Residential Energy in PA

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PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

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Pennsylvania Housing Research Center

- The Pennsylvania Housing Research Center (PHRC) provides and facilitates education, training, innovation, research, and dissemination to the residential construction industry for the purpose of improving the quality and affordability of housing.
- Educational programs and publications by the PHRC address a wide range of topics relevant to the home building industry and are designed to reach a diverse audience: builders, code officials, remodelers, architects, developers, engineers, planners, landscape architects, local government officials, educators, etc. to provide professional development and continuing education

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Description

One of the more challenging portions of the Uniform Construction Code (UCC) for residential builders is the ongoing evolution of energy code provisions. This session will provide an overview of the energy-related code provisions in the UCC with an emphasis on the recent changes associated with the 2018 ICC adoption. More specifically, this session will dive into some of the ongoing challenges faced by builders and contractors, including air sealing and blower door testing, energy code compliance paths, and the PA Alternative Residential Energy Provisions. This session will require some storytelling on the part of attendees – the speakers will want to know where the stress is the greatest in their markets as it relates to energy.

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What Is Building Science?

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What Is Building Science?

- The study of the interaction between
  - Occupants
  - Building components/systems, and
  - Environment
- Focusing on flows of
  - Heat
  - Air
  - Moisture

5

Source: DOE Building America

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What is the Building Enclosure?

- "That part of any building that physically separates the exterior environment from the interior environment(s) is called the building enclosure or building envelope."

  - Dr. John Straube, BSD-018: The Building Enclosure

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Building Enclosure Functions

- Support (structural)
- Control (heat, air, moisture, smoke, odor, sound, fire, insects, etc.)
- Aesthetics (exterior and interior finishes)
- Distribution of Services (MEP)

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Building Science Principles

- Heat Flow
- Moisture Flow
- Air Flow

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Heat/Moisture/Air Flow

- "Control" function
- Heat, air, and moisture flow through the building enclosure based on differences in pressures or concentrations
- High pressure ⟶ low pressure
- High concentration ⟶ low concentration

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Heat Flow

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Heat Flow

- From hot to cold (high concentration to low concentration)
- Summer - flow directed inward
- Winter - flow directed outward

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Heat Flow Mechanisms – Conduction

- Conduction
  - Heat flow through a substance or material by direct contact
  - Conduction takes place within a single material or between materials in direct contact
- Where does conduction occur in a home?

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Heat Flow Mechanisms – Convection

- Convection
- Transfer of heat through air (for building enclosures)
- Where does convection occur in a home?

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Heat Flow Mechanisms – Radiation

- Radiation
  - Transfer of heat through electromagnetic waves traveling in a gas or vacuum
- Where does radiation occur in a home?

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Managing Heat

- When a thermal gradient is present, heat flow cannot be stopped, but can be managed by installing thermal insulation
- Heat will always flow through path of least resistance
- How do we measure the insulating value of different materials?

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Thermal Properties

- Thermal resistance (R-Value)
  - Higher R-Value = better insulating value
- Thermal transmittance (U-Value)
- U-Value = 1/(R-Value)
  - R-Value = Insulation
  - U-Value = Fenestration

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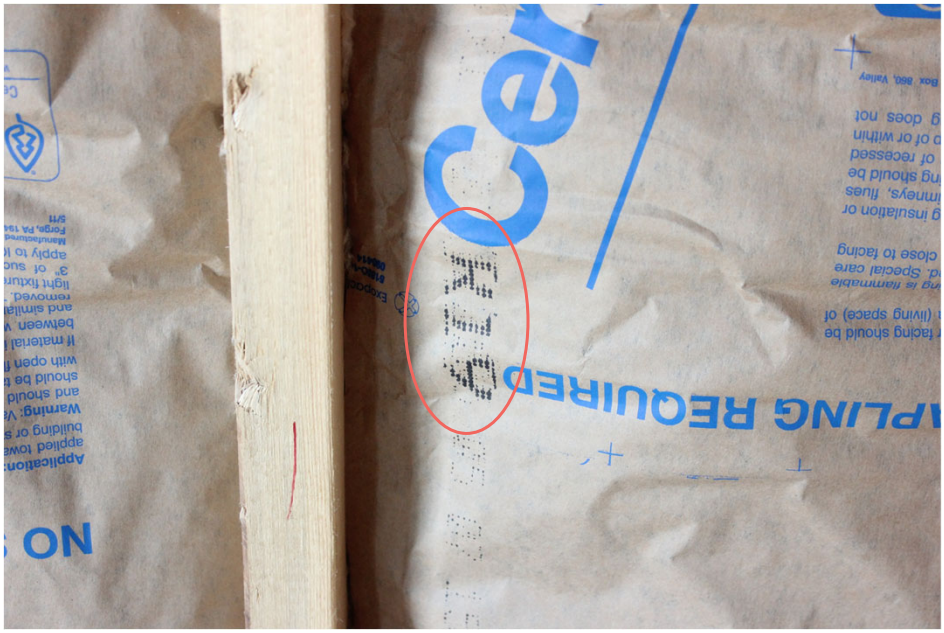

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Conductive Heat Loss

- $Q = U \times A \times \Delta T$
  - Q = heat flow (Btu/hr)
  - U = thermal conductivity (U = 1/R)
  - A = surface area (square feet)
  - ΔT = temperature difference across component (°F)

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Thermal Bridging

- Material with lower R-Value allowing heat to pass through assembly with much higher overall R-Value
- Example: Wood stud wall
  - Insulation (cavity) = R-20
  - 2x6 stud ~ R-7.5

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Building Enclosure Functions

- Support (structural)
- Control (heat, air, moisture, smoke, odor, sound, fire, insects, etc.)
- Aesthetics (exterior and interior finishes)
- Distribution of Services (MEP)

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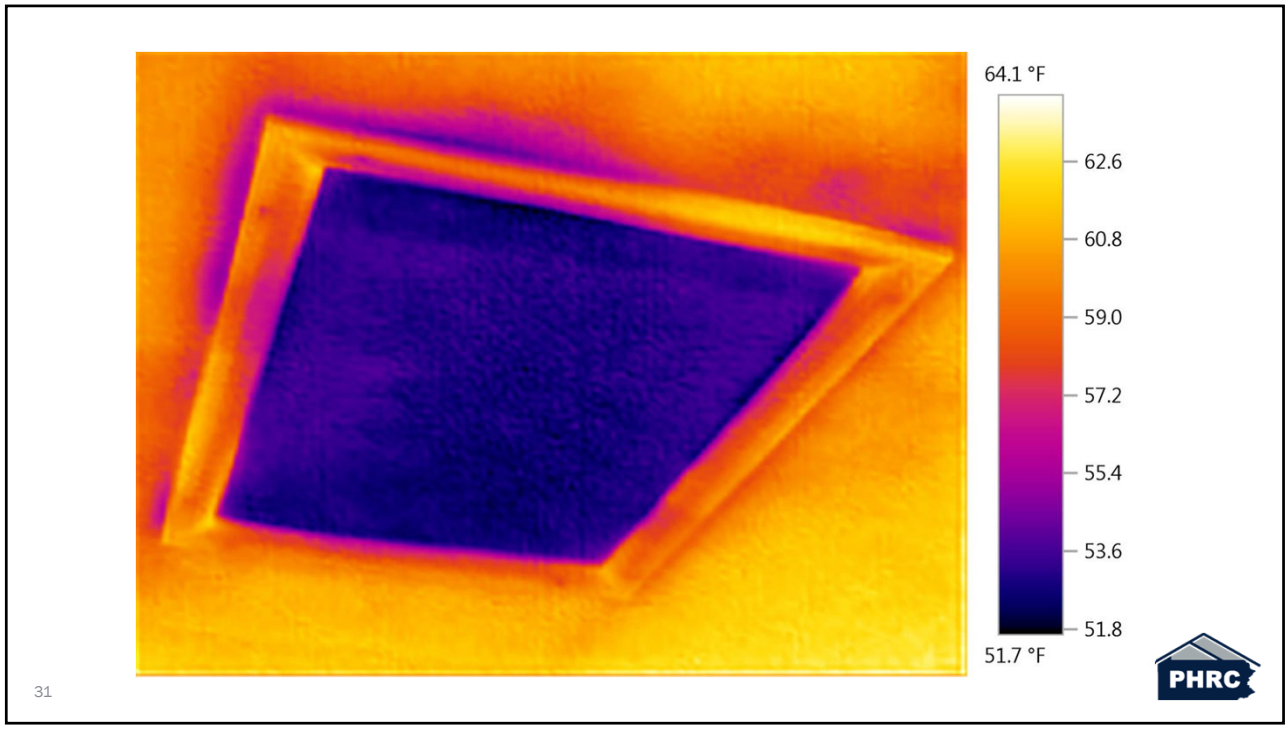
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62.6
60.8
59.0
57.2
55.4
53.6
51.8
51.7 °F
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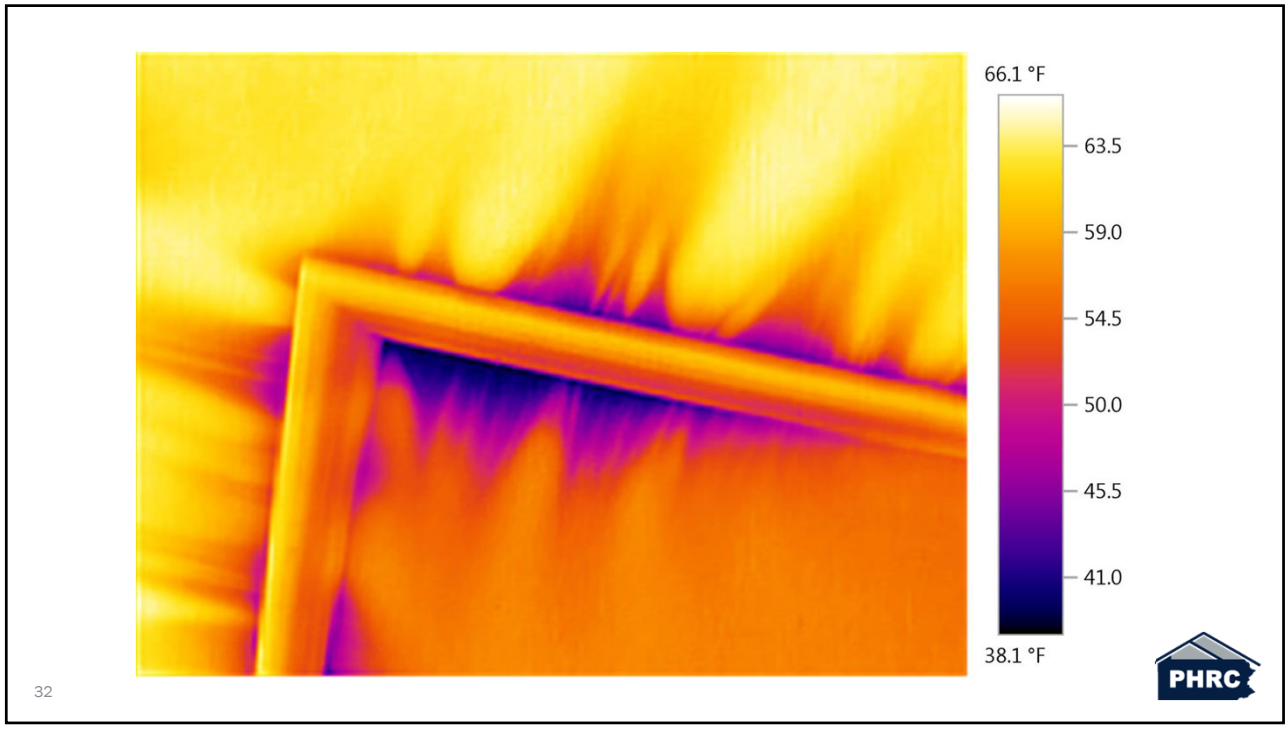
66.1 °F
63.5
59.0
54.5
50.0
45.5
41.0
38.1 °F
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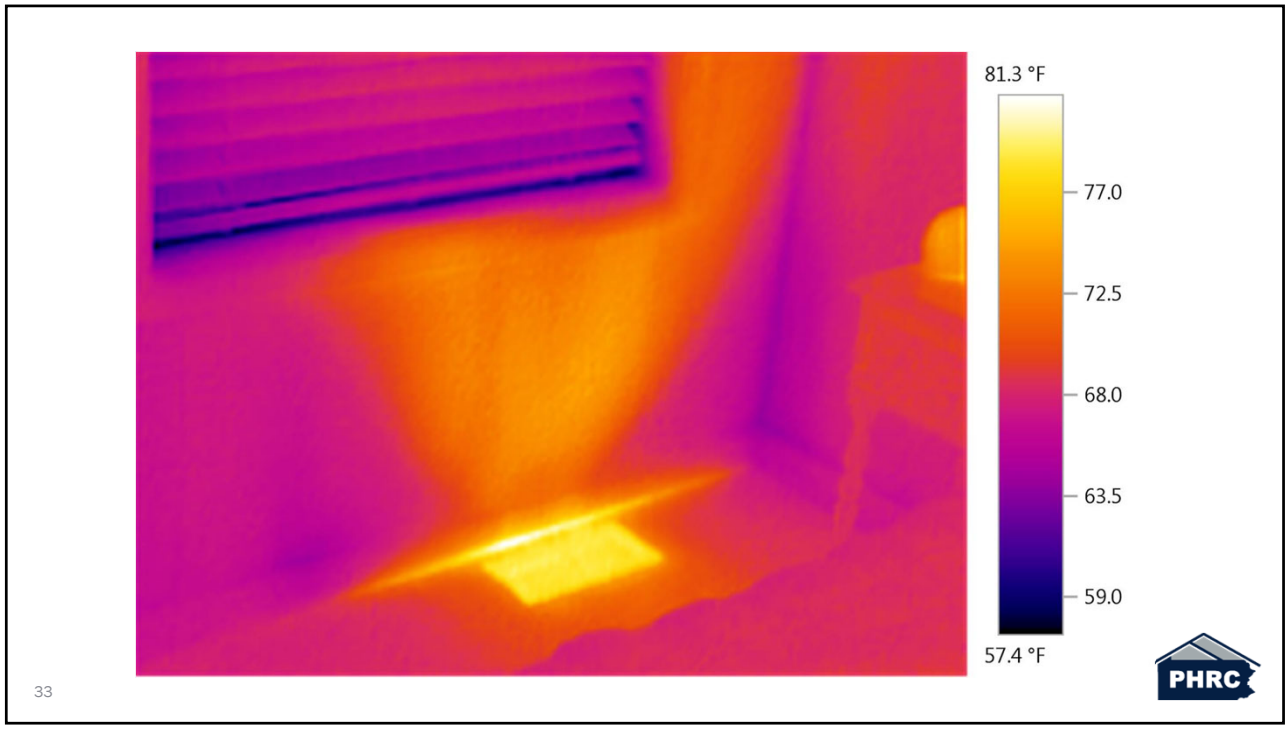
81.3 °F
77.0
72.5
68.0
63.5
59.0
57.4 °F
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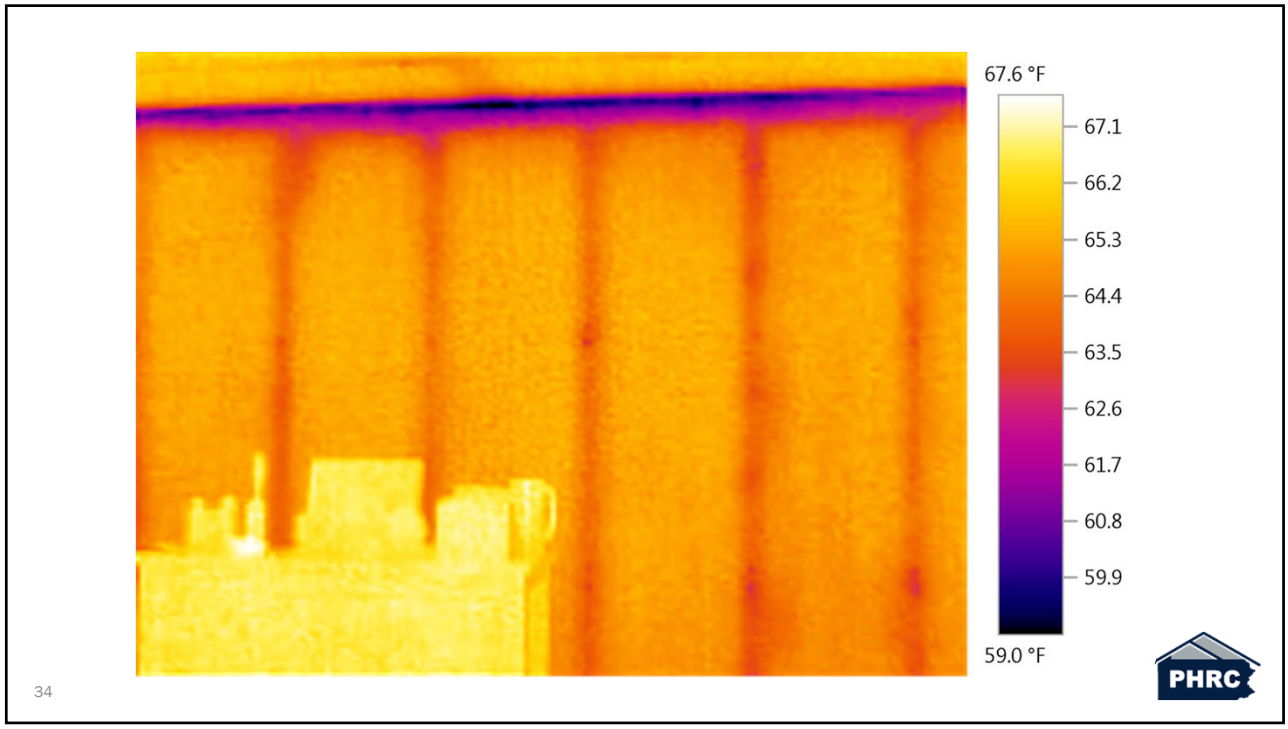
67.6 °F
67.1
66.2
65.3
64.4
63.5
62.6
61.7
60.8
59.9
59.0 °F
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Air Flow

