the necessary equations and back-ground data was generated so that users would merely input the basic assembly materials data (e.g. R-values of insulations, sheathings, etc.) and allow the spread sheet to calculate within seconds the result. This excel spread sheet is available at no cost to any potential user (e.g. code official, design professional, building owner, etc.)

The proponent wishes to schedule time to present to the IECC Residential Committee this proposal, discuss, and to take questions from the Committee.

Bibliography:

AISI, "Development of a U-factor Calculation Procedure for Cold-Formed Steel C-Shaped Clear Wall Assemblies," American Iron and Steel Institute, Washington, DC, Research Report RP20-2, April 2020.

AISI, "North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing," American Iron and Steel Institute, Washington, DC, AISI S250-21.

Cost Impact:

The code change proposal will decrease the cost of construction.

This proposed change we expect will decease the cost of construction by eliminating the need to prepare an application to the alternative means and methods process. This is because of the standards wider range of envelope assembly options that the user is permitted to calculate in order to demonstrate compliance

IRCEPI-1-21

REPI-39 Knee Wall

Definition

Knee wall – An *above-grade wall* assembly, or wall defined by vertical truss members, of any height that separate conditioned space from unconditioned buffer spaces, such as ventilated attics, entry porch roofs, etc., rather than ambient outdoors.

R402.2.3 (N1102.2.3) Attic knee ~~or pony~~ wall.

~~R402.2.3 Attic knee or pony wall.~~

Attic knee ~~or pony~~ wall assemblies that separate conditioned space from unconditioned attic spaces shall meet the same insulation requirements as above-grade walls. ~~be constructed to be insulated to the R-value of the above grade wall~~. ~~described in Table R402.1.3.~~ Such Knee ~~or pony~~ walls shall have a sealed air barrier between conditioned and ~~to the~~ unconditioned space and shall have an air barrier on the attic or unconditioned side of the assembly.

~~Air permeable insulation installed in knee or pony wall cavities shall be enclosed on six sides of the cavity. Insulation installed in knee or pony wall cavities shall be installed in substantial contact with the air barrier.~~

R402.2.3.1 Where vertical ~~Knee or pony wall cavities defined by~~ roof truss framing members are used to separate conditioned space and unconditioned space, they shall meet the same insulation requirements as the above-grade walls. ~~be insulated to the same~~ ~~R-value as the above grade wall.~~

~~level as other exterior above grade walls. Vertical or diagonal surfaces that are greater than 1 foot (305 mm) in height into a ventilated attic shall be considered a knee or pony wall. Vertical or diagonal surfaces that are 1 foot (305 mm) or less in height into a ventilated attic shall be buried with insulation to maintain the ceilings required Rvalue~~.

Table R402.4.1.1
AIR BARRIER, AIR SEALING AND INSULATION INSTALLATION [a]

COMPONENT	AIR BARRIER, AIR SEALING CRITERIA	INSULATION INSTALLATION CRITERIA
Knee ~~or pony~~ wall~~s~~	Knee ~~or pony~~ walls shall have a sealed air barrier between conditioned and unconditioned space. ~~and shall be sheathed on the attic or unconditioned side of the assembly.~~	Insulation installed in a knee ~~or pony~~ wall assembly shall ~~be~~ meet the same insulation requirements as above-grade walls.

	~~be constructed to have a sealed air barrier on six sides of the wall assembly including to the unconditioned side of the assembly.~~	~~installed in accordance with Section R402.2.3~~
Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. ~~Knee walls shall be sealed.~~	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance, *R*-value, of not less than R-3 per inch. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.

Reason Statement

Attic knee walls, in the field, are a unique assembly that have been overlooked by the IECC. The assembly separates interior conditioned space from exterior unconditioned space but is buffered from directly being connected to the ambient outdoors by a ventilated attic. The ventilated attic space often has harsher unconditioned side temperatures than normal above grade walls causing more significant heat loss or gain through the assembly than through normal insulated above grade walls. This being the case we see across the country, in the field, that attic knee walls are often insulated to a lower R-value than the exterior walls associated with the same house. In addition, the IECC has not been clear about the need for attic sheathing and a sealed air barrier systems installation.

This proposal defines, describes how to address, and adds this unique assembly to the list of required assemblies that must be detailed in the requirements section of the IECC. It will ensure proper air barriers, insulation installation, air sealing of the assembly and will increase the performance of the home.

Raised ceiling that protrude into the attic are unique knee wall applications on which the code offers no guidance. They are particularly troublesome for maintaining the continuity of the building thermal envelope and therefore have been added to this section as a means to define when the vertical or diagonal surface must be treated as a knee wall and when normal attic insulation can be mounded over the raised ceiling.








Cost

In theory, this assembly has been addressed as an above grade wall so this new section of code should not add cost to the construction of a home. In reality, this assembly has not been viewed in most of the country as a typical above grade wall so cost will be added to construction because of the realization of the significance of the assembly and the heat loss and gain that is driven through it because of it being adjacent to the ventilated attic.

The R-value of this part of the above grade wall assembly could be traded off to a lower R-value, or the same R-value that is currently being installed when using the UA alternative, Total Building Performance, or ERI compliance pathways. This would lower the cost associated with this code proposal. However, as cost goes down implementation would still become better because the proposal would ensure that the installed insulation is enclosed with sheathing on the attic side and that an air barrier has been defined this making the assembly perform better.

REPI-39-21

IECC®: R402.2.3 (N1102.2.3) (New), TABLE R402.4.1.1 (N1102.4.1.1) (New), TABLE R405.2, TABLE R406.2

Proponents: Robby Schwarz, BUILDTank, Inc., representing BUILDTank, Inc. (robby@btankinc.com)

2021 International Energy Conservation Code

Add new text as follows:

R402.2.3 (N1102.2.3) Attic knee or pony wall. R402.2.3 Attic knee or pony wall. Attic knee or pony wall assemblies that seperate conditioned space from unconditioned attic spaces shall be constructed to be insulated to the R-value of the above grade wall described in Table R402.1.3. Knee or pony walls shall have a sealed air barrier to the unconditioned side of the assembly. Air permeable insulation installed in knee or pony wall cavities shall be enclosed on six sides of the cavity. Insulation installed in knee or pony wall cavities shall be installed in substantial contact with the air barrier. Knee or pony wall cavities defined by roof truss framing shall be insulated to the same level as other exterior above grade walls. Vertical or diagonal surfaces that are greater than 1 foot (305 mm) in height into a ventilated attic shall be considered a knee or pony wall. Vertical or diagonal surfaces that are 1 foot (305 mm) or less in height into a ventilated attic shall be buried with insulation to maintain the ceilings required R-value.

TABLE R402.4.1.1 (N1102.4.1.1) AIR BARRIER, AIR SEALING AND INSULATION INSTALLATION[a]

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
Knee or pony walls	Knee or pony walls shall be constructed to have a sealed air barrier on six sides of the wall assembly including to the unconditioned side of the assembly.	Insulation installed in a knee or pony wall shall be installed in accordance with Section R402.2.3.

Revise as follows:

TABLE R405.2 (TABLE N1105.2) REQUIREMENTS FOR TOTAL BUILDING PERFORMANCE

SECTION[a]	TITLE
General	
R401.2.5	Additional energy efficiency
R401.3	Certificate
Building Thermal Envelope	
R402.1.1	Vapor retarder
R402.2.3	Attic knee or pony wall
~~R402.2.3~~ R402.2. 4	Eave baffle
R402.2.4.1	Access hatches and doors
R402.2.10.1	Crawl space wall insulation installations
R402.4.1.1	Installation
R402.4.1.2	Testing
R402.5	Maximum fenestration U-factor and SHGC
Mechanical	
R403.1	Controls
R403.3, including R403.3.1, except Sections R403.3.2, R403.3.3 and R403.6	Ducts
R403.4	Mechanical system piping insulation
R403.5.1	Heated water circulation and temperature maintenance systems
R403.5.3	Drain water heat recovery units
R403.6	Mechanical ventilation
R403.7	Equipment sizing and efficiency rating
R403.8	Systems serving multiple dwelling units
R403.9	Snow melt and ice systems
R403.10	Energy consumption of pools and spas
R403.11	Portable spas
R403.12	Residential pools and permanent residential spas
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls

a. Reference to a code section includes all the relative subsections except as indicated in the table.

TABLE R406.2 (TABLE N1106.2) REQUIREMENTS FOR ENERGY RATING INDEX

SECTION[a]	TITLE
General	
R401.2.5	Additional efficiency packages
R401.3	Certificate
Building Thermal Envelope	
R402.1.1	Vapor retarder
R402.2.3 ~~R402.2.3~~ R402.2. 4	Attic knee or pony wall Eave baffle
R402.2.4.1	Access hatches and doors
R402.2.10.1	Crawl space wall insulation installation
R402.4.1.1	Installation
R402.4.1.2	Testing
Mechanical	
R403.1	Controls
R403.3 except Sections R403.3.2, R403.3.3 and R403.3.6	Ducts
R403.4	Mechanical system piping insulation
R403.5.1	Heated water calculation and temperature maintenance systems
R403.5.3	Drain water heat recovery units
R403.6	Mechanical ventilation
R403.7	Equipment sizing and efficiency rating
R403.8	Systems serving multiple dwelling units
R403.9	Snow melt and ice systems
R403.10	Energy consumption of pools and spas
R403.11	Portable spas
R403.12	Residential pools and permanent residential spas
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
R406.3	Building thermal envelope

a. Reference to a code section includes all of the relative subsections except as indicated in the table.