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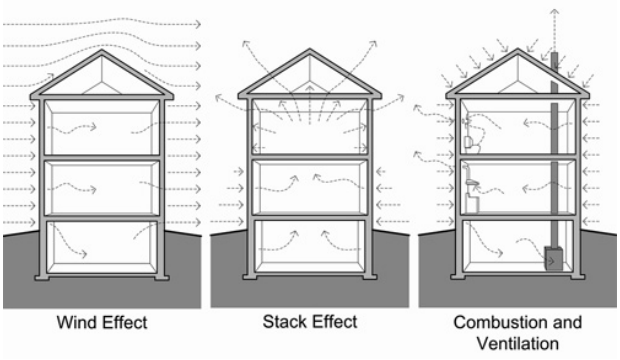
Wind

- Positive Pressure at Windward side
- Negative Pressure at Leeward side



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Source: "BSD-014: Air Flow Control in Buildings" (Building Science Corporation)

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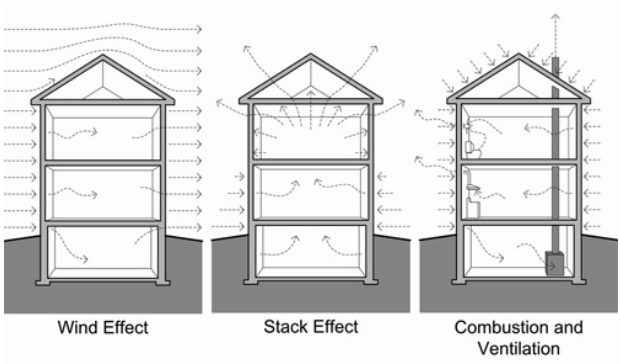
Stack Effect

- Hot air rises
  - Exfiltration above Neutral Pressure Plane
  - Infiltration below Neutral Pressure Plane



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Source: "BSD-014: Air Flow Control in Buildings" (Building Science Corporation)

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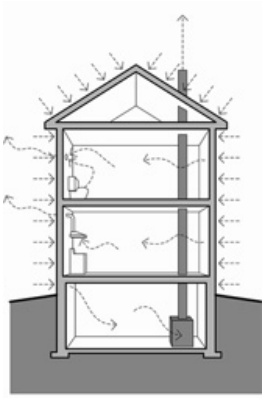
Mechanical System Operation

- Bath fans
- Dryer exhaust
- Range hoods
- HVAC units
  - Duct leakage can pressurize or depressurize depending on the location of the leaks
    - Supply side leaks = depressurization
    - Return side leaks = pressurization



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Source: "BSD-014: Air Flow Control in Buildings" (Building Science Corporation)

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Effects of Pressure Differences

- Unwanted air drawn from attic, crawlspace, storage areas, garage
  - Stale, stagnant
  - Pollutants
  - Moisture
- Unwanted heat transfer
  - Uncomfortable drafts
- Moisture into building cavities
- Backdrafting
  - Exhaust from combustion appliances enters house

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Managing Air Flow

- Create a continuous air barrier

- Air barrier vs Vapor barrier vs Vapor retarder
  - Housewrap can be an air barrier and a vapor retarder
  - Bare drywall is an air barrier but not a vapor retarder
  - Poly is an air barrier and a vapor barrier

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Air Barrier Materials

- 1/2” Drywall
- Mechanically Fastened Housewrap
- Plywood / OSB
- XPS rigid foam sheathing
- Spray foam insulation
- Spray-applied air barriers
- Self-Adhered Sheet air barriers
- Concrete
- Polyethylene

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Air Sealing

- Creating an Air Barrier System
  - Properly limiting air infiltration requires a continuous air barrier at the building enclosure
  - Achieved with tape, caulk, adhesive, gasket, foam
    - Assembly perimeter (wall/attic, wall/floor, wall/foundation)
    - Penetrations, seams, etc.

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How Do We Air Seal?

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General Air Barrier *Methods*

- Drywall Method
- Spray Foam Method
- Sheathing/Framing Method
- Housewrap Method

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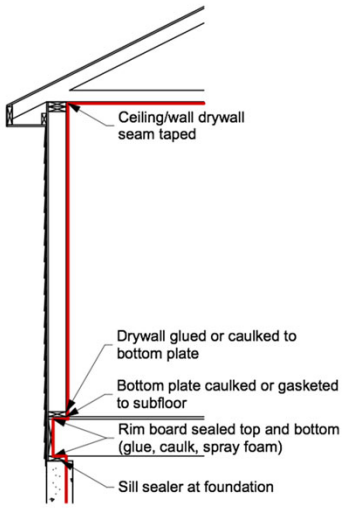
Drywall Method

- Notes:
  - Majority of homes utilize this method at ceilings (unless unvented attics installed).



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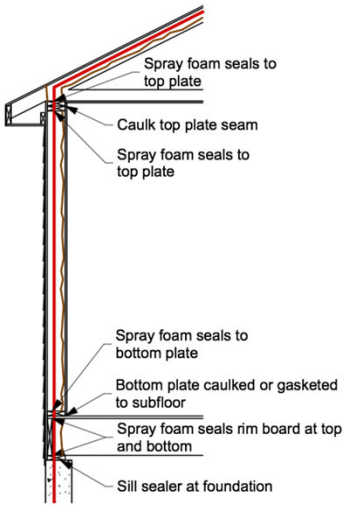
Spray Foam Method

- Notes:
  - Spray foam only effective in cavities and relies on sealed framing joints.



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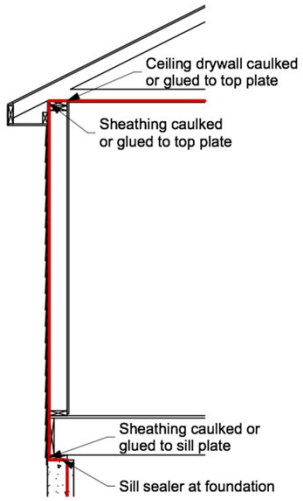
Sheathing/ Framing Method

- Notes:
  - Attention to detail!



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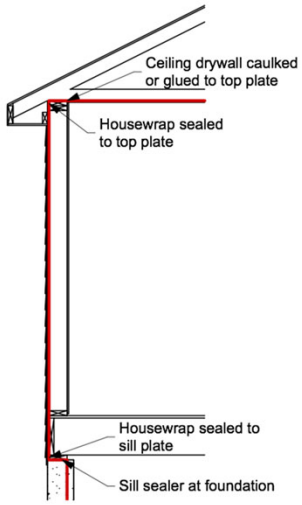
Housewrap Method

- Notes:
  - Many builders believe this is their method but are forgetting some of the key details.



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What Do We Seal?

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N1102.4 Air Leakage

- The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R1102.4.1 through R1102.4.5.