Reason: Attic knee walls, often named pony walls in the field, are a unique assembly that has been overlooked by the IECC. The assembly separates interior conditioned space from exterior unconditioned space, but it buffered from directly being connected to the ambient outdoors by a ventilated attic. The ventilated attic space often has harsher unconditioned side temperatures that normal above grade walls causing more significant heat loss or gain through the assembly than through normal insulated above grade walls. This being the case we see across the country in the field that attic knee or pony walls are often insulated to a lower R-value than the exterior walls associated with the same house. In addition, the IECC has not been clear about the need for attic side enclosed and sealed air barrier systems installation.
This proposal defines, describes how to address, and adds this unique assembly to the list of required assemblies that must be detailed in the requirements section of the IECC. It will ensure proper air barriers, insulation installation, air sealing of the assembly and will increase the performance of the home.

Cost Impact: The code change proposal will increase the cost of construction.
In theory, this assembly has been addressed as an above grade wall so this new section of code should not add cost to the construction of a home. In reality, this assembly has not been viewed in most of the country as a typical above grade wall so cost will be added to construction because of the realization of the significance of the assembly and the heat loss and gain that is driven through it because of it be adjacent to the ventilated attic.

The R-value of this part of the above grade wall assembly could traded off to a lower R-value, or the same R-value that is currently being installed when using the UA alternative, Total Building Performance, or ERI compliance pathways. This would lower the cost associated with this code proposal. However, as cost goes down implementation would still become better because the proposal would ensure that the installed insulation is enclosed in a six-sided air sealed cavity which performs to better mitigate heat loss and gain through the assembly.

REPI-40-21

IECC®: R402.2.6, TABLE R402.2.6, AISI (New) (with 2022-4-22 Revisions)

Proponents:

Jonathan Humble, representing American Iron and Steel Institute (Jhumble@steel.org)

2021 International Energy Conservation Code

Revise as follows:

R402.2.6 (N1102.2.6) Steel-frame ceilings, walls and floors.

Steel-frame ceilings, walls and floors shall comply with the insulation requirements of Table R402.2.6 or the *U*-factor requirements of Table R402.1.2. The calculation of the *U*-factor for a steel-framed ceilings and walls in an envelope assembly shall use a series-parallel path calculation method be determined in accordance with AISI S250 as modified herein.

a) Where the steel-framed wall contains no cavity insulation, and uses continuous insulation to satisfy the U-factor maximum, the *steel-framed wall* member spacing is permitted to be installed at any on-center spacing.

b) Where the steel-framed wall contains framing at 24 inch (600 mm) on center with a 23% framing factor or framing at 16 inch (400 mm) on-center with a 25% framing factor, the next lower framing member spacing input values shall be used when calculating using AISI S250.

c) Where the steel-framed wall contains less than 23% framing factors the AISI S250 shall be used without any modifications.

d) Where the steel-framed wall contains other than standard C-shape framing members the AISI S250 calculation option for other than standard C-shape framing is permitted to be used.

Delete without substitution:

TABLE R402.2.6 STEEL-FRAME CEILING, WALL AND FLOOR INSULATION R-VALUES

WOOD FRAME *R*-VALUE REQUIREMENT	COLD-FORMED STEEL-FRAME EQUIVALENT *R*-VALUE[a]
Steel Truss Ceilings[b]	
R-30	R-38 or R-30 + 3 or R-26 + 5
R-38	R-49 or R-38 + 3
R-49	R-38 + 5
Steel Joist Ceilings[b]	
R-30	R-38 in 2 x 4 or 2 x 6 or 2 x 8 R-49 in any framing
R-38	R-49 in 2 x 4 or 2 x 6 or 2 x 8 or 2 x 10
Steel-frame Wall, 16 inches on center	
R-13+5	R-0 + 15 or R-13 + 9 or R-15 + 8.5 or R-19 + 8 or R-21 + 7
R-13+10	R-0+20 or R-13 + 15 or R-15 + 14 or R-19 + 13 or R-21 + 13
R-20	R-0 + 14.0 or R-13 + 8.9 or R-15 + 8.5 or R-19 + 7.8 or R-21 + 7.5
R-20 + 5	R-13 + 12.7 or R-15 + 12.3 or R-19 + 11.6 or R-21 + 11.3 or R-25 + 10.9
R-21	R-0 + 14.6 or R-13 + 9.5 or R-15 + 9.1 or R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7
Steel-frame Wall, 24 inches on center	
R-13+5	R-0 + 15 or R-13 + 7.5 or R-15 + 7 or R-19 + 6 or R-21 + 6
R-13+10	R-0 + 20 or R-13 + 13 or R-15 + 12 or R-19 + 11 or R-21 + 11
R-20	R-0 + 14.0 or R-13 + 7.7 or R-15 + 7.1 or R-19 + 6.3 or R-21 + 5.9
R-20+5	R-13 + 11.5 or R-15 + 10.9 or R-19 + 10.1 or R-21 + 9.7 or R-25 + 9.1

~~R-21~~	~~R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9~~
~~Steel Joist Floor~~	
~~R-13~~	~~R-19 in 2 x 6, or R-19 + 6 in 2 x 8 or 2 x 10~~
~~R-19~~	~~R-19 + 6 in 2 x 6, or R-19 + 12 in 2 x 8 or 2 x 10~~

~~a. The first value is cavity insulation *R*-value; the second value is continuous insulation *R*-value. Therefore, for example, "R-30 + 3" means R-30 cavity insulation plus R-3 continuous insulation.~~

~~b. Insulation exceeding the height of the framing shall cover the framing.~~

Add new standard(s) as follows:

AISI

AISI American Iron and Steel Institute

25 Massachusetts Avenue, NW, Suite 800

Washington DC 20001.

AISI - S250 - 21 North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing

Attached Files

- **AISI_CFSD-Report-RP20-2-Final.pdf**
  http://localhost/proposal/106/879/files/download/23/
- **AISI S250-21&S250-21-C_s.pdf**
  http://localhost/proposal/106/879/files/download/22/

REPI-40-21

IECC®: R402.2.6, TABLE R402.2.6, AISI (New)

Proponents:

Jonathan Humble, representing American Iron and Steel Institute (Jhumble@steel.org)

2021 International Energy Conservation Code

Revise as follows:
R402.2.6 (N1102.2.6) Steel-frame ceilings~~,~~ and walls ~~and floors~~.
Steel-frame ceilings~~,~~ and walls~~, and floors~~ shall comply with the ~~insulation requirements of Table R402.2.6 or the~~ *U*-factor requirements of Table R402.1.2. The ~~calculation of the~~ *U*-factor for a steel-frame envelope assembly shall ~~use a series-parallel path calculation method~~ be determined in accordance with AISI S250.
Delete without substitution:

~~TABLE R402.2.6 STEEL-FRAME CEILING, WALL AND FLOOR INSULATION R-VALUES~~

WOOD FRAME *R*-VALUE REQUIREMENT	COLD-FORMED STEEL-FRAME EQUIVALENT *R*-VALUE[a]
Steel Truss Ceilings[b]	
R-30	R-38 or R-30 + 3 or R-26 + 5
R-38	R-49 or R-38 + 3
R-49	R-38 + 5
Steel Joist Ceilings[b]	
R-30	R-38 in 2 × 4 or 2 × 6 or 2 × 8 R-49 in any framing
R-38	R-49 in 2 × 4 or 2 × 6 or 2 × 8 or 2 × 10
Steel-frame Wall, 16 inches on center	
R-13 + 4.2 or R-21 + 2.8 or R-0 + 9.3 or R-15 + 3.8 or R-21 + 3.1	
R-13+5	R-0 + 15 or R-13 + 9 or R-15 + 8.5 or R-19 + 8 or R-21 + 7
R-13+10	R-0+20 or R-13 + 15 or R-15 + 14 or R-19 + 13 or R-21 + 13
R-20	R-0 + 14.0 or R-13 + 8.9 or R-15 + 8.5 or R-19 + 7.8 or R-21 + 7.5
R-20 + 5	R-13 + 12.7 or R-15 + 12.3 or R-19 + 11.6 or R-21 + 11.3 or R-25 + 10.9
R-21	R-0 + 14.6 or R-13 + 9.5 or R-15 + 9.1 or R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7
Steel-frame Wall, 24 inches on center	
R-0 + 9.3 or R-13 + 3.0 or R-15 + 2.4	
R-13+5	R-0 + 15 or R-13 + 7.5 or R-15 + 7 or R-19 + 6 or R-21 + 6
R-13+10	R-0 + 20 or R-13 + 13 or R-15 + 12 or R-19 + 11 or R-21 + 11
R-20	R-0 + 14.0 or R-13 + 7.7 or R-15 + 7.1 or R-19 + 6.3 or R-21 + 5.9
R-20+5	R-13 + 11.5 or R-15 + 10.9 or R-19 + 10.1 or R-21 + 9.7 or R-25 + 9.1
R-21	R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9
Steel Joist Floor	
R-13	R-19 in 2 × 6, or R-19 + 6 in 2 × 8 or 2 × 10
R-19	R-19 + 6 in 2 × 6, or R-19 + 12 in 2 × 8 or 2 × 10

a. The first value is cavity insulation *R*-value; the second value is continuous insulation *R*-value. Therefore, for example, "R-30 + 3" means R-30 cavity insulation plus R-3 continuous insulation.

b. Insulation exceeding the height of the framing shall cover the framing.

Add new standard(s) as follows:

AISI American Iron and Steel Institute 25 Massachusetts Avenue, NW, Suite 800 Washington DC 20001
AISI American Iron and Steel Institute.