50

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

50

N1102.4.1 Building Thermal Envelope

- The building thermal envelope shall comply with Sections N1102.4.1.1 and N1102.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.
  - N1102.4.1.1 – Installation
  - N1102.4.1.2 – Testing

51

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

51

N1102.4.1.2 Testing

- The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding five air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with 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 building 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 building official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope.

52

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Blower Door Concept

- Depressurize the home to an exaggerated pressure difference to quantify air infiltration and compare with established benchmarks
- ACH_{50} = Air Changes per Hour at pressure difference of 50 Pa
  - Current limit in Pennsylvania is 5 ACH_{50} if tested
  - 50 Pa simulates roughly a 20 mph wind on all sides of the home

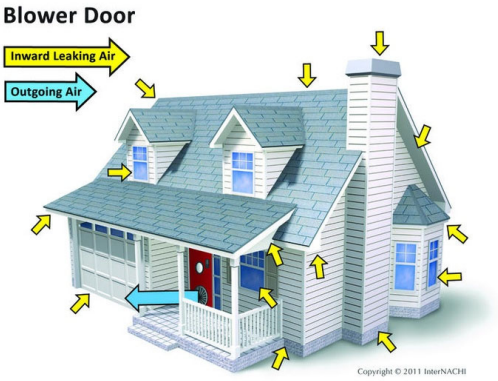

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Image Source: https://www.naeci.com/blower-door-testing

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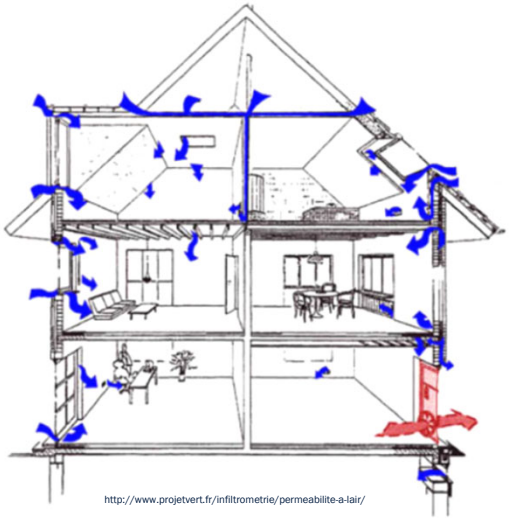
Airtightness Requirement: 3 ACH50



http://www.projetvert.fr/infiltrometrie/permeabilite-a-lair/

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- Measured in Air Changes Per Hour at 50 Pascals (ACH50 / ACH_{50})
  - 50 pascals – equivalent to 20 MPH wind on the house

Value we need (Air Changes Per Hour @ 50 Pascals)

Value from the blower door pressure gauge (Cubic Feet Per Minute @ 50 Pascals)

Constant (60 minutes per hour)

$$ACH_{50} = \frac{CFM_{50} \times 60}{V} < 3$$

Volume of the House (Cubic Feet)

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N1102.4.1.1 Installation

- The components of the building thermal envelope as listed in Table N1102.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table N1102.4.1.1, as applicable to the method of construction. Where required by the building official, an approved third party shall inspect all components and verify compliance.

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Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Table N1102.4.1.1 Air Barrier and Insulation Installation

- General requirements
- Ceiling/attic
- Walls
- Windows, skylights and doors
- Rim joists
- Floors
- Crawl space walls
- Shafts, penetrations
- Narrow cavities
- Garage separation
- Recessed lighting
- Plumbing and wiring
- Shower / tub on exterior wall
- Electrical / phone box on exterior walls
- HVAC register boots
- Concealed sprinklers

56

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

56

Walls

- Air Barrier Criteria
  - 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.
- Insulation Installation Criteria
  - Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with material having an R-value of R-3 per inch min.
  - Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.

57

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Image Source: https://www.jlconline.com/how-to/exteriors/sealing-the-foundation-to-the-framing_o

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Windows, Skylights and Doors

- Air Barrier Criteria
  - The space between window/door jambs and framing, and skylights and framing shall be sealed.
- Insulation Installation Criteria

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Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Floors

- Air Barrier Criteria
  - The air barrier shall be installed at any exposed edge of insulation.
- Insulation Installation Criteria
  - Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing or continuous insulation.

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Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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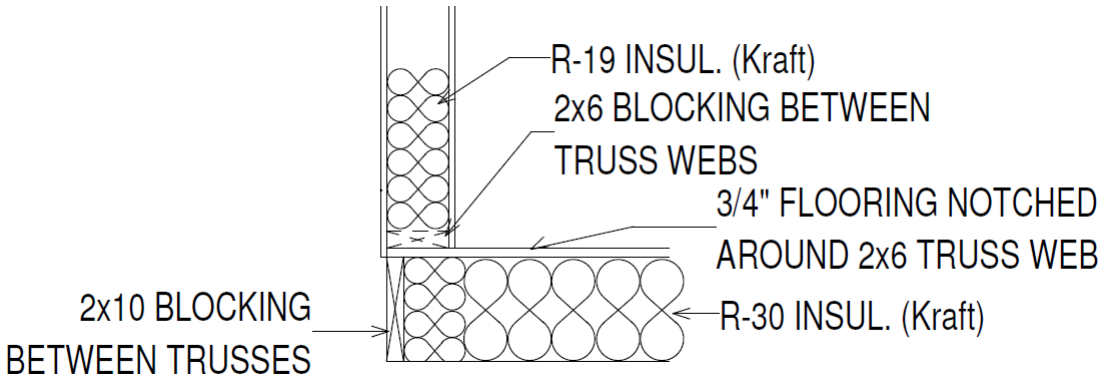

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Building Assemblies

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Fundamental Building Assemblies

- Roof
- Wall
- Floor
- Foundations & Basements
- Slab-on-Grade

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UCC Residential Code Summary

Base code

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Statutory Amendments

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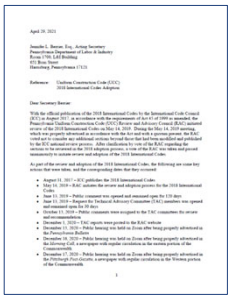

RAC amendments

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UCC Energy Code Summary

Chapter 11

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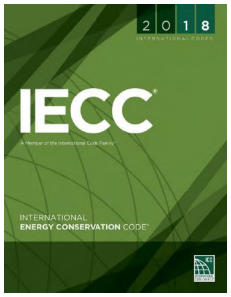

Residential Provisions

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PA Alternative Residential Energy Provisions

Coming Soon!

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IECC Compliance Options

Prescriptive

Sections R402.1 through R402.3, R403.3.1, R403.3.4, and R403.5.3

Indicated as **(Prescriptive)**

Total UA Alternative

Section R402.1.4

Calculate manually

RES*check*

Other software

Simulated Performance Alternative

Section R405

RES*check*

Other software

ERI Path

Section R406

HERS Index

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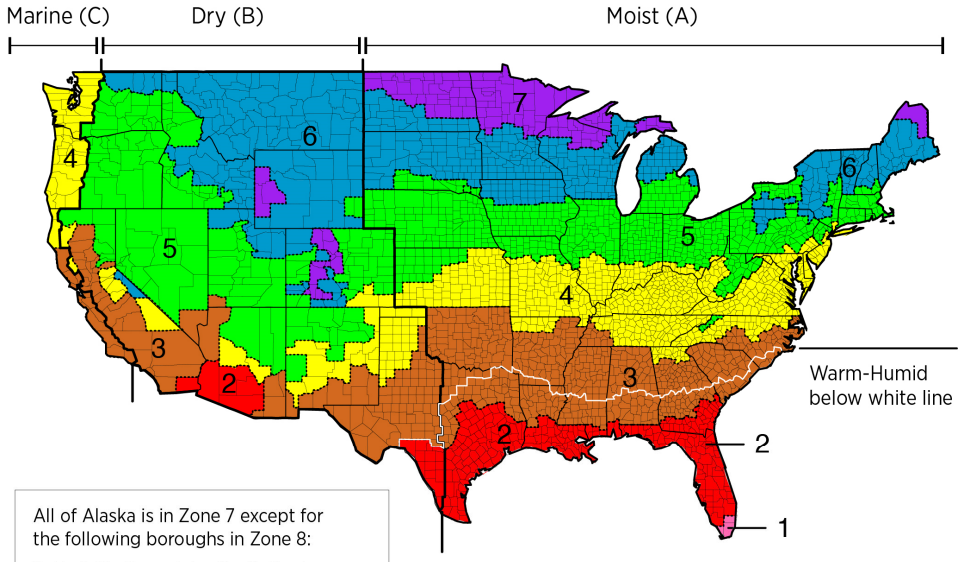

All of Alaska is in Zone 7 except for the following boroughs in Zone 8:

Bethel, Northwest Arctic, Dellingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

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Image Source: https://basc.pnnl.gov/images/iecc-climate-zone-map

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Climate Zones in PA

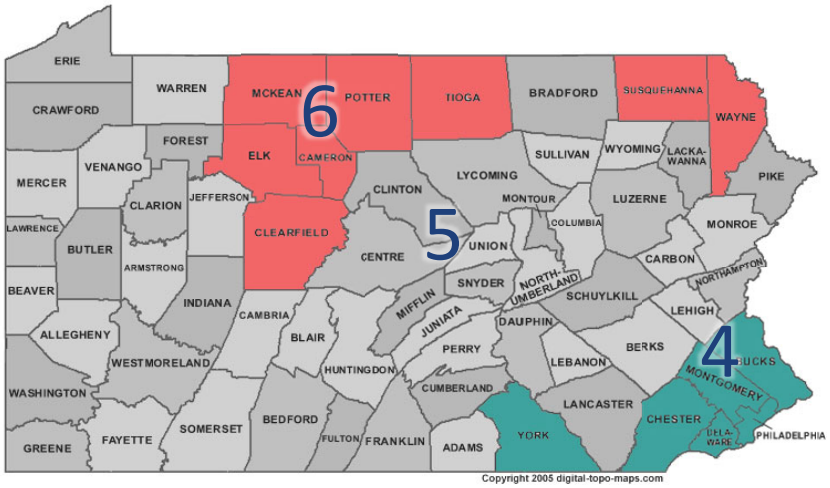

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Image Source: digital-topo-maps.com

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2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Fundamental Building Assemblies

- Roof
- Wall
- Floor
- Foundations & Basements
- Slab-on-Grade

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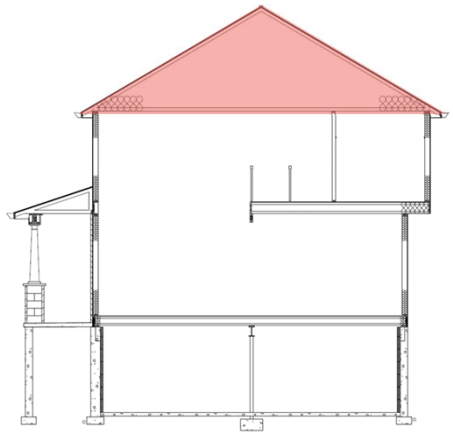
Roof/Attic Assembly

- Roof covering
- Underlayment
- Flashing
- Ventilation
- Air barrier
- Vapor retarder
- Insulation



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Where is the Air Barrier?

- Vented Roofs
  - Air barrier located at ceiling
  - Most commonly drywall ceiling strategy
- Unvented Roofs
  - Spray Foam
  - Rigid Foam Sheathing with taped joints
- Continuous and sealed to air barrier at wall

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Common Insulation Options

- Vented Roofs
  - Blown-in Cellulose or Fiberglass
  - Fiberglass Batt
- Unvented Roofs
  - Spray Foam
  - Rigid Foam Sheathing (can be in combination with air-permeable insulation)

2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
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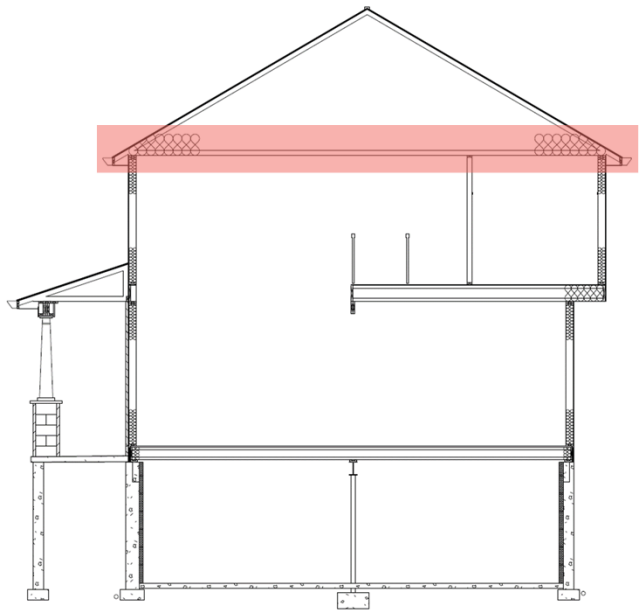
Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.



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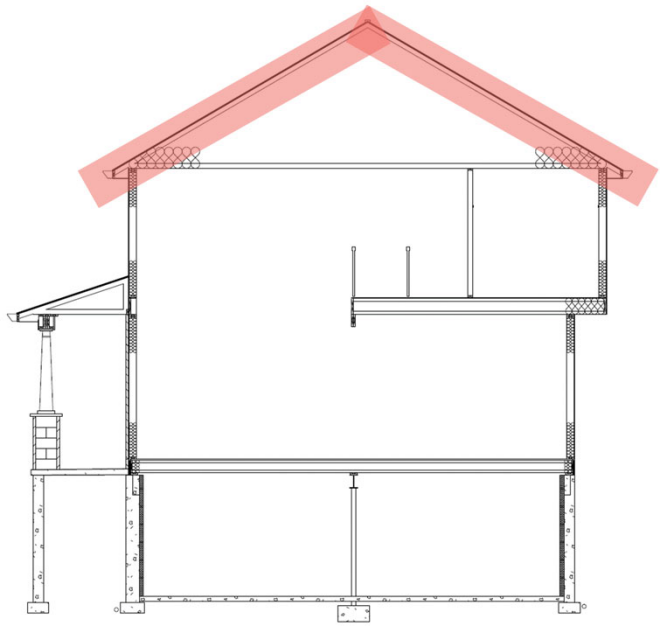

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2018 IRC Section N1102.2.1 Roof R-Value Reduction

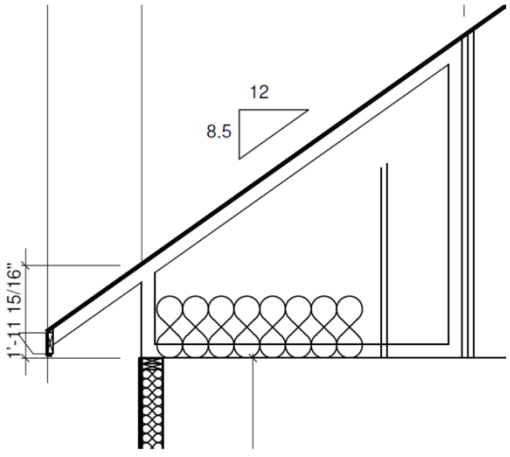
- **N1102.2.1 – Ceilings with attic spaces.** When Section N1102.1.2 would require R-49 insulation in the ceiling, installing R-38 over 100 percent of the ceiling area requiring insulation shall be deemed to satisfy the requirement for R-49 wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves.

79

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

79

Raised Heel Trusses



80

80

2018 IRC Section N1102.2.2 – Reduction of Ceiling Insulation

- **Change Type:** Modification
- **Change Summary:** When applying the exception for insulation in ceilings without attics, the insulation must extend to the outside of the top plate.
- N1102.2.2 (R402.2.2) Ceilings without attic spaces. Where Section N1102.1.2 requires insulation R-values greater than R-30 in the ceiling and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation R-value for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed. This reduction of insulation from the requirements of Section N1102.1.2 shall be limited to 500 square feet (46 m2) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the U-factor alternative approach in Section N1102.1.4 and the Total UA alternative in Section N1102.1.5.

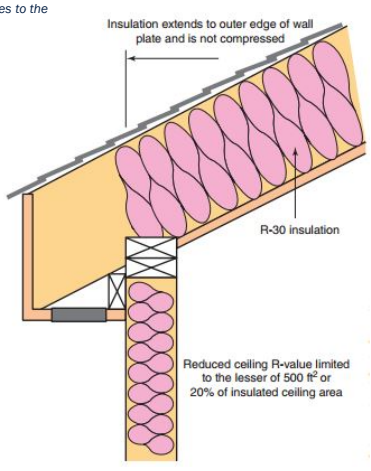
81

Source: International Code Council (ICC). (2018). 2018 Significant Changes to the International Residential Code, Country Club Hill, Ill.

81

N1102.2.2 – Reduction of Ceiling Insulation – Cont.

Source: International Code Council (ICC). (2018). 2018 Significant Changes to the International Residential Code, Country Club Hill, Ill.



Reduced R-value for vaulted ceiling

© International Code Council

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Roof Questions?

83

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Fundamental Building Assemblies

- Roof
- Wall
- Floor
- Foundations & Basements
- Slab-on-Grade

84

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Wall Assembly

- Wall cladding
- Flashing
- Air Barrier
- Vapor Retarder
- Insulation
- Windows & Doors

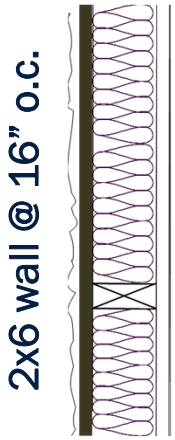
2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

R-Value Of Total Wall Assembly



Component	Cavity R-value	Frame R-value
Outside air film	0.17	0.17
Lap siding	0.62	0.62
7/16" OSB	0.62	0.62
Batt insulation	21	--
2x6 stud	--	6.88
Gypsum board	0.45	0.45
Inside air film	0.68	0.68
Total R-values	23.54	9.42
Total U-factor (1/R-value)	0.0425	0.1062

$U_{overall}$ = (0.0425x.75)+(0.1062x.25) = 0.0584
$R_{overall}$ = 1/0.0584 = **17.1**

87

Source: Data pulled from "Typical Thermal Properties of Common Building and Insulating Matererials": 2009 ASHRAE Handbook

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Insulation Types

- Blankets, batts, and rolls
- Loose-fill and blown-in
- Spray foam
- Rigid foam

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Different Types Of Insulation

- Blanket, Batts and Rolls
  - Fiberglass
  - Mineral wool

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Fiberglass Batt Insulation

- Two types
  - Kraft-faced (serves as vapor retarder and used to install)
  - Unfaced (friction fit)
- Width = stud bay
  - 16” o.c. spacing = 14.5”
- R-Value
  - Standard-density = R 3.2/inch
  - High-density = R 3.6/inch

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Proper Installation

- Fiberglass batts rely on entrapped air to provide thermal resistance
  - Gaps/voids
  - Compression
- Example:
  - Standard R-19 batt designed for attics (6-1/4” thick), but was used in walls and compressed to 5-1/2”

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Fiberglass Batt Insulation

- Installation of paper faced batt
  - Face staple
- Refer to the manufacturer's installation instructions for stapling requirements

93

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Fiberglass Batt Insulation

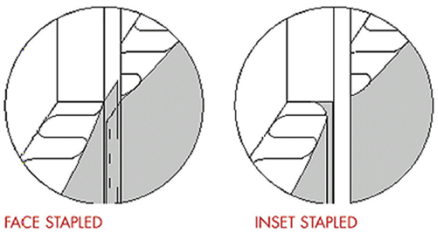
- Installation of paper faced batt
  - Face staple
  - Inset staple
- Refer to the manufacturer's installation instructions for stapling requirements

94

94

Fiberglass Batt Insulation

- Face vs. Inset staple?
  - Both are usually allowed and if inset staple is done correctly, it does not reduce the grading of the installation
  - Refer to the manufacturer's installation instructions for stapling requirements



95

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Fiberglass Batt Insulation

- Installation fiberglass batt
  - Face staple
  - Inset staple
  - Unfaced batt

96

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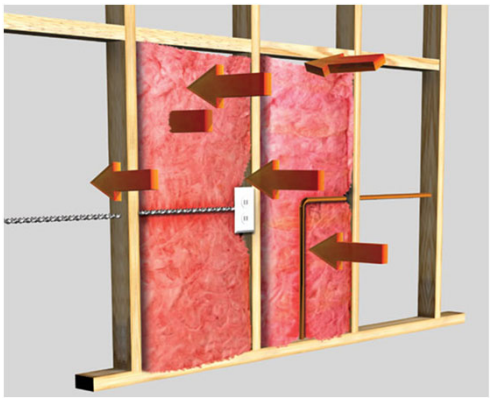
Full Alignment

97

Source: www.certainteed.com

97

Free Of Voids And Gaps



- Insulation should fill the entire cavity
- Insulation should be tight fitting around electrical boxes and cut to proper length to eliminate voids and gaps

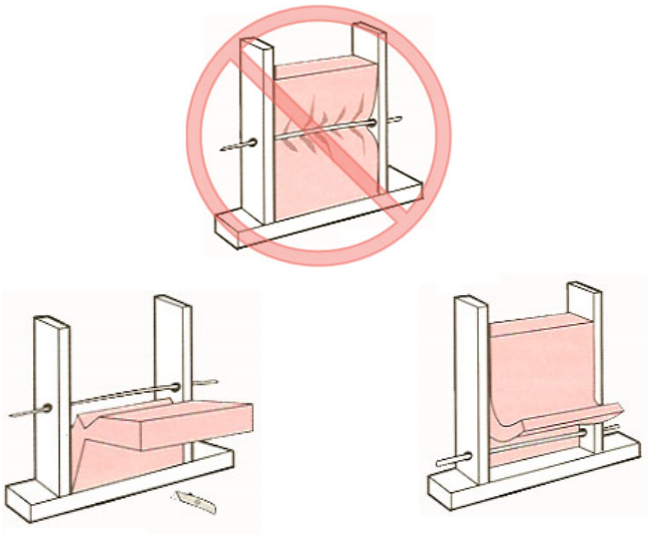
98

Source: McGraw Hill Construction

98

Free Of Compression

- Insulation should be free of compression caused by obstructions in the stud bay



Source: Oikos.com

99

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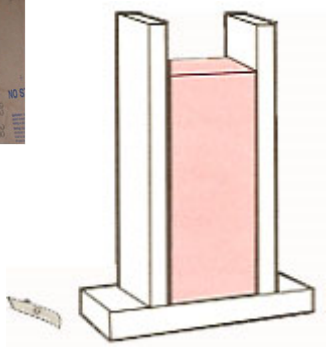
Narrow Cavities

- Batts in narrow cavities should be cut to fit
  - Narrow stud bays
  - Corners
  - Around blocking



100

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Narrow Cavities

- Batts in narrow cavities should be cut to fit
  - Narrow stud bays
  - Corners
  - Around blocking

101

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Different Types Of Insulation

- Loose-fill and Blown-in
  - Fiberglass

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Blown-In Fiberglass

- Common systems:
  - Blow in Blanket System (BIBS)
  - Insulsafe
  - Optima
  - Johns Manville Spider
- R-Value = 3.2 – 4.2/inch
- Achieving proper density is critical

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Different Types Of Insulation

- Loose-fill and Blown-in
  - Cellulose

105

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Cellulose

- More resistant to air flow than fiberglass
- R-Value = 3.1 – 3.7/inch
- High recycled content
  - Pre and post-consumer paper + fire retardant + mold inhibitor
- Two Installation Options
  - Damp-spray
  - Air-permeable netting (dry fill)

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Cellulose Installation

Source: Green Fiber

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Different Types Of Insulation

- Spray polyurethane foam
  - Two component
  - Open-cell

    Vs.
  - Closed-cell

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Open-Cell Spray Foam

- Half pound foam = 0.5 PCF
- R-Value = 3.5 – 3.6/inch
- Vapor semi-permeable or vapor permeable (full cavity)
- Often requires interior vapor retarder
  - Remember: vapor semi-permeable = Class III

Closed-Cell Spray Foam

- Two pound foam = 2.0 PCF
- R-Value = 6.0 – 6.5/inch
- Vapor semi-impermeable
  - Class II vapor retarder
- Can be used in Flash and Batt systems

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Different Types Of Insulation

- Rigid foam board
  - EPS, XPS, Polyiso

Expanded Polystyrene (EPS)

Extruded Polystyrene (XPS)

Foil-Faced Polyisocyanurate (polyiso)

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Exterior Foam Insulation

- Benefits
  - Reduced thermal bridging
  - CAN reduce risk of condensation in wall cavities
- Challenges
  - Flashing details
  - Cladding attachment
  - Double vapor retarder

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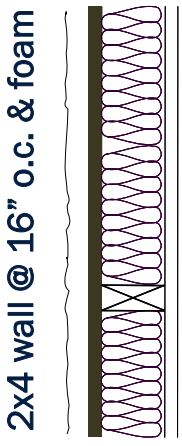
R-Value Of Total Wall Assembly



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7/16" OSB	0.62	0.62
Batt insulation	13	--
Rigid Foam	5	5
2x4 stud	--	4.38
Gypsum board	0.45	0.45
Inside air film	0.68	0.68
Total R-values	20.54	11.92
Total U-factor (1/R-value)	0.0487	0.0839

$U_{overall}$ = (0.0487x.75)+(0.0839x.25) = 0.0575
$R_{overall}$ = 1/0.0575 = **17.4**

Source: "Typical Thermal Properties of Common Building and Insulating Matererials": 2009 ASHRAE Handbook

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Wall Questions?