AISI - S250 - 21 North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing

Attached Files

- **AISI_CFSD-Report-RP20-2-Final.pdf**
  http://localhost/proposal/106/879/files/download/23/
- **AISI S250-21&S250-21-C_s.pdf**
  http://localhost/proposal/106/879/files/download/22/

Reason Statement:

The purpose of this proposal is to address the issue of having to submit to the code official a request to use the alternative means and methods provisions for cold-formed steel framing designs that are not shown in the IECC. For example, Section C402.1.4.2 addresses only wall framing spacing for 16 and 24 inch on center spacing and is limited to cavity plus continuous insulation options only, whereas, in the market there are many more framing spacing and insulation options used.

This proposal recommends that the Section be modified to recognize the ANSI/AISI/COFS S250 standard. This standard covers cold-formed steel wall framing spacings from 6 inches to 24 inches on center, covers member sizes from 3.5 inches to 12 inches wide, and covers member thicknesses from 0.033 inches thick to 0.064 inches thick. This standard will provide greater latitude for the user of the IECC by mitigating the necessity of having to submit for approval under alternate means and methods provisions. Further, this standard also includes provisions for evaluation of wall assemblies where all the insulation is located outside the wall cavity, which is an option the IECC does not cover.

This standard also contains provisions for calculating ceiling assemblies constructed of cold-formed steel framing with either conventional c-shape framing members, or truss construction with insulation in the attic and with additional continuous insulation below the truss framing. Previous to this proposal we found users applying the 2003 IECC provisions, which contained the calculation procedures, as part of the alternative means and methods submission process to demonstrate compliance. This proposal is intended to mitigate that additional step.

The ANSI/AISI/COFS S250 was approved and published in September 2021.

As part of AISI's effort to make this document user friendly, an excel spread sheet containing all the necessary equations and back-ground data was generated so that users would merely input the basic assembly materials data (e.g. R-values of insulations, sheathings, etc.) and allow the spread sheet to calculate within seconds the result. This excel spread sheet is available at no cost to any potential user (e.g. code official, design professional, building owner, etc.)

The proponent wishes to schedule time to present to the IECC Residential Committee this proposal, discuss, and to take questions from the Committee.

Bibliography:

AISI, "Development of a U-factor Calculation Procedure for Cold-Formed Steel C-Shaped Clear Wall Assemblies," American Iron and Steel Institute, Washington, DC, Research Report RP20-2, April 2020.

AISI, "North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing," American Iron and Steel Institute, Washington, DC, AISI S250-21.

Cost Impact:

The code change proposal will decrease the cost of construction.

This proposed change we expect will decease the cost of construction by eliminating the need to prepare an application to the alternative means and methods process. This is because of the standards wider range of envelope assembly options that the user is permitted to calculate in order to demonstrate compliance.

REPI-40-21

Residential Cool Roof: REPI-068-21 Supporting Documentation

Table of Contents

Introduction

Code Proposal Summary

The original proposal introduced cool roof requirements for low-rise residential buildings in IECC climate zones 0 to 5. The revised proposal introduces cool roof requirements for warmer climate zones 0 to 3 only, aligning it with new construction requirements of IECC 2021 commercial buildings per Section C402.3. The revised proposal also includes an exception when radiant barrier is installed. The cool roof proposal for 2024 IECC adds the following:

- High Solar Reflectance Index (SRI) requirements for low sloped and steep sloped roofs
- Definition of low sloped (<2:12) and steep sloped (>=2:12) roof in Residential Energy Efficiency Section.
- List of exceptions from Section C402.3
- Material selection and Aged Solar Reflectance (ASR) and Thermal Emittance (TE) values for low sloped and steep sloped roof buildings in Standard Reference Design in Section R405.4.2

- Building Envelope Alterations requirements in Section R503.1.1 to include cool roof requirements
- Waterproof coating requirement for Tropical Climate Region requirements in Section R407.2

Code Language

The proposal team suggests alterations from the original proposal, as shown in red below.

Add new definition as follows:

LOW-SLOPED ROOF. A roof giving a slope less than 2 units vertical in 12 units horizontal.

STEEP-SLOPED ROOF. A roof giving a slope greater than or equal to 2 units vertical in 12 units horizontal.

Add new text as follows:

R402.6 Roof Reflectance.

Roofs in Climate Zones 0 through 3 shall comply with one or more of the options in Table R402.6.

Table R402.6 Minimum roof reflectance.[a]

Roof slope	**Three-year aged solar reflectance index** [b]
Low-slope	75[b, c]
Steep-slope	16

a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for solar reflectance shall be assigned a 3-year-aged solar reflectance in accordance with Section R402.6.1
b. Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-S100.
c. Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h × ft 2 × °F (12 W/m 2 × K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.

Exceptions: ~~The following roofs and portion of roofs are exempt from the requirements of Table R402.6:~~

1. ~~Roofs in climate zones 6-8~~ Roofs with a radiant barrier with an emittance of 0.05 or less.
2. Roofs where ~~more~~ not less than 75 percent of roof area ~~complies with one or more of the exceptions below~~ are covered by one or more of the following:
3. ~~Portions of the roof that are covered by one or more of the following:~~

2.1. Photovoltaic systems or components
2.2. Solar air or water heating systems or components
2.3. Vegetative roofs or landscaped roofs
2.4. Above roof decks or walkways
2.5. Skylights
2.6. HVAC systems and components, and other opaque objects mounted above the roof
2.7. Portions of roof shaded during the peak sun angle on the summer solstice by permanent features of the building or by permanent features of adjacent buildings.
2.8. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot (74kg/m^2) or 23 psf (117kg/m^2) pavers.

R402.6.1 Aged roof solar reflectance.

Where an aged solar reflectance required by Section R402.6 is not available, it shall be determined in accordance with Equation 4-3.

Equation 4-3

$R_{aged}=[0.2+0.7(R_{initial}-0.2)]$

where:

R_{aged} = The aged solar reflectance.

$R_{initial}$ = The initial solar reflectance determined in accordance with CRRC-S100.

Revise as follows:

TABLE R405.4.2(1) (TABLE N1105.4.2(1)) SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

Building Component	**Standard Reference Design**	**Proposed Design**
Roofs	Type: ~~composition shingle on wood sheathing~~ Low-sloped: Modified bitumen Steep-sloped: asphalt shingles	As proposed
	Gross Area: same as proposed	As proposed
	Low-sloped: (Aged) Solar ~~absorptance~~ reflectance = ~~0.75~~ 0.63 Steep-sloped: (Aged) Solar reflectance = 0.2	As proposed
	Thermal Emittance = ~~0.9~~ 0.75	As proposed

R407.2 Tropical Climate Region

Compliance with this section requires the following:

1. Not more than one-half of the occupied space is air conditioned.
2. The *occupied* space is not heated.
3. Solar, wind or other renewable energy source supplies not less than 80 percent of the energy for service water heating.
4. Glazing in *conditioned spaces* has a *solar heat gain coefficient* (SHGC) of less than or equal to 0.40, or has an overhang with a projection factor equal to or greater than 0.30.
5. Permanently installed lighting is in accordance with Section R404.
6. The exterior roof surface complies with one of the options in Table ~~C402.3~~<u>R402.6</u> ~~of the International Energy Conservation Code- Commercial Provisioner the roof~~ or ceiling has insulation with an *R-value* of R-15 or greater. Where attics are present, attics above the insulation are vented and attics below the insulation are invented.
7. Roof surfaces have a slope of not less than ¼ unit vertical in 12 units horizontal (21-percent slope). The finished roof does not have water accumulation areas.
8. Operable fenestration provides a ventilation area of not less than 14 percent of the floor area in each room. Alternatively, equivalent ventilation is provided by a ventilation fan.
9. Bedrooms with *exterior walls* facing two different directions have operable fenestration on exterior walls facing two directions.
10. Interior doors to bedrooms are capable of being secured in the open position.
11. A ceiling fan or ceiling fan rough-in in provided for bedrooms and the largest space that is not used as a bedroom.

R503.1.1. Building Envelope

Building envelope assemblies that are part of the *alteration* shall comply with Section 402.1.2 or R402.1.4, Sections R402.2.1 through R402.2.12, R402.3.1, R402.3.2, R402.4.3<u>,</u> <u>R402.6</u> and R402.4.5.

> **Exception:** The following alterations shall not be required to comply with the requirements for new construction provided that the energy use of the building is not increased:
>
> 1. Storm windows installed over existing fenestration.
> 2. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation.
> 3. Construction where the existing roof, wall or floor cavity is not exposed.
> 4. Roof recover<u> where the new roofing meets the reflectance requirements under R402.6</u>.
> 5. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
> 6. Surface-applied window film installed on existing single pane fenestration assemblies to reduce solar heat gain provided that the code does not require the glazing or fenestration assembly to be replaced.

Code Background

Cool roof is a relatively inexpensive energy conservation measure to passively reduce cooling load in warmer regions. Cool roofs provide high solar reflectance and thermal emittance and are generally of light color shade such as white or grey. In addition to energy benefits, cool roofs also help reduce air temperature controlling urban heat island effect and peak electricity demand controlling potential power outages.

The proposed cool roof requirements are based on California 2022 Title 24 residential new construction cool roof requirements. Cool roofs were shown to be cost effective in select warmer climate zones that are a subset of IECC climate zones 2 and 3. 2022 Title 24, Part 6 requires aged solar reflectance index (SRI) of 75 in low sloped roof buildings and SRI of 16 in steep sloped roof buildings. The proposed addition to the residential standards aligns climate zone applicability with 2021 IECC commercial new construction cool roof requirements of Section 402.3 for climate zones 0 to 3.

A wide range of cool roof products are available in the market for both low-sloped and steep-sloped roof applications. There are approximately 3000 roofing products listed with Cool Roof Rating Council (CRRC) and a majority of those are appropriate for both low-sloped and steep-sloped installations. These products include single-ply, fluid applied membrane, asphaltic membrane, and metal coating products and modified bitumen-based products that are commonly used for cool roof installations. The proposal team based material selection and associated costs on the 2022 Title 24 Codes and Standards Enhancement (CASE) Report (Frontier Energy et. al., 2020) conducted in 2020 for single family alterations.[1] The CASE report is the latest reference on cool roof cost available that refers to other external studies (Freedonia group, 2019) (TRC, 2016a) (TRC, 2016b) for both material selection and cost estimates.

Methodology

Simulation Tool

This analysis used EnergyPlus v9.5 for modeling energy savings.

Description of Prototype

The proposal team selected one single-family prototype house to evaluate the cost-effectiveness of the proposed measure. The building geometry was consistent with PNNL's 2021 IECC determination (Salcido, Chen, Xie, & Taylor, 2021a), also reflected in DOE's prototype building files (US Department of Energy, 2021). The detailed specifications are documented in an earlier PNNL report evaluating the 2012 IECC revisions (Lucas, Mendon, & Goel, 2013). Where the PNNL reports are silent, the proposal team used building attributes consistent with the Standard Reference Design established for the Total Building Performance Option in the 2021 IECC, or common building construction practice if no requirements are specified in any of the reference documents.

The proposal team assumed the foundation types shown in Table 1, considering both typical construction for the PNNL representative city and for the region included in that climate zone.

Table 1. Foundation Type Assumption by Climate Zone

IECC Climate Zone	Representative City	Foundation Type
1A	Honolulu, HI	slab-on-grade
2A	Tampa, FL	slab-on-grade
2B	Tucson, AZ	slab-on-grade
3A	Atlanta, GA	slab-on-grade
3B	El Paso, TX	slab-on-grade

Weather Locations

TMY3 weather files were used for energy simulations based on the representative cities listed in Table 2 below. Our analysis focuses on three climate zones with warm weather conditions, and where new home construction is relatively active: 1A, 2A, 2B, 3A and 3B.

Table 2. Thermal Climate Zone and Representative Cities

Climate Zone	Thermal Climate Zone Name	TMY3 Weather Station	Representative City
1A	Very Hot Humid	Honolulu International Airport, Hawaii	Honolulu, HI
2A	Hot Humid	Tampa-MacDill Air Force Base	Tampa, FL
2B	Hot Dry	Tucson/Davis-Monthan AFB, Arizona	Tucson, AZ
3A	Warm Humid	Atlanta/Hartsfield Jackson International Airport, Georgia	Atlanta, GA
3B	Warm Dry	El Paso International Airport, Texas	El Paso, TX

Description of base and proposed cases

The proposal team assumed a baseline matching the IECC 2021 standard reference design for residential roofs from Table R405.4.2(1). Th standard reference design solar absorptance is 0.75 and the Thermal Emittance is 0.90. Solar absorptance was translated to the EnergyPlus metric of ASR of 0.25.

The proposed case aligns with roof requirements for low-slope and steep-slope residential buildings from California's Title 24, Part 6, Section 150.1(c)11. The proposed cool roof specification for low sloped roof is also aligned with the 2021 IECC cool roof requirements for commercial buildings.

Table 3 summarizes the base case and proposed case roof specification for low slope and steep slope roofs.

Table 3: Summary of Base Case and Proposed case

Roof Slope	Baseline	Proposed
Low-slope	IECC Standard Reference Design: ASR = 0.25, TE = 0.90	ASR = 0.63, TE = 0.75
Steep-slope		ASR = 0.2, TE = 0.75

Given that the standard reference design assumes a slightly better roof specification than the proposed specification, the proposal team did not conduct energy analysis for the steep sloped roof.

The proposed cool roof specification for low sloped roof is also aligned with the 2021 IECC cool roof requirements for commercial buildings.

LCC Approach

The Life Cycle Cost (LCC) approach used is similar to the DOE/PNNL cost analysis methodology (U.S. Department of Energy, 2015), but it uses updated sources for some parameters and is simplified to ease the burden for proponents to analyze their proposed amendments.

The methodology uses an LCC approach, where the cashflows over a 30-year analysis period for cash outflows (expenses, negative values) and inflows (savings, positive values) are used to calculate a net present value based on the time value of money. A positive LCC value indicates that the savings of a measure exceed its costs over the analysis period, while a negative value indicates the opposite.

For costs, the methodology assumes that any up-front incremental costs are financed through the mortgage on the home. Most proposed code amendments will predominantly impact new construction, and most new homes are financed through a 30-year mortgage. Given the high standard deductible for federal income taxes ($25,900 for joint filers), it is assumed that the increase in mortgage payments does not result in a change in income taxes. It is also assumed that proposed measures have a minimal impact on property assessments for local taxes, so changes in property taxes are assumed to be zero. Property tax assessments tend to be based on high-level data points, such as floor area, general condition, location, number of bedrooms and bathrooms, presence of air conditioning, and types of wall and floor finishes. It is not clear that the cost of efficiency-related features will result in an identical increase in property-tax valuation, and the DOE/PNNL methodology document provides no supporting evidence for the assumption that it will.

Energy prices used to calculate savings are based on national averages of projected prices. The LCC is calculated both with the social benefit of avoided carbon, and assuming a zero societal cost of carbon (SCC). When included, the SCC is calculated using the energy savings, U.S. EIA emissions factors, and social cost data from the technical support document of the Interagency Working Group on Social Cost of Greenhouse Gases (2021). Specifically, this proposal used the 2020-2050 5-year time series of social cost of carbon dioxide at a 3% discount rate in Interagency Working Group on Social Cost of Greenhouse Gases (2021), interpolating for interim years.

Table 6 summarizes the parameters in the LCC modeling and their sources.

Table 6. LCC Assumptions

Parameter	Value	Source
Real discount rate	3% or 7%	IECC subcommittee
Inflation Rate	2.3%	Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2021
Nominal discount Rate	3%, 5.3% or 9.3%	DOE/PNNL, or real rate from IECC subcommittee (based on Office of Management & Budget – OMB) plus inflation
First cost for measure	$413	See Incremental Cost section
Replacement cost for measure	$413	See Incremental Cost section
Baseline fuel prices	$0.137 / kWh $1.1803 / therm natural gas $2.48 / gallon propane	2021 US residential price from EIA
Fuel price escalators	-0.10% for electricity 0.50% for natural gas 1.4% for propane	EIA AEO 2021 reference case, residential by fuel, national
Social cost of carbon	$51 in 2020. See source document for time series.	Interagency Working Group on Social Cost of Greenhouse Gases, 3% discount rate values.
Period of Analysis	30 years	Mortgage loan
Mortgage Interest Rate	3.00% nominal	DOE / PNNL 2021 Analysis
Down Payment Rate	12%	DOE / PNNL 2021 Analysis
Points and Loan Fees	1.00% nominal	DOE / PNNL 2021 Analysis

Impacts:

Energy and Carbon Savings

Energy savings are calculated by subtracting simulated annual energy consumption of proposed and baseline for low-slope and steep-slope buildings. Table 4 provides energy consumption of the base scenario, energy savings from proposed cool roof measure for low-sloped single-family building and corresponding annual energy cost savings. The results demonstrate reduction in heating load and around 4% reduction in cooling energy savings.

Table 4: Energy and Cost Savings Results

Climate Zone	Heating system	Case	Total kBtu	Elec kbtu	Gas kbtu	Total kBtu savings	Total kWh savings	Total Therms savings	$/yr savings
1A	Heat Pump	Base	55,361	55,361					
		Proposed	54,587	54,587		774	227	0	$29.8
	Gas Furnace	Base	68,517	51,810	16,707				
		Proposed	67,791	51,075	16,717	725	215	0	$28.2
2A	Heat Pump	Base	55,518	55,518					
		Proposed	54,696	54,696		822	241	0	$31.7
	Gas Furnace	Base	78,333	48,904	29,429				
		Proposed	77,720	47,990	29,730	613	268	-3	$32.1
2B	Heat Pump	Base	57,734	57,734					
		Proposed	56,865	56,865		869	255	0	$33.5
	Gas Furnace	Base	82,984	49,624	33,360				
		Proposed	82,374	48,632	33,742	610	291	-4	$34.3
3A	Gas Furnace	Base	87,097	40,221	46,876				
		Proposed	87,013	39,654	47,359	84	166	-5	$16.8
	Heat Pump	Base	57,627	57,627					
		Proposed	57,426	57,426		200	59	0	$7.7
3B	Gas Furnace	Base	78,979	42,562	36,417				
		Proposed	78,677	41,698	36,979	302	253	-6	$27.4
	Heat Pump	Base	53,946	53,946					
		Proposed	53,414	53,414		532	156	0	$20.5

Incremental Cost

The proposal team collected measure cost from the following categories of sources,

1. Literature review of past studies on cool roof cost effectiveness analysis
2. Product cost from online retailers such as Home Depot, Lowes etc.
3. RSMeans Online
4. Interview cool roof contractor/distributor/manufacturer

The most recent literature on cool roof cost analysis, 2022 CASE Study (California Utilities Statewide Codes and Standards Team, 2020b), selected modified bitumen with cap sheet as the dominant material selection for low-rise residential building based on a (Freedonia group, 2019) study. The proposal team reviewed the a (Freedonia group, 2019) study including a revised version (Roofing, 2021) that confirmed the material selection for a new construction low -rise residential roofing baseline to be modified bitumen, refer to Table 5 below,