119

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Fenestration

120

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Fenestration Performance

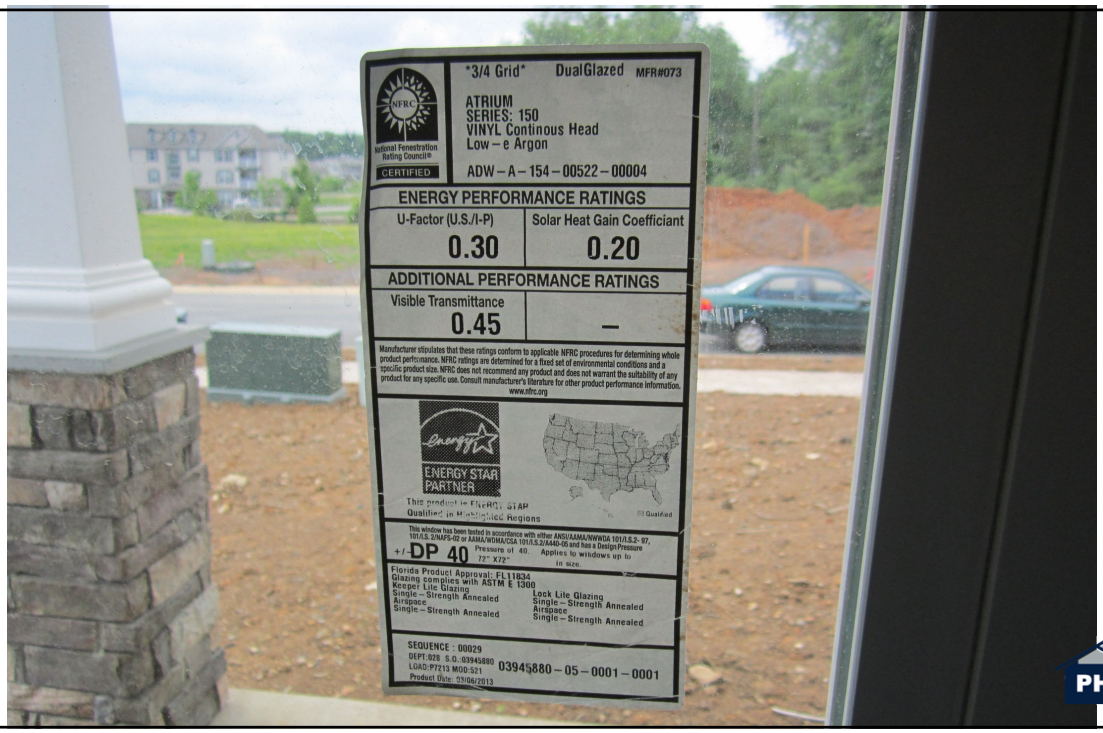
- Natural Light
- Glazing Performance
  - U-Factor
  - Solar Heat Gain Coefficient
  - Visible Transmittance
  - Gas Fillings
  - Low-E Coatings

123

Glazing Performance

- Measures of performance
  - U-Factor
  - Solar Heat Gain Coefficient
  - Visible Transmittance
  - Air Leakage

124



125

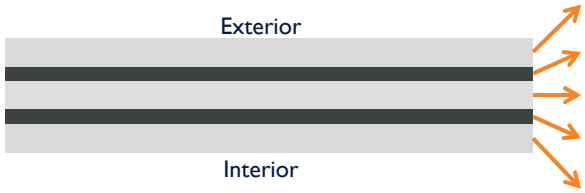
U-Factor

- Thermal Transmittance (U-Factor)
  - Rate at which a glazing unit transmits non-solar heat flow
  - Includes heat transfer by conduction, convection, and radiation
  - Area-weighted average (including glazing, frame, edge of glazing), not just center of glass

PHRC

126

U-Factor for Double Glazing



1. Outside Air Film
2. Glass
3. Air space / gas filling
4. Glass
5. Inside Air Film

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Solar Heat Gain Coefficient (SHGC)

- Solar Heat Gain Coefficient (SHGC)
  - Ratio of solar heat passing through glass to solar heat falling on the glass at 90° angle
  - Fraction of solar radiation admitted through the unit and released as heat within the structure
    - Windows with high SHGC's allow more solar heat gain during the winter months (can be desirable in heating climates)
- Impact: Solar heat gained through windows can account for up to 40% of the heat removed through summer air conditioning
  - *Source: Residential Energy (Krigger)*

128

How Can Windows Be More Efficient?

- Strategies to Reduce U-Factor (Increase R-Value)
  1. Multiple panes
  2. Gas fillings
  3. Special coatings

129

Gas Fillings

- Certain gases, such as argon, can improve the efficiency of windows when used as a filling in multiple-pane units
  - An argon filled layer between glass panes can have a higher R-Value than still air
  - Argon weighs more than air, thus reducing the impact of convection within the space

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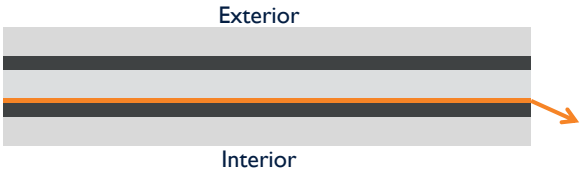
Low-E Coatings

- Emissivity (e) = relative ability of a surface to emit radiant energy
  - Opposite of emissivity = reflectivity, or the ability of a surface to reflect or reject radiant energy
- Low-E, in the context of windows, refers to a metallic coating on one of the glazed surfaces (facing the air space) that is used to increase the energy efficiency of windows
  - In heating dominated climates, low-e coatings are used to lower U-factor
  - In cooling dominated climates, low-e coatings are used to lower SHGC

131

Low-E Coatings in Heating Climates



1. Outside Air Film
2. Glass
3. Air space / gas filling
4. Low-E coating
5. Glass
6. Inside Air Film

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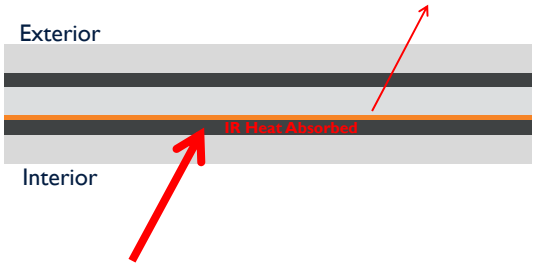
What Does a Low-E Coating Do?

- A large portion of winter heat loss (in heating climates) through windows is through infrared radiation
  - Interior glass pane absorbs radiant heat
  - Low-E coating resists reradiation of heat through air space (and to the exterior)



133

2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
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3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

134

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

134

Fenestration Questions?

135

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Fundamental Building Assemblies

- Roof
- Wall
- Floor
- Foundations & Basements
- Slab-on-Grade

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Floor Assembly

- Floor systems become part of building enclosure when:
  - Basements/crawlspaces unconditioned
  - Balconies
  - Cantilevers

137

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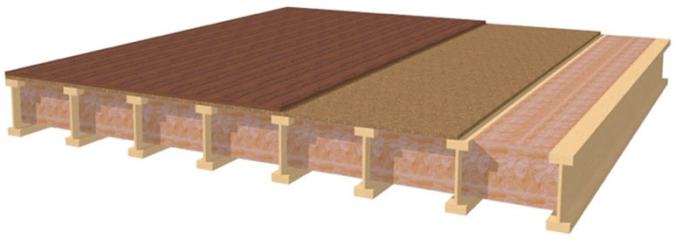
Insulated Floor Assembly



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2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
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1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
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7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

139

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

139

Rim Board Insulation

- Critical detail
  - High condensation potential
  - Air sealing crucial
  - Insulation exposure (flame spread)

140

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Typical Rim Joist Assembly

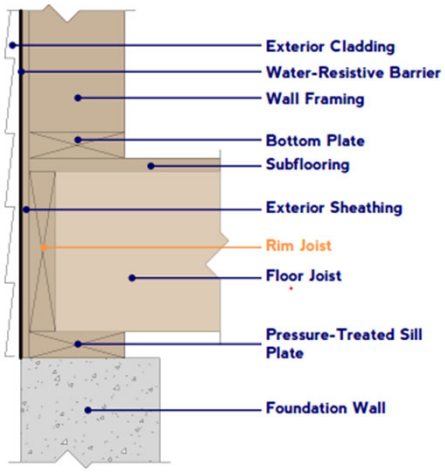

Figure 1: Uninsulated rim joist assembly

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Rim Joists with Fiberglass Batt Insulation

- Air with a high relative humidity can come in contact with the cooler rim joist by means of convection because fiberglass batt insulation is air permeable
- During the winter months, condensation and frost can occur on the inside face of the rim joist material
- The risk of condensation typically outweighs this drying potential, unless it is implemented with the appropriate conditions

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Fiberglass Batt Insulation

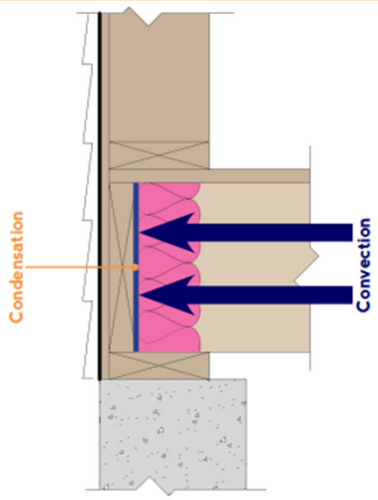

Figure 2: Rim joist assembly w/fiberglass insulation

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Rim Joist Insulation

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Rim Joists with Interior Foam Insulation

- This assembly can be achieved through spray polyurethane foam or foam board
- Foam insulation has a much lower air and water vapor permeability than batt insulation
- Foam also raises the temperature of the interior surface of the assembly
- These two factors lead to a lower risk of condensation

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Interior Foam Insulation

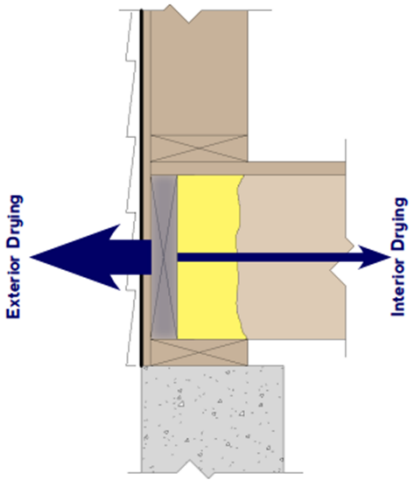
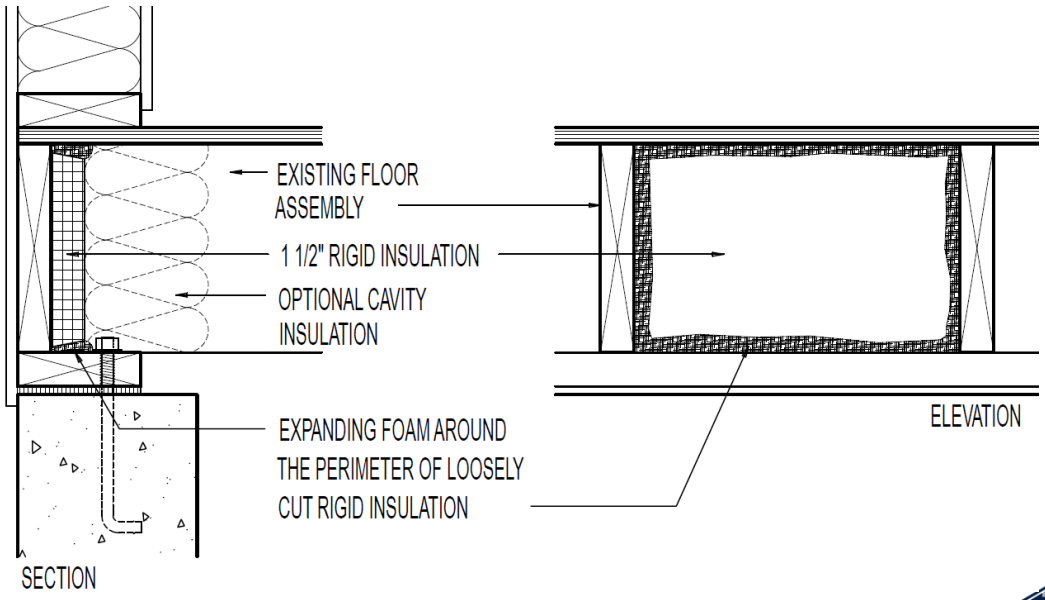


Figure 3: Rim joist w/interior foam insulation

146

146



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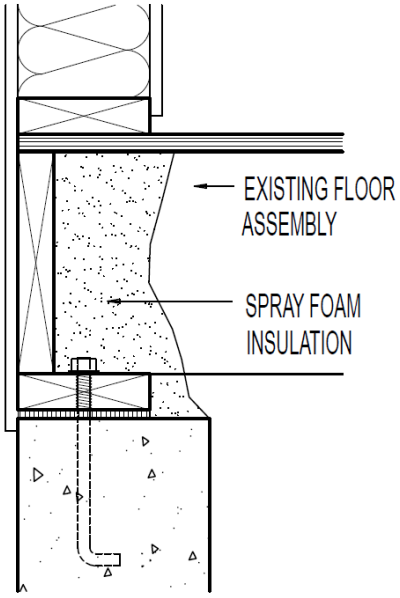

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150

Floor Questions?