Table 5. New Residential Low Slope Roofing Material – Market Share

Item	2019	2024
New Residential Low-Slope Roofing Demand		
Bituminous:	94%	93%
Built-Up Roofing	4%	3%
Modified Bitumen Roofing	55%	53%
Standard Roll Roofing	35%	37%
Plastic:	2%	3%
TPO Single-Ply Membranes	2%	2%
PVC Single-Ply Membranes	1%	1%
Other Plastic	0%	0%
Rubber:	1%	2%
EPDM	1%	2%
Other Rubber	0%	0%
Metal & Other Products	2%	2%

The other suitable materials are single ply plastic membranes such as Thermoplastic Polyolefin (TPO) or Poly-Vinyl Chloride (PVC), that are getting more popular. It is commonly used for flat roofs of commercial or high-rise residential buildings. Based on conversations with roofing contractors and distributors, TPO is an up-and-coming material choice for flat roofs. The California Study (California Utilities Statewide Codes and Standards Team, 2020b) estimated an incremental cost of cool roof measure for modified bitumen cap sheet product to be between $0.17 and $0.82 based on interviews from contractors. This incremental cost estimate is primarily material cost since the labor cost does not change significantly with cool roof installation over a baseline asphaltic roof. The proposal team also reviewed the reach code studies (TRC, 2016a) (TRC, 2016b) evaluating cool roof measure in California. The reach code study collected costs from contractors and distributors for different material types including modified bitumen cap sheet and single-ply membranes such as TPO or PVC. The 2016 reach code cost database is filtered for the proposed ASR and TE specifications of IECC cool roof measure, summarized in Table 6 below,

Table 6. Incremental Cost Estimate

Scenario	ASR/TE	Material	Cost
Baseline	0.25/0.9	Standard modified bitumen material with cap sheet	$0.22/ft2
Proposed	0.63/0.75	TPO/PVC	$0.55/ft2
Incremental Cost *(Modified Bitumen to TPO/PVC)*			**$0.33/ft2**

TPO/PVC is selected in proposed scenario based on the availability of the material and its cost effectiveness. The total incremental cost for single family building prototype is $413. If a cool roof modified bitumen option is selected in proposed scenario, the incremental cost can be as high as $0.58/ft^2 as suggested by 2022 Single Family Alterations CASE Study (California Utilities Statewide Codes and Standards Team, 2020b) and other cost references such as DOE, 2016 California reach code studies.

Cost Effectiveness Results

This analysis considered Cost Effectiveness under two scenarios – including the Societal Cost of Carbon (SCC) and ignoring the SCC. The proposal team calculated the LCC for each climate zone, for each heating system, using the approach described above.

Only climate zones 1 and 2 are cost effective under a nominal discount rate of 3%, 5.3%, and 9.3%, ignoring the social cost of carbon (SCC: assumes SCC = $0), Table 7 below. (The 5.3% and 9.3% nominal discount rates assume a real discount rate of 3% and 7% respectively, plus 2.3% for inflation.) Results are more cost-effective when the SCC of $51 per metric ton is included.

Table 7. Cost effectiveness results summary with 3%, 5.3% and 9.3% nominal discount rates

LCC Assumptions	**3% nominal discount rate** (DOE/PNNL) **SCC = $0**	**3% nominal discount rate** (DOE/PNNL) **SCC = $51**	**5.3% nominal** 3% real discount rate (OMB) + inflation **SCC = $0**	**5.3% nominal** 3% real discount rate (OMB) + inflation **SCC = $51**	**9.3% nominal** 7% real discount rate (OMB) + inflation **SCC = $0**	**9.3% nominal** 7% real discount rate (OMB) + inflation **SCC = $51**
LCC ($) CZ 1A	$63	$222	$24	$137	$3	$71
LCC ($) CZ 2A	$121	$289	$67	$186	$30	$103
LCC ($) CZ 2B	$170	$347	$103	$229	$53	$130
LCC ($) CZ 3A	($476)	($396)	($370)	($312)	($249)	($213)
LCC ($) CZ 3B	($147)	($18)	($129)	($37)	($95)	($38)
Cost effective CZs	**1,2**	**1,2**	**1,2**	**1,2**	**1,2**	**1,2**

As an example, Table 8 shows the LCC inputs and results for Climate Zone 2A, for the natural gas furnace with nominal discount rate of 5.3%.

Table 8. Example LCC Calculation for Climate Zone 2A and Natural Gas Furnace

Net measure cost	$413	2021$
Measure electric savings	268	kWh/year
Measure natural gas savings	-3	therms/year
Measure propane savings	0	gallons/year
Change in maintenance or other non-energy operating costs	0	2021$/year
Year of first replacement	16	For measures with life <30 years, # of years from date of construction
Year of second replacement	N/A	For measures with life <30 years, # of years from date of construction
With Social Cost of Carbon (SCC)		
Measure incremental LCC	$181.3	2020$ (+ for savings, - for increased cost)
Simple payback	10.9	Years
Without Social Cost of Carbon		
Measure incremental LCC	$67.33	2020$ (+ for savings, - for increased cost)
Simple payback	12.43	Years

For each climate zone, the proposal team generated a table similar to the one above for the three heating systems: natural gas furnace, electric heat pump, and propane furnace, and weighted results based on the prevalence of that heating system type. The proposal team repeated the process for all climate zones studied.

The cost effectiveness results including the SCC are shown in Table 10, Table 12 and Table 14 below for each heating system type, and for the weighted average for each climate zone. As shown, the proposed measure is cost-effective in climate zones 1 and 2 using the approach of weighting results by heating-fuel prevalence. As an aside, although there was higher energy savings from the gas furnace than heat pump, because of the higher cost of electricity per kBTU than natural gas, the monetized energy savings is higher in the heat pump scenario.

The cost-effectiveness results are shown below, at different discount rates. For each discount rate, this analysis first shows LCC results excluding SCC (assuming SCC = $0), followed by results that include the SCC: assumes SCC = $51 per metric ton.

For a nominal discount rate of 3%, assuming SCC = $0 (ignoring carbon):

Table 9. Cost Effectiveness Results for Cool Roof Measure, **excluding** SCC, nominal discount rate of **3%**

Scenario	Heating System Prevalence for CZ1 (% of single-family homes)	Heating System Prevalence for CZ2 (% of single-family homes)	Heating System Prevalence for CZ3 (% of single-family homes)	LCC ($) 1A	LCC ($) 2A	LCC ($) 2B	LCC ($) 3A	LCC ($) 3B
Natural gas furnace	24.6%	35.4%	35.5%	$31.79	$120.87	$169.63	($310.84)	($33.21)
Electric heat pump	73.4%	60.6%	61.5%	$74.70	$124.76	$174.82	($526.06)	($179.19)
Propane furnace	2%	4%	3%	$31.79	($19.28)	($17.23)	($544.42)	($313.51)
Weighted savings	**100%**	**100%**	**100%**	**$63.39**	**$120.84**	**$169.63**	**($475.56)**	**($147.15)**

For a nominal discount rate of 3%, assuming SCC = $51 per metric ton:

Table 10. Cost Effectiveness Results for Cool Roof Measure, **including** SCC, nominal discount of **3%**

Scenario	Heating System Prevalence for CZ1 (% of single-family homes)	Heating System Prevalence for CZ2 (% of single-family homes)	Heating System Prevalence for CZ3 (% of single-family homes)	LCC ($) 1A	LCC ($) 2A	LCC ($) 2B	LCC ($) 3A	LCC ($) 3B
Natural gas furnace	24.6%	35.4%	35.5%	$183.57	$281.11	$336.46	($241.92)	$87.47
Electric heat pump	73.4%	60.6%	61.5%	$234.95	$294.90	$354.85	($484.41)	($69.06)
Propane furnace	2%	4%	3%	$183.57	$138.61	$146.46	($479.41)	($197.52)
Weighted savings	**100%**	**100%**	**100%**	**$221.99**	**$288.93**	**$346.73**	**($396.19)**	**($17.89)**

For a nominal discount rate of 5.3% (real discount rate of 3%), assuming SCC = $0 (ignoring carbon):

Table 11. Cost Effectiveness Results for Cool Roof Measure, **excluding** SCC, nominal discount rate of **5.3%**

Scenario	Heating System Prevalence for CZ1 (% of single-family homes)	Heating System Prevalence for CZ2 (% of single-family homes)	Heating System Prevalence for CZ3 (% of single-family homes)	LCC ($) 1A	LCC ($) 2A	LCC ($) 2B	LCC ($) 3A	LCC ($) 3B
Natural gas furnace	24.6%	35.4%	35.5%	$1.37	$67.33	$103.29	($248.40)	($44.81)
Electric heat pump	73.4%	60.6%	61.5%	$32.80	$69.47	$106.14	($407.24)	($153.17)
Propane furnace	2%	4%	3%	$1.37	($31.78)	($28.86)	($413.60)	($243.04)

Weighted savings	100%	100%	100%	$24.43	$66.79	$102.62	($369.87)	($129.23)

For a nominal discount rate of 5.3% (real discount rate of 3%), assuming SCC = $51 per metric ton:

Table 12. Cost Effectiveness Results for Cool Roof Measure, **including** SCC, nominal discount rate of **5.3%**

Scenario	Heating System Prevalence for CZ1 (% of single-family homes)	Heating System Prevalence for CZ2 (% of single-family homes)	Heating System Prevalence for CZ3 (% of single-family homes)	LCC ($) 1A	LCC ($) 2A	LCC ($) 2B	LCC ($) 3A	LCC ($) 3B
Natural gas furnace	24.6%	35.4%	35.5%	$109.32	$181.30	$221.94	($199.39)	$41.02
Electric heat pump	73.4%	60.6%	61.5%	$146.78	$190.48	$234.18	($377.62)	($74.84)
Propane furnace	2%	4%	3%	$109.32	$80.52	$87.56	($367.36)	($160.55)
Weighted savings	**100%**	**100%**	**100%**	**$137.23**	**$186.34**	**$228.58**	**($312.44)**	**($36.52)**

For a nominal discount rate of 9.3% (real discount rate of 7%), assuming SCC = $0 (ignoring carbon):

Table 13. Cost Effectiveness Results for Cool Roof Measure, **excluding** SCC, nominal discount rate of **9.3%**

Scenario	Heating System Prevalence for CZ1 (% of single-family homes)	Heating System Prevalence for CZ2 (% of single-family homes)	Heating System Prevalence for CZ3 (% of single-family homes)	LCC ($) 1A	LCC ($) 2A	LCC ($) 2B	LCC ($) 3A	LCC ($) 3B
Natural gas furnace	24.6%	35.4%	35.5%	($12.16)	$30.71	$53.93	($170.66)	($40.28)
Electric heat pump	73.4%	60.6%	61.5%	$7.93	$31.37	$54.81	($273.37)	($110.95)
Propane furnace	2%	4%	3%	($12.16)	($29.21)	($25.96)	($270.51)	($160.10)
Weighted savings	**100%**	**100%**	**100%**	**$2.53**	**$29.88**	**$52.88**	**($249.08)**	**($95.16)**

For a nominal discount rate of 9.3% (real discount rate of 7%), assuming SCC = $51 per metric ton:

Table 14. Cost Effectiveness Results for Cool Roof Measure, **including** SCC, nominal discount rate of **9.3%**

Scenario	Heating System Prevalence for CZ1 (% of single family homes)	Heating System Prevalence for CZ2 (% of single family homes)	Heating System Prevalence for CZ3 (% of single family homes)	LCC ($) 1A	LCC ($) 2A	LCC ($) 2B	LCC ($) 3A	LCC ($) 3B
Natural gas furnace	24.6%	35.4%	35.5%	$53.68	$100.22	$126.30	($140.76)	$12.08
Electric heat pump	73.4%	60.6%	61.5%	$77.45	$105.18	$132.91	($255.30)	($63.18)
Propane furnace	2%	4%	3%	$53.68	$39.29	$45.05	($242.31)	($109.79)
Weighted savings	**100%**	**100%**	**100%**	**$71.33**	**$102.79**	**$129.70**	**($213.13)**	**($37.90)**

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Proposed modifications for REPI-68

Original proposed changes shown in black. Modifications relative to REPI-68 shown in blue.

Summary of changes:

- Changed definitions to remove "giving a" for slope and to align with IBC definitions.
- Moved climate zone requirements from the exceptions to the charging language and only required in Climate Zones 0-3 (instead of CZs 0-5).
- Added radiant barrier as exception #1
- Cleaned up exception language for clarity
- Added R402.6 to Table R406.2

Add new definition as follows:

LOW-SLOPED ROOF. A roof ~~giving a~~ slope less than 2 units vertical in 12 units horizontal (17-percent slope).

STEEP-SLOPED ROOF. A roof ~~giving a~~ slope ~~greater than or equal to~~ 2 units vertical in 12 units horizontal (17-percent slope) or greater.

Add new text as follows:

R402.6 Roof Reflectance.

Roofs in Climate Zones 0 through 3 shall comply with one or more of the options in Table R402.6.

Table R402.6 Minimum roof reflectance.[a]

Roof slope	Three-year aged solar reflectance index [b]
Low-slope	75[b, c]
Steep-slope	16

a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for solar reflectance shall be assigned a 3-year-aged solar reflectance in accordance with Section R402.6.1

b. Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-S100.

c. Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h × ft 2 × °F (12 W/m 2 × K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.

Exceptions: ~~The following roofs and portion of roofs are exempt from the requirements of Table R402.6:~~

1. ~~Roofs in climate zones 6-8~~ Roofs with a radiant barrier with an emittance of 0.05 or less.
2. Portions of the roof that include or are covered by one or more of the following:

    2.1. ~~Photovoltaic~~ *On-site renewable energy* systems or components
    2.2. Solar air or water heating systems or components
    2.3. Vegetative roofs or landscaped roofs
    2.4. Above roof decks or walkways
    2.5. Skylights
    2.6. HVAC systems and components, and other opaque objects mounted above the roof

3. Portions of roof shaded during the peak sun angle on the summer solstice by permanent features of the building or by permanent features of adjacent buildings.
4. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot ($74 kg/m^2$) or 23 psf ($117 kg/m^2$) pavers.
5. Roofs where portions exempted by exceptions 2, 3, and 4 make up ~~more~~ not less than 75 percent of the total roof area. ~~complies with one or more of the exceptions below~~:

R402.6.1 Aged roof solar reflectance.

Where an aged solar reflectance required by Section R402.6 is not available, it shall be determined in accordance with Equation 4-3.

Equation 4-3

$R_{aged}=[0.2+0.7(R_{initial}-0.2)]$

where:

R_{aged} = The aged solar reflectance.

$R_{initial}$ = The initial solar reflectance determined in accordance with CRRC-S100.

Revise Table R405.2(1) as follows:

TABLE R405.4.2(1) (TABLE N1105.4.2(1)) SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Roofs	Type: ~~composition shingle on wood sheathing~~ Low-sloped: Modified bitumen Steep-sloped: asphalt shingles	As proposed

	Gross Area: same as proposed	As proposed
	Low-sloped: (Aged) Solar ~~absorptance~~ reflectance = ~~0.75~~ 0.63 Steep-sloped: (Aged) Solar reflectance = 0.2	As proposed
	Thermal Emittance = ~~0.9~~ 0.75	As proposed

Revise Table R406.2 as follows:

TABLE R406.2 REQUIREMENTS FOR ENERGY RATING INDEX

SECTION	TITLE
Building Thermal Envelope	
R402.6	Roof Reflectance

R407.2 Tropical Climate Region

Compliance with this section requires the following:

1. Not more than one-half of the occupied space is air conditioned.
2. The *occupied* space is not heated.
3. Solar, wind or other renewable energy source supplies not less than 80 percent of the energy for service water heating.
4. Glazing in *conditioned spaces* has a *solar heat gain coefficient* (SHGC) of less than or equal to 0.40, or has an overhang with a projection factor equal to or greater than 0.30.
5. Permanently installed lighting is in accordance with Section R404.
6. The exterior roof surface complies with one of the options in Table ~~C402.3~~R402.6 ~~of the International Energy Conservation Code- Commercial Provisioner the roof~~ or ceiling has insulation with an *R-value* of R-15 or greater. Where attics are present, attics above the insulation are vented and attics below the insulation are invented.
7. Roof surfaces have a slope of not less than ¼ unit vertical in 12 units horizontal (21-percent slope). The finished roof does not have water accumulation areas.
8. Operable fenestration provides a ventilation area of not less than 14 percent of the floor area in each room. Alternatively, equivalent ventilation is provided by a ventilation fan.
9. Bedrooms with *exterior walls* facing two different directions have operable fenestration on exterior walls facing two directions.
10. Interior doors to bedrooms are capable of being secured in the open position.
11. A ceiling fan or ceiling fan rough-in in provided for bedrooms and the largest space that is not used as a bedroom.

R503.1.1. Building Envelope

Building envelope assemblies that are part of the *alteration* shall comply with Section 402.1.2 or R402.1.4, Sections R402.2.1 through R402.2.12, R402.3.1, R402.3.2, R402.4.3, R402.6 and R402.4.5.

Exception: The following alterations shall not be required to comply with the requirements for new construction provided that the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.
2. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation.
3. Construction where the existing roof, wall or floor cavity is not exposed.
4. Roof recover where the new roofing meets the reflectance requirements under R402.6.
5. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
6. Surface-applied window film installed on existing single pane fenestration assemblies to reduce solar heat gain provided that the code does not require the glazing or fenestration assembly to be replaced.

Add new standard(s) as follows:

ASTM ASTM International 100 Barr Harbor Drive, P.O. Box C700 West Conshohocken PA 19428-2959

ASTM C1549-2016 Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer

ASTM E903-2012 Standard Test Method for Solar Absorptance, Reflectance and Transmittance of Materials Using Integrating Spheres (Withdrawn 2005)

ASTM E1918-06(2016) Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-sloped Surfaces in the Field

ASTM E1980- 11 Standard Practice for Calculating Solar Reflectance of Horizontal and Low-sloped Opaque Surfaces

CRRC Cool Roof Rating Council 2435 North Lombard Street Portland OR 97217

ANSI/CRRC-S100-2020 Standard Test Methods for Determining Radiative Properties of Materials

REPI-77-21

IECC®: SECTION 202 (New), R403.3, TABLE R403.3 (New), R403.3.2, R403.3.3, TABLE R403.3.2 (New), R403.3.3.1, TABLE R405.4.2(1)

Proponents:

David Springer, representing on behalf of the California Statewide Utility Codes and Standards Team (iecc-ducts2@2050partners.com); Mark Lyles, representing New Buildings Institute (markl@newbuildings.org)

2021 International Energy Conservation Code

Add new definition as follows:
HIGH PERFORMANCE ATTIC. A vented attic with insulation at the roof deck having an insulation value of not less than R-19 and insulation at the ceiling in compliance with Table R402.1.3.
Revise as follows:
R403.3 Ducts.

Ducts and air handlers shall be installed in accordance with Table R403.3 and Sections R403.3.1 through R403.3.7.