151

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Fundamental Building Assemblies

- Roof
- Wall
- Floor
- Foundations & Basements
- Slab-on-Grade

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2018 IRC Section N1102.2.9 Basement Walls

- **N1102.2.9 Basement walls.** Walls associated with conditioned basements shall be insulated from the top of the basement wall down to 10 feet (3048 mm) below grade or to the basement floor, whichever is less. Walls associated with unconditioned basements shall meet this requirement unless the floor overhead is insulated in accordance with Sections N1102.1.2 and N1102.2.8.

153

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

153

2018 IRC Table N1102.1.2

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4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

154

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

154

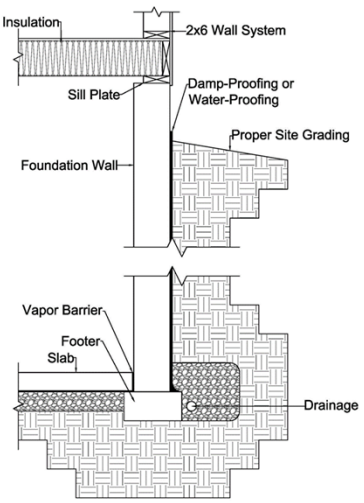
Example Assemblies

- No insulation (ceiling insulated)
- Exterior
- Blanket
- Continuous
- Cavity
- Combination

155

155

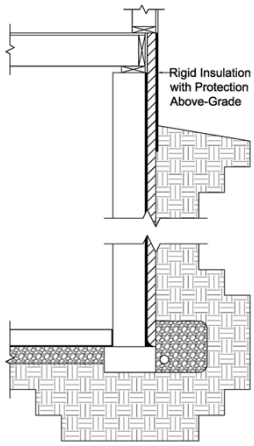
Un-Insulated Basement Wall



156

156

Exterior Continuous



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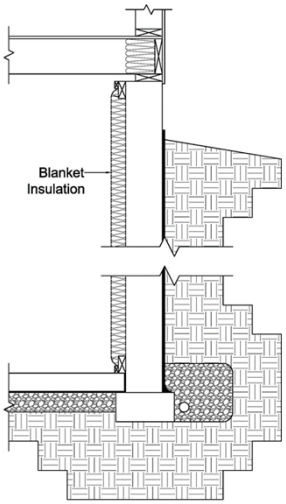
Interior Draped



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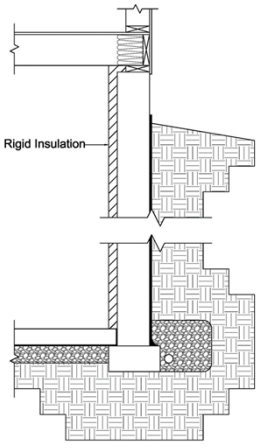
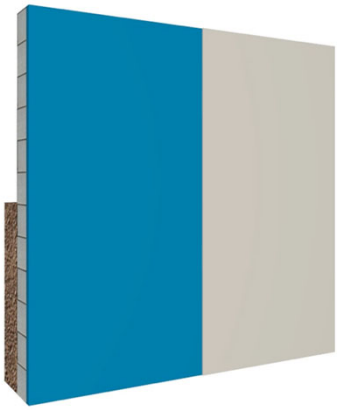
159

159

Interior Continuous





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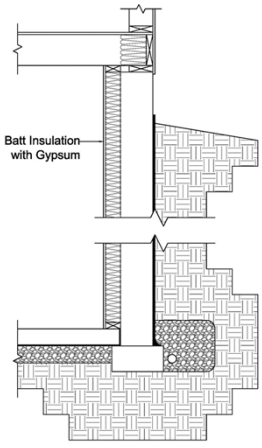
Interior Cavity



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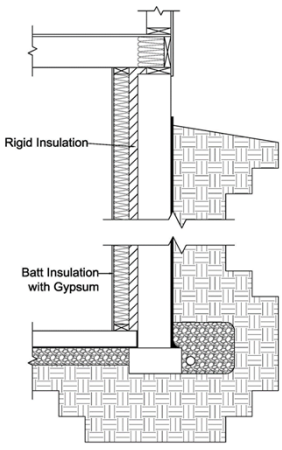
163

163

Interior Combination



164

164

Foundation Questions?

165

165

Fundamental Building Assemblies

- Roof
- Wall
- Floor
- Foundations & Basements
- Slab-on-Grade

166

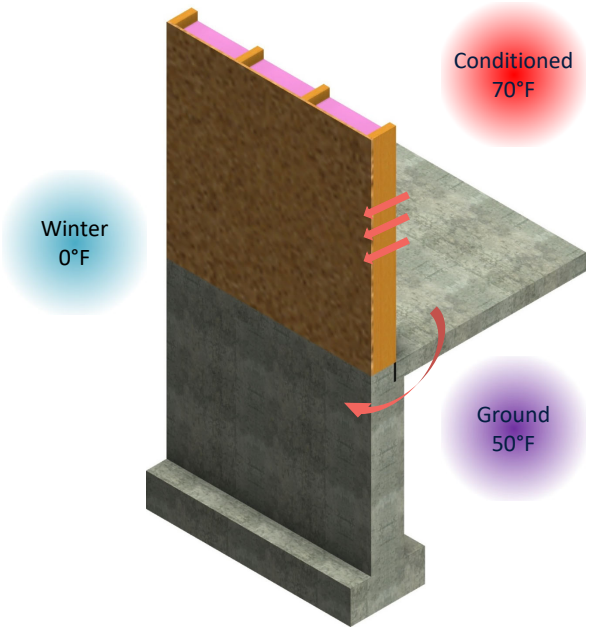
166

Slab Edge Heat Loss

- Temperature of slab perimeter may be below dew point in heating climates for significant periods of time
  - Condensation risk
  - Even with temperature above dew point, slab edge heat loss can elevate relative humidity to levels high enough to support mold growth

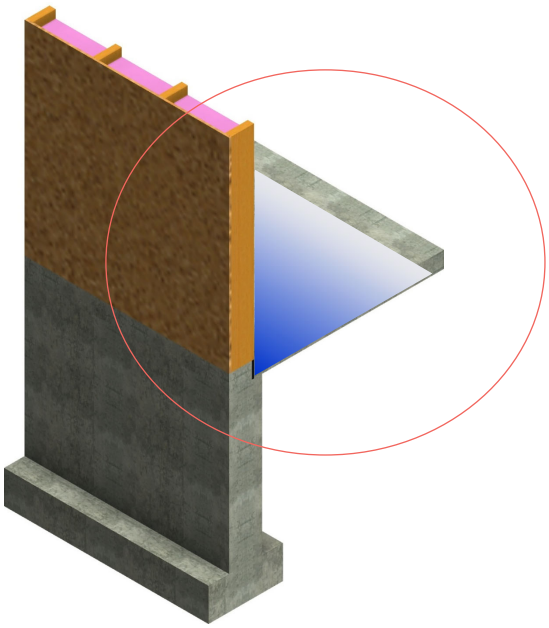
167

167



168

168



169

169

2018 IRC Section N1102.2.10 Slab-On-Grade Floors

- **N1102.2.10 Slab-on-grade floors.** Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table 402.1.2.
  - The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall
  - Insulation located below grade shall be extended the distance provided in Table N1102.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building
  - Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil
  - The top edge of the insulation installed between the exterior wall and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the exterior wall
  - Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation

170

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

170

2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

171

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

171

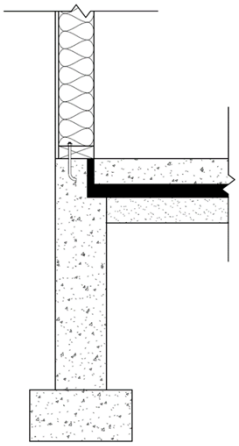
Options For Placement

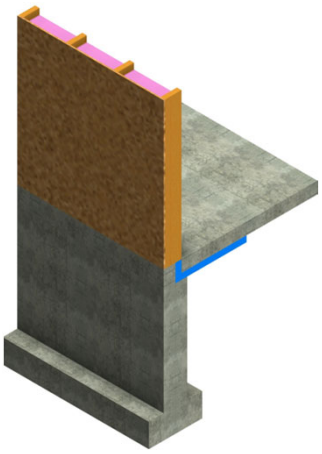
- Interior/Horizontal
- Interior/Vertical
- Exterior

172

172

Interior/Horizontal





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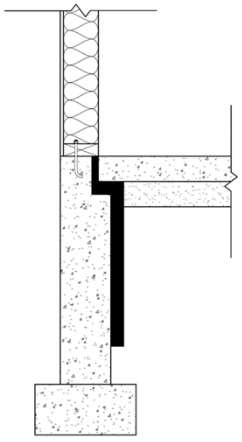
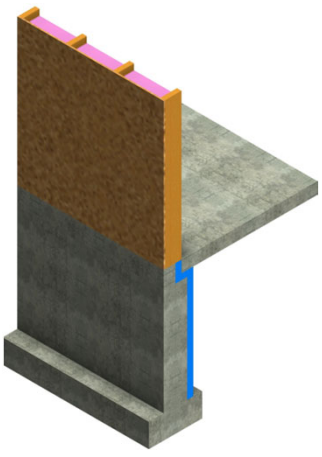
Interior/Vertical

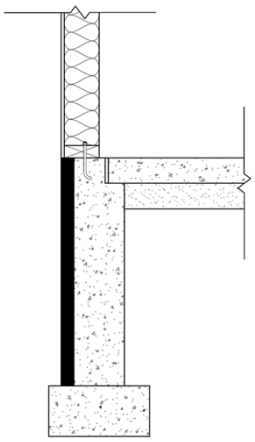


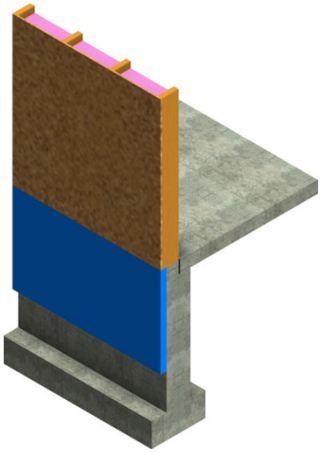


174

174

Exterior





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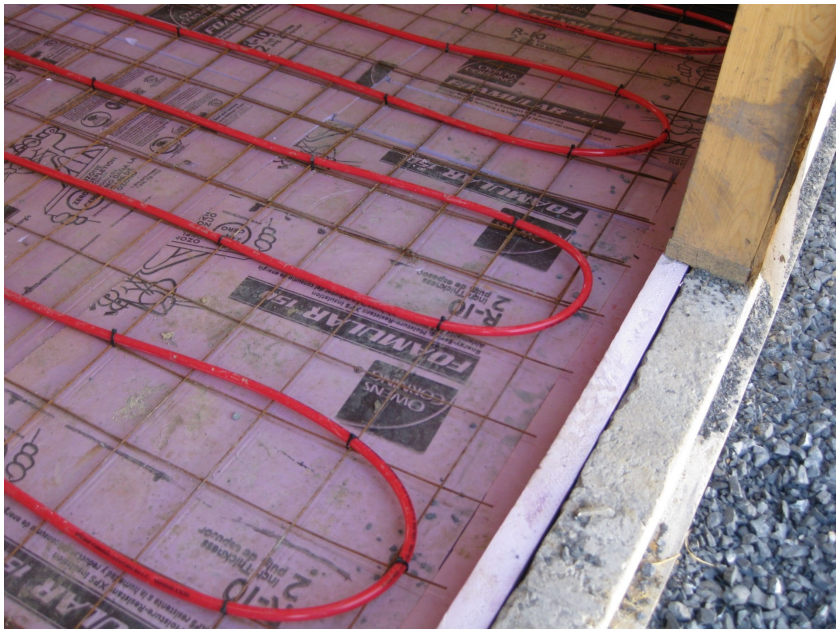
2018 IRC Section N1102.2.10 Slab-On-Grade Floors

- **N1102.2.10 Slab-on-grade floors.** Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table 402.1.2.
  - The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall
  - Insulation located below grade shall be extended the distance provided in Table N1102.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building
  - Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil
  - The top edge of the insulation installed between the exterior wall and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the exterior wall
  - Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation

177

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

177



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178

Slab-On-Grade Questions?