Add new text as follows:

TABLE R403.3 DUCT LOCATION[a,b]

CLIMATE ZONE	DUCT LOCATION
0A, 1A, 2A, 3A	R403.3.1 or R403.3.3
0B, 1B	R403.3.1 or R403.3.3
4A, 5A	R403.3.1 or R403.3.2
2B, 3B, 3C, 4B, 4C, 5B, 5C	R403.3.1, R403.3.2, or within a *high performance attic*
6A, 6B, 7, 8	R403.3.1 or R403.3.3

a. Where the air handler is located outside of conditioned space, up to 10 feet of ductwork shall be allowed to be installed outside of conditioned space. Ductwork outside of conditioned space shall be insulated to an R-value of not less than R-8.

b. Ducts buried beneath a building shall be insulated to an R-value of not less than R-8.

Revise as follows:
R403.3.1 ~~R403.3.2~~ Ducts located in conditioned space.

For ductwork to be considered inside a *conditioned space,* it shall comply with one of the following:

1. The duct system shall be located completely within the *continuous air barrier* and within the building thermal envelope, including within a non-vented attic space.

2. Ductwork in ventilated attic spaces shall be buried within ceiling insulation in accordance with Section R403.3.3 ~~and all of the following conditions shall exist:~~

   ~~2.1. The air handler is located completely within the *continuous air barrier* and within the *building thermal envelope*.~~

   ~~2.2. The duct leakage, as measured either by a rough-in test of the ducts or a post-construction total system leakage test to outside the *building thermal envelope* in accordance with Section R403.3.6, is less than or equal to 1.5 cubic feet per minute (42.5 L/min) per 100 square feet (9.29 m²) of *conditioned floor area* served by the duct system.~~

   ~~2.3. The ceiling insulation *R* value installed against and above the insulated duct is greater than or equal to the proposed ceiling insulation *R* value, less the *R* value of the insulation on the duct.~~

3. Ductwork in floor cavities located over unconditioned space shall comply with all of the following:

   3.1. A *continuous air barrier* installed between unconditioned space and the duct.

   3.2. Insulation installed in accordance with Section R402.2.7.

   3.3. A minimum R-19 insulation installed in the cavity width separating the duct from unconditioned space.

4. Ductwork located within *exterior walls* of the *building thermal envelope* shall comply with the following:

   4.1. A *continuous air barrier* installed between unconditioned space and the duct.

   4.2. Minimum R-10 insulation installed in the cavity width separating the duct from the outside sheathing.

   4.3. The remainder of the cavity insulation shall be fully insulated to the drywall side.

R403.3.2 ~~R403.3.3~~ Ducts buried within ceiling insulation.

Where supply and return air ducts are partially or completely buried in ceiling insulation, such ducts shall comply with all of the following:

1. The supply and return ducts shall have an insulation *R*-value not less than ~~R-8~~ R-13 for ducts 10 inches (76 mm) in diameter and larger and not less than R-8 for ducts smaller than 10 inches (76 mm) in diameter.

2. At all points along each duct, ~~the sum of the ceiling insulation *R*-value against and above the top of the duct, and against and below the bottom of the duct, shall be not less than R-19, excluding the *R*-value of the duct insulation.~~ the ducts shall be located directly on or within 5.5 inches (140 mm) of the ceiling.

~~3.~~ ~~In Climate Zones 0A, 1A, 2A and 3A, the supply ducts shall be completely buried within ceiling insulation, insulated to an *R*-value of not less than R-13 and in compliance with the vapor retarder requirements of Section 604.11 of the International Mechanical Code or Section M1601.4.6 of the International Residential Code, as applicable.~~

~~**Exception:** Sections of the supply duct that are less than 3 feet (914 mm) from the supply outlet shall not be required to comply with these requirements.~~

Add new text as follows:

TABLE R403.3.2 EQUIVALENT DUCT R-VALUE FOR BURIED DUCTS

	LARGEST NOMINAL DUCT SIZE (R-8)								
CEILING R-VALUE	**6**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20**
R-30	R-13	R-13	R-13	R-8	R-8	R-8	R-8	R-8	R-8
R-38	R-18	R-13	R-13	R-13	R-13	R-8	R-8	R-8	R-8
R-49	R-26	R-18	R-18	R-13	R-13	R-13	R-8	R-8	R-8
R-60	R-26	R-26	R-26	R-26	R-26	R-18	R-18	R-13	R-13

Revise as follows:

R403.3.3 ~~R403.3.3.1~~ ~~Effective R-value of deeply~~ Deeply buried ducts.

Where supply and return air ducts are required to be deeply buried, such ducts shall comply with all of the following:

1. The air handler is located completely within the *continuous air barrier* and within the *building thermal envelope*.

2. The duct leakage, as measured either by a rough-in test of the ducts or a postconstruction total system leakage test to outside the *building thermal envelope* in accordance with Section R403.3.6, is less than or equal to 1.5 cubic feet per minute (42.5 L/min) per 100 square feet (9.29 m2) of *conditioned floor area* served by the duct system.
3. ~~Where using the Total Building Performance Compliance Option in accordance with Section R401.2.2 , sections of ducts that are installed in accordance with Section R403.3.3,~~ The ducts shall be located directly on or within 5.5 inches (140 mm) of the ceiling, surrounded with blown-in attic insulation having an *R*-value of R-30 or greater and located such that the top of the duct is not less than 3.5 inches (89 mm) below the top of the insulation, shall be considered as having an effective duct insulation *R*-value of R-25.
4. In Climate Zones 0A, 1A, 2A, and 3A the supply ducts shall be encapsulated with 1½" of closed cell spray urethane foam insulation.

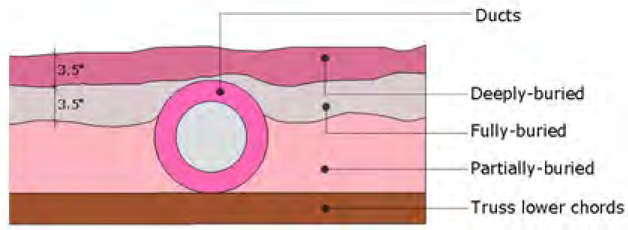
TABLE R405.4.2(1) SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

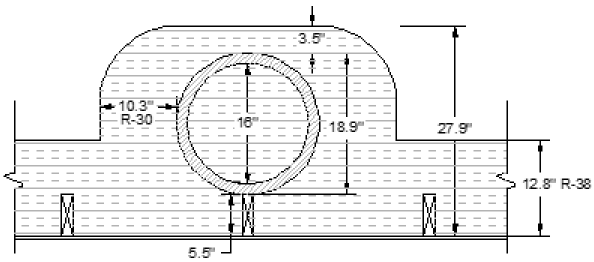
BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Thermal distribution systems	Duct insulation: in accordance with Section R403.3.1. A thermal distribution system efficiency (DSE) of 0.88 shall be applied to both the heating and cooling system efficiencies for all systems other than tested duct systems. Duct location: same as proposed design. **Exception:** For nonducted heating and cooling systems that do not have a fan, the standard reference design thermal distribution system efficiency (DSE) shall be 1. For tested duct systems, the leakage rate shall be 4 cfm (113.3 L/min) per 100 ft^2 (9.29 m^2) of *conditioned floorarea* at a pressure of differential of 0.1 inch w.g. (25 Pa).	Duct location: as proposed. For ducts complying with Section R403.3.3, ducts shall be considered in conditioned space. Duct insulation: as proposed. For ducts complying with Section R403.3.2, the effective R-value of the duct shall be considered as listed in Table R403.3.2. For ducts complying with Section R403.3.3 the effective R-value shall be R-25. As tested or, where not tested, as specified in Table R405.4.2(2).

Reason Statement:

This measure would increase stringency for duct distribution efficiency and encourage ducts in conditioned space and other distribution efficiency alternatives by adding a table that specifies prescriptive requirements for different duct locations and insulation requirements by climate zone. Another table is added that describes effective R-values for partially or fully buried ducts. The exclusion of duct insulation requirements (Section 403.3) is eliminated from the Total Building Performance table. Requirements for fully buried ducts that qualify them as ducts in conditioned space were clarified, as well as for ducts in a non-vented attic that qualify as ducts in conditioned space.
IECC Section 403.3.1 requires minimum R-8 duct insulation and allows ducts to be installed in a vented attic, which is less stringent than the California Title 24 prescriptive requirement that ducts must be located in a High-Performance Ventilated Attic (HVPA) or in Conditioned Space (DCS). HPVAs are a lower cost alternative to DCS for reducing duct loss in warmer, drier climate zones, but in cold climates they are susceptible to water damage resulting from condensation on or within roof decks.

For Prescriptive and Total Building compliance, IECC requires at least one "Additional Efficiency Package" to be selected. This list includes ducts and air handlers installed in conditioned space (R408.2.4). The added Table 403.3 allows DCS as a prescriptive option while allowing lower cost options, without precluding DCS from being used as an Additional Efficiency Package measure.

As of 2018 the IECC recognizes buried ducts, but unlike Title 24 (Alternative Calculation Manual 2.4.4.10), IECC apparently provides no performance credit for partially or fully buried ducts, nor does it require a duct design. Deeply buried ducts continue to qualify as DCS and are given an R-value of 25 if they meet specific requirements that are included 2021 IECC Sections R403.3.2(2), R403.3.3(3), and R403.3.3.1The first figure below (from Shapiro 2013) illustrates differences between partially, fully, and deeply buried ducts. The second figure shows a 16-inch R-8 deeply buried duct installed in an R-38 attic that meets the requirements of R403.3.3.1. Covering the top of the duct with 3.5 inches of blown-in insulation would make the depth of insulation surrounding the duct nearly 28 inches deep. It could be difficult to fit this assembly into a low attic, and insulation to that depth would have to be mounded several feet laterally around the duct to prevent slough-off. In humid climate zones it is necessary to encapsulate the duct in 1.5 inches of spray foam to prevent surface condensation. The 2021 IECC leakage to outside limitation of 1.5 cfm per 100 ft^2 of conditioned floor area may also be difficult to attain, though encapsulation will reduce leakage. 