179

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PA Alternative Residential Energy Provisions Update

www.phrc.psu.edu

PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

180

UCC Energy Code Summary: 2/14/22

Chapter 11

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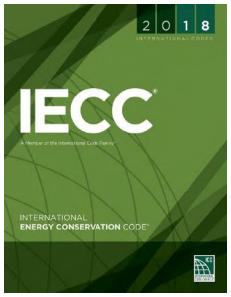

Residential Provisions

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181

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PA Alternative Residential Energy Provisions

- Based on the 2018 IECC and UCC Amendments
- Compliance allowed by UCC Title 34, Chapter 403
- Created and published by the Pennsylvania Housing Research Center
- Allows trade-offs

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2021 PA Alternative Residential Energy Provisions

183

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PA UCC Section 301(c)

- (c) Prescriptive methods for energy-related standards.– The department shall, within 180 days of the effective date of this section, by regulation promulgate prescriptive methods to implement the energy-related standards of the Uniform Construction Code which take into account the various climatic conditions through this Commonwealth. In deriving these standards the department shall seek to balance energy savings with initial construction costs.

184

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12 Pa. Code §145.42. Alternate standards.

(Chapter 145 – Industrial Housing and Components)

- (1) As an alternate to the ICC International Residential Code, Chapter 11, regarding energy efficiency, the manufacturer may use the applicable edition of one of the following:
  - (i) The prescriptive methods for residential buildings in the International Energy Conservation Code compliance guide containing state maps, prescriptive energy packages and related software published by the United States Department of Energy, Building Standards and Guidelines Program (REScheckTM).
  - (ii) Pennsylvania's Alternative Residential Energy Provisions developed by the Pennsylvania Housing Research Center at the Pennsylvania State University.

185

Source: http://www.pacodeandbulletin.gov/Display/pacode?file=/secure/pacode/data/012/chapter145/s145.42.html&d=reduce

185

Scope Clarification

SECTION PA100

GENERAL

PA101 Scope. The provisions of this document regulate energy efficiency for the design and construction of buildings regulated by the 2018 International Residential Code (IRC) as incorporated in the PA Uniform Construction Code (UCC) in the Commonwealth of Pennsylvania. In addition, the provisions of this document only apply to new construction of one- and two-family dwellings and townhouses not more than three stories above grade plane in height with a separate means of egress and their accessory structures not more than three stories above grade plane in height and are not applicable to alteration, repair, addition, and change of occupancy of existing buildings and structures.

Exception: Portions of the building envelope that do not enclose conditioned space.

186

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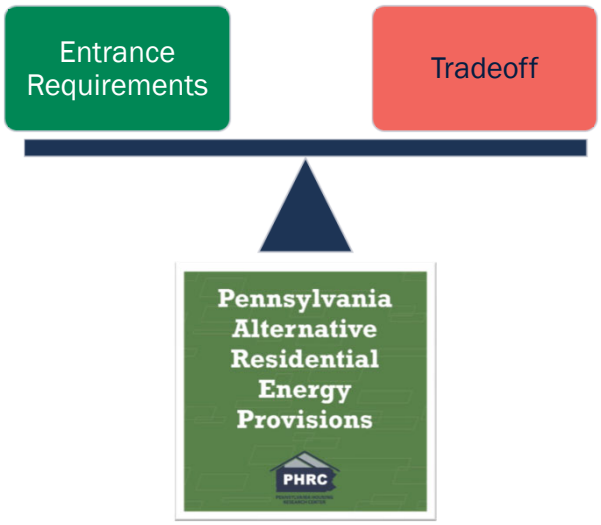
PA Alternative Residential Energy Provisions



- Choose one (1) Entrance Requirement
  - "Energy Enhancement Options"
- Receive ALL tradeoffs
- Energy modeling completed (BEopt) to ensure equivalent energy usage

187

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Energy Enhancement Options

Table PA104
Energy Enhancement Options

Option	Description		Minimum efficiency by climate zone		
			South (4)	Central (5)	North (6)
1	Ductless heat pumps		8.5 HSPF *and* 15 SEER	10 HSPF *and* 15 SEER	10 HSPF *and* 15 SEER
2	All air ducts located inside the thermal envelope		Compliant	Compliant	Compliant
3	Geothermal or water source heat pump installed		Compliant	Compliant	Compliant
4	Improved efficiency air source heat pump installed		9.5 HSPF *and* 19 SEER	9.5 HSPF *and* 19 SEER	11 HSPF *and* 19 SEER
5	Improved efficiency condensing furnace installed		92 AFUE	95 AFUE	95 AFUE
6	Exterior continuous insulation		R20+10	R20+10	R20+15
7	Improved efficiency windows		U-factor = 0.21	U-factor = 0.19	U-factor = 0.15
8	Package: Improved efficiency windows and higher attic R-value with raised heel truss[a]	Windows	U-factor = 0.25	U-factor = 0.21	U-factor = 0.19
		Attic	R-value = 60	R-value = 60	R-value = 60
9	Package: Improved efficiency windows and heat pump water heater	Windows	U-factor = 0.25	U-factor = 0.21	U-factor = 0.19
		Heat Pump Water Heater	Compliant	Compliant	Compliant

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.
b. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

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Energy Enhancement Options

1. Ductless heat pumps

Minimum efficiency by climate zone		
South (4)	Central (5)	North (6)
8.5 HSPF *and* 15 SEER	10 HSPF *and* 15 SEER	10 HSPF *and* 15 SEER

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.
b. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

189

Image Source: http://synergy-green-builders.com/tag/mini-split-pump/

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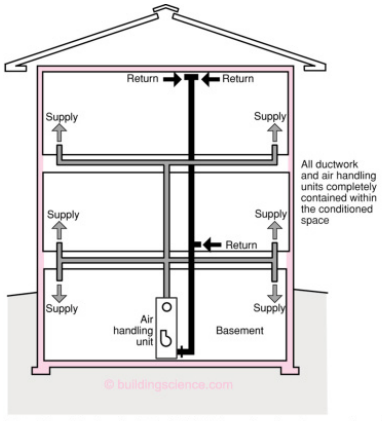
Energy Enhancement Options

2. All air ducts located inside the thermal envelope



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

Minimum efficiency by climate zone		
South (4)	Central (5)	North (6)
Compliant	Compliant	Compliant

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.
b. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

190

Image Source: https://buildingscience.com/documents/information-sheets/information-sheet-ducts-in-conditioned-space

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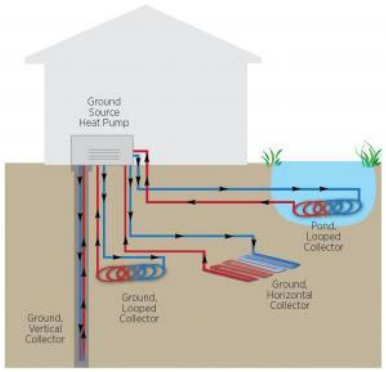
Energy Enhancement Options

3. Geothermal or water source heat pump installed



Minimum efficiency by climate zone		
South (4)	**Central (5)**	**North (6)**
Compliant	Compliant	Compliant

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.
b. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

Image Source: https://basc.pnnl.gov/resource-guides/geothermal-heat-pumps

191

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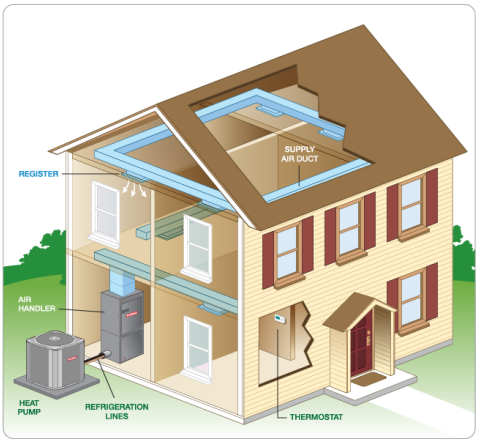
Energy Enhancement Options

4. Improved efficiency air source heat pump installed



Minimum efficiency by climate zone		
South (4)	**Central (5)**	**North (6)**
9.5 HSPF *and* 19 SEER	9.5 HSPF *and* 19 SEER	11 HSPF *and* 19 SEER

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.
b. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

Image Source: https://www.goodmanmfg.com/resources/heating-cooling-101/how-a-heat-pump-works

192

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Energy Enhancement Options

5. Improved efficiency condensing furnace installed

Minimum efficiency by climate zone		
South (4)	Central (5)	North (6)
92 AFUE	95 AFUE	95 AFUE

Notes:

a. Full height of uncompressed insulation shall extend over the top plate at the eaves.

b. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

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Energy Enhancement Options

6. Exterior continuous insulation

Minimum efficiency by climate zone		
South (4)	Central (5)	North (6)
R20+10	R20+10	R20+15

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Energy Enhancement Options

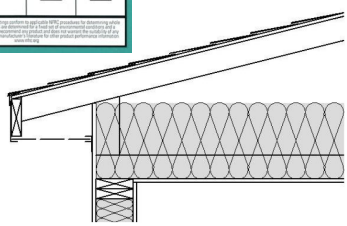
7. Improved efficiency windows

Minimum efficiency by climate zone		
South (4)	Central (5)	North (6)
U-factor = 0.21	U-factor = 0.19	U-factor = 0.15

Image Source: http://peoriasiding.com/tag/best-replacement-windows-in-illinois/

Energy Enhancement Options

8. Package: Improved efficiency windows & higher attic R-value with raised heel truss



	Minimum efficiency by climate zone		
	South (4)	Central (5)	North (6)
Windows	U-factor = 0.25	U-factor = 0.21	U-factor = 0.19
Attic	R-value = 60	R-value = 60	R-value = 60

Notes:
a. Full height of uncompressed insulation shall extend over the top plate at the eaves.

Image Source: TOP - http://peoriasiding.com/tag/best-replacement-windows-in-illinois/
BOTTOM – 2018 PA Alternative Energy Provisions

Energy Enhancement Options

9. Package: Improved efficiency windows & heat pump water heater

	Minimum efficiency by climate zone		
	South (4)	Central (5)	North (6)
Windows	U-factor = 0.25	U-factor = 0.21	U-factor = 0.19
Heat Pump Water Heater	Compliant	Compliant	Compliant

Image Source: LEFT - http://peoriasiding.com/tag/best-replacement-windows-in-illinois/
RIGHT – http://westinghousewaterheating.com/electric-heat-pump-water-heater.html

197

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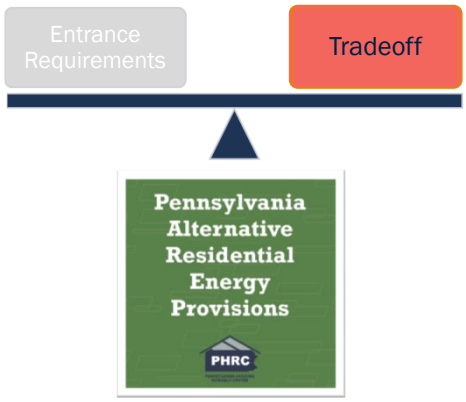
Energy Tradeoffs

- ALL of the following are allowed as a reduction when at least one energy enhancement option has been met.