For the Total Building Performance compliance option in Section R405, the standard reference design Distribution System Efficiency (DSE) is 0.88 in Table R405.4.2(1), regardless of climate zone or duct location. For the proposed design, the DSE is either as tested or the default value of 0.88 if ducts are in conditioned space, and as tested if any part of the distribution system is outside conditioned space. The Prescriptive compliance option requirements in Section R403.3.6 require duct testing, but Tables R405.2 (Total Building Performance) and R406.2 (ERI) exclude this requirement.
The following code language changes are recommended to improve clarity and add options for improved distribution efficiency:

- Add prescriptive alternatives for partially/fully buried ducts and for ducts in high performance attics for all climate zones and include a table in R403.3 that provides a single, conservative equivalent duct insulation value for partially or fully covered ducts given the attic insulation R-value and the diameter of the largest duct.
- Change the current requirement for R-13 duct insulation in Zones 0A-3A when ducts are fully buried to a requirement to encapsulate them in 1.5 inches of closed cell spray foam insulation.
- Consolidate all deeply buried duct requirements (qualifying it as DCS) in one code section, including insulation requirements and duct leakage.
- Explicitly add ducts and air handlers in a non-vented attic that is inside the *continuous air barrier* as a DCS option.

The proposed code change provides clear duct location and insulation options that vary by climate zone that add flexibility and that can reduce costs of systems with higher distribution effectiveness. This will encourage more thoughtful and appropriate duct design and installation practices that will result in significant energy savings and comfort improvements over the currently allowed R-8 attic ducts. The language will also be easier for builders and code officials to follow.

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Cost Impact:

The code change proposal will increase the cost of construction.

Distribution effectiveness will be improved by requiring enhancements that reduce losses from R-8 ducts in standard vented attics. This will reduce heating and cooling energy use and hot climate peak loads. Simulations by the Consortium for Advanced Residential Buildings predicted annual energy savings of 5% to 20% for deeply buried ducts (Hoeschele 2015). To quantify annual savings prototype houses must be modeled in each climate zone and for each duct system type.

Costs will vary by climate zone, distribution system type, construction details, system size, and other factors. Reduced loads open the possibility of specifying lower capacity systems which can save on equipment costs. Costs can also be minimized by applying creative solutions such as designing trusses to accommodate a plenum space for ducts, and advanced equipment approaches such as multi-split heat pumps or distributed hydronic fan coils supplied by air-to-water heat pumps.

Ducts in Conditioned Space. Hoeschele (2015) cites cost components for various methods for moving ducts into conditioned space, including the value of floor space for locating heating and cooling equipment indoors, the cost of sealing duct chases, cost savings for reducing the size of equipment due to reduced loads, costs for dropping ceilings or creating attic chases to house the ducts, and cost savings for compact duct designs. The study estimated the range of costs for moving ducts to conditioned space, either by creating attic duct chases or furring out duct chases below the ceiling was from $373 to $3,129 for a 2,100 ft^2 one story prototype and $286 to $2,388 for a two-story 2,700 ft^2 prototype. Costs for dropped ceilings were lower than for attic chases. Use of "plenum trusses" demonstrated in Building America projects could reduce these costs.

Non-Vented Attics. Hoeschele (2015) used actual costs from a production builder to estimate costs for 2,100 ft2 one-story and 2,700 ft2 two-story prototype houses based on R-30 foam roof deck insulation. Net costs including air conditioner savings. Estimated costs were $1.37 and $0.69 per square foot for the two prototypes, respectively.

High-Performance Attics. A Codes and Standards Enhancement report (CEC 2015) prepared for the California Energy Commission to support a 2016 Title 24 standards change estimated incremental costs for a "blended" 2,430 ft^2 house of $589 to $1,042, depending on climate zone.

Buried Ducts. Proposed changes will have no impact on costs and may reduce insulation costs and simplify compliance and verification by eliminating the need to provide R-19 insulation under or over larger ducts that are not fully buried in attic insulation.

Deeply Buried Ducts. Shapiro (2013) determined that buried ducts in humid climates must be encapsulated in ccSPF insulation to prevent condensation. Hoeschele (2015) estimated total incremental costs of $1,383 and $1,059 for the 2,100 and 2,700 ft^2 prototypes, respectively. Costs included increasing attic insulation from R-30 to R-60 to achieve a weighted average duct R-value of 20.

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IECC®: R408.2.6 (N1108.2.6) (New), ASTM Chapter 06 (New)

Proponents:

Amanda Hickman, representing Reflective Insulation Manufacturers Association (RIMA) (amanda@thehickmangroup.com)

2021 International Energy Conservation Code

Add new text as follows:
R408.2.6 (N1108.2.6) Radiant barriers installed in vented attics.

In Climate Zones 1, 2, and 3, vented attics shall be installed with radiant barriers. Radiant barriers shall be tested in accordance with ASTM C1313/1313M and installed in accordance with ASTM C1743.

Add new standard(s) as follows:

ASTM ASTM International 100 Barr Harbor Drive, P.O. Box C700 West Conshohocken PA 19428-2959

C1313/C1313M-13(2019) Standard Specifications for Sheet Radiant Barriers Construction Applications

ASTM ASTM International 100 Barr Harbor Drive, P.O. Box C700 West Conshohocken PA 19428-2959

C1743-19	Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction

Reason Statement:

This language is being proposed to add an additional option to this section to increase flexibility and energy savings. According to the DOE[1], some studies show that radiant barriers can reduce cooling costs 5% to 10% when used in a warm, sunny climate. The reduced heat gain may even allow for a smaller air conditioning system. https://www.energy.gov/energysaver/weatherize/insulation/radiant-barriers

In cooling climates, attic radiant barriers (ARBs) have been shown to conserve substantial amounts of energy by reducing temperatures in vented attics. Lower attic temperatures slow the rate of temperature differential – driven heat transfer from ceiling envelope elements and HVAC equipment and ducting.

Attic radiant barriers are extensively used across Climate Zones 1, 2 and 3, i.e. in the sunbelt areas, and numerous demonstration projects and studies have confirmed the energy savings and cost-effectiveness of these installations. Such radiant barrier products have been on the market for over 24 years and are used by 87 of the top 100 US Builders. They have an established history and have been accepted into several regional code requirements and are included in the Energy Star Reference Home Guidelines. Over one billion square feet of radiant barriers are installed annually.
The codes that include radiant barrier are:

IBC 2021

- Section 1510, Radiant Barriers Installed Above Deck

Hawaii Title 3, Chapter 181.1 2015

- Section 407.2 Requirements
- Table 407.1 Points Option

Texas

- City of Austin Ordinance No. 20210603-055, City Code Chapter 12-25, Article 12, R402.6

2020 Florida Building Code, Energy Conservation, 7th Edition

- R405.7.1 Installation criteria for homes claiming the radiant barrier option
- Figure R405.7.1 Acceptable attic radiant barrier configurations
- Table 303.2.1 Insulation Installation Standards

2019 California Title 24, Part 6

- Section 100.1 Definitions
- Section 110.8 Mandatory requirements for insulation, roofing products and radiant barriers

This product has two ASTM Standards that are applicable – ASTM C1313, “Standard Specification for Sheet Radiant Barriers for Building Construction Applications,” and ASTM C1743, “Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Residential Building Construction”. This proposal requires the use of radiant barriers in a manner consistent with the existing language in the Energy Star for Homes – “Version 3, Exhibit 1” and, additionally, requires that the radiant barriers comply with the two ASTM standards just referenced.

A comprehensive review of radiant barrier studies was performed by Mario Medina, Ph.D. P.E. “This paper provides a general description of RBs, including installation configurations, the physical principles that make them work, and the laboratory and field experiments used to evaluate their thermal performance. An extensive review of the literature is summarized, highlighting fundamental issues, such as reduced ceiling heat flows, reduced space cooling and heating loads, and changes in attic temperatures produced by the installation of RBs in residential attics.”

[2] The document has been mentioned here as an additional reference related to radiant barrier product information and to highlight the scope of “benefit” studies that have been completed.

Another study, performed in 2008 by the Energy Center of Appalachian State University[3], compared a pair of adjacent four-bedroom Centex model homes in Charlotte using a total of 61 senors installed in and outside of the houses. It found:

* A 23-degree drop in the peak attic temperature in the home outfitted with radiant heat barrier versus the similar home without the barrier;

* A 20% reduction in the run-time of the air conditioning unit during the seven hours of peak attic temperatures;

* A 57% improvement in the efficiency of cooled air delivered through the air ducts during the same period.

Bibliography:

[1]Department of Energy - Energy Saver website https://www.energy.gov/energysaver/weatherize/insulation/radiant-barriers

[2] Medina, Mario, “A Comprehensive Review of Radiant Barrier Research Including Laboratory and Field Experiments”, report prepared for the Reflective Insulation Manufacturers Association.

[3] Davis, Bruce Eugene & Tiller, Jeffrey, “Radiant Barrier Impact on Selected Building Performance Measurements, Model Home Case Study, Centex Homes“.

Cost Impact:

The code change proposal will neither increase nor decrease the cost of construction.

This proposal only adds an additional cost-effective option to R408, which will promote more flexibility in the code.

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