198

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2018 IRC Section N1102.2.2

- Ceilings without attic spaces
  - Where Section N1102.1.2 requires insulation R-values greater than R-30 in the ceiling and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation R-value for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed.
  - This reduction of insulation from the requirements of Section N1102.1.2 shall be limited to 500 square feet (46 m2) or 20 percent of the total insulated ceiling area, whichever is less.

199

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Energy Tradeoffs

1. Cathedral ceilings: R-30 insulation, for up to 75% of the total *living space* square footage area

PA302.2 Ceilings without attic spaces. Where the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, such as cathedral ceilings, the minimum required insulation for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed. This reduction of insulation from the requirements of Section PA301 shall be limited to 75% of the total *living space* square footage area.

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2018 IRC Section N1102.2.4

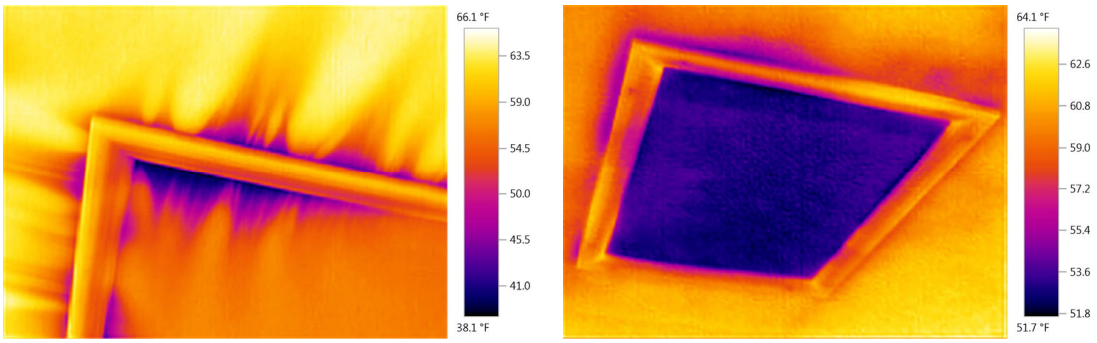
- Access hatches and doors
  - Access doors from conditioned spaces to unconditioned spaces such as attics and crawl spaces shall be weatherstripped and insulated to a level equivalent to the insulation on the surrounding surfaces.

201

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

201

Attic Access Gone Wrong



202

202

Energy Tradeoffs

2. Attic Hatches: R-20 instead of full insulation req't

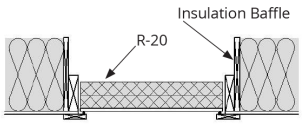


Figure PA302.3 (1)
Attic Hatch

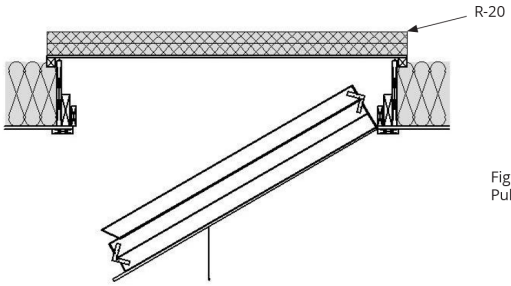


Figure PA302.3 (2)
Pull-Down Stairs

PA302.4 Access hatches and doors. Access hatches and doors from conditioned spaces to unconditioned spaces (e.g., attics and crawl spaces) shall be weather stripped. Both vertical and horizontal access hatches shall be insulated to a minimum of R-20 with rigid foam permanently attached to the access hatch. This is not intended to restrict the use of proprietary products meeting the intent of this provision. Side hinged access door shall meet the fenestration requirements of Table PA301.

A wood framed or equivalent baffle or retainer is required to be provided when loose fill insulation is installed. The purpose of which is to prevent the loose fill insulation from spilling into the living space when the attic access is opened. Areas around access hatches required to service equipment shall provide a permanent means of maintaining the installed R-value of the insulation.

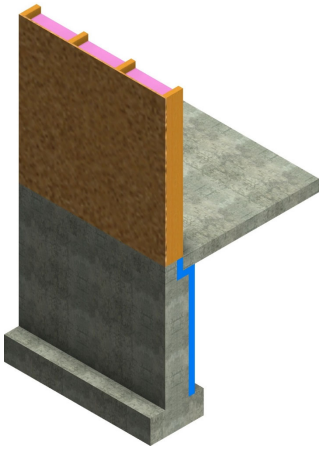
Exception: Vertical doors that provide access from conditioned to unconditioned spaces shall be permitted to meet the fenestration requirements of Table PA301 based on the applicable climate zone specified in section PA201.1.

PHRC

203

2018 IRC Section N1102.2.10

- Slab-on-grade floors
  - The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall



204

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Energy Tradeoffs

3. Slab edge insulation: Thermal break

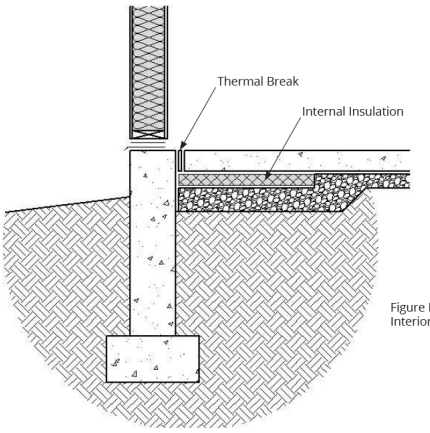

Figure PA302.7.2
Interior Slab Insulation

PA302.9.2 Interior Insulation. Interior insulation shall be installed from the bottom of the slab and extend the distance provided in Table PA301 by any combination of vertical insulation or horizontal insulation extending under the slab. The slab edge shall be separated from the foundation wall by a continuous ½ inch thermal break as per Figure PA302.8.(2) A thermal break shall be created by a material suitable for ground contact, which includes, but is not limited to, asphalt impregnated fiber board or extruded polystyrene. Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation.

Note: The provisions in PA302.9.2 only apply to unheated slabs. For heated slabs, refer to requirements in 2018 IRC Table N1102.1.2 (R402.1.2) and 2018 IRC Section N1102.2.10 (R402.2.10).

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2018 IRC Section N1102.3.4

- Opaque door exemption
  - One side-hinged opaque door assembly not greater than 24 square feet (2.22 m2) in area shall be exempt from the U-factor requirement in Section N1102.1.2.

206

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Energy Tradeoffs

4. Opaque doors: 54ft² U-factor exemption (instead of 24ft²)

PA303.4 Opaque door exemption. One door assembly, including side hinged opaque doors, sidelights and transoms, up to 54 square feet (5.02 m²) in area is exempted from the U-factor requirement in Table PA301.

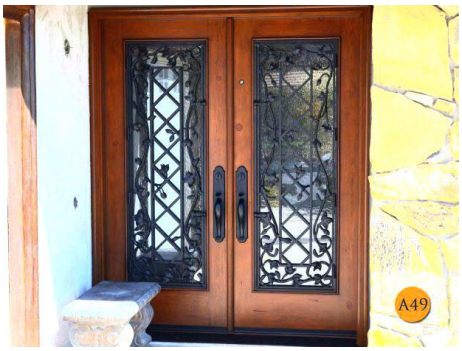

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Image Source: http://openi.co/prehung-exterior-french-doors/exterior-french-doors-interior-rustic-wood-prehung-installing-with/

207

N1101.6, Tables N1101.10.3(1) & N1101.10.3(2) – Fenestration Definitions and U-Factors

- **Change Type:** Gpevmjgexmsr
- **Change Summary:** Xli$hijmrmsrw$jsv$wo}pklxw$erh$zivxgep$jiriwxvexmsr$lezi$fiir$q szih$yrhivlihijmrmsrjsvjiriwxvexmsrerhe$hijmrmsr$jsv$steuyi$hssvlewfiir$ehhih2
- JIRIWXVEXMSR2$Tvshygxw$pewwmjmihewlmklv$zivxgep$jiriwxvexmsrsvwo}pklxw2
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- STEUYI$HSSV2$E$hssv$lex$w$rsxiwwler94tivgirx$steuyi$r$wyvjegi$evie2

208

Source: International Code Council (ICC). (2018). 2018 Significant Changes to the International Residential Code, Country Club Hill, Ill.

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2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

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Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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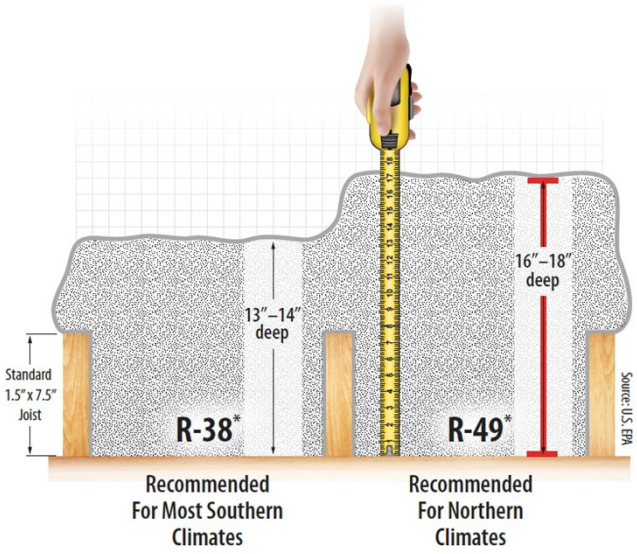
Attic Insulation

- How much thicker?



* Recommended Dept. of Energy attic insulation levels for commonly used fiberglass, mineral wool, and cellulose insulation assuming about R-3 per inch.

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Energy Tradeoffs

5. CZ4 Attic Insulation: R-38 insulation (instead of R-49)

Table PA301

Insulation and Fenestration Requirements by Component[a]

Climate Zone	Fenestration[b] U-factor	Skylights[b] U-factor	Glazed Fenestration SHGC[b,e]	Ceiling R-value	Wood Frame Wall R-value	Mass Wall R-value[h]	Floor R-value	Basement[c] Wall R-value	Slab[d] R-value and depth	Crawlspace[c] Wall R-value
South (4)	0.32	0.55	0.4	38	20[h] or 13+5[g]	8/13	19	10/13	10, 2 ft	10/13
Central (5)	0.30	0.55	NR	49	20[h] or 13+5[g]	13/17	30[f]	10/13	10, 2 ft	10/13
North (6)	0.30	0.55	NR	49	23, 20+5[g], , or 13+10[g]	15/20	30[f]	10/13	10, 4 ft	10/13

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Image Source: 2021 PA Alternative Energy Provisions

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2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

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Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Basement Wall Insulation

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Energy Tradeoffs

6. Basement Walls: R-10 insulation option (instead of R-15)

Table PA301

Insulation and Fenestration Requirements by Component[a]

Climate Zone	Fenestration[b] U-factor	Skylights[b] U-factor	Glazed Fenestration SHGC[b,e]	Ceiling R-value	Wood Frame Wall R-value	Mass Wall R-value[h]	Floor R-value	Basement[c] Wall R-value	Slab[d] R-value and depth	Crawlspace[c] Wall R-value
South (4)	0.32	0.55	0.4	38	20[h] or 13+5[g]	8/13	19	10/13	10, 2 ft	10/13
Central (5)	0.30	0.55	NR	49	20[h] or 13+5[g]	13/17	30[f]	10/13	10, 2 ft	10/13
North (6)	0.30	0.55	NR	49	23, 20+5[g], , or 13+10[g]	15/20	30[f]	10/13	10, 4 ft	10/13

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2018 IRC Table N1102.1.2

Table N1102.1.2 (R402.1.2)
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT [a]

Climate Zone	Fenestration *U*-Factor	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[j]	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BAWSEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20 + 5[h] or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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Energy Tradeoffs

7. CZ6 Walls: Cavity-Only Wall Insulation Option

Table PA301
Insulation and Fenestration Requirements by Component[a]

Climate Zone	Fenestration[b] U-factor	Skylights[b] U-factor	Glazed Fenestration SHGC[b,e]	Ceiling R-value	Wood Frame Wall R-value	Mass Wall R-value[h]	Floor R-value	Basement[c] Wall R-value	Slab[d] R-value and depth	Crawlspace[c] Wall R-value
South (4)	0.32	0.55	0.4	38	20[h] or 13+5[g]	8/13	19	10/13	10, 2 ft	10/13
Central (5)	0.30	0.55	NR	49	20[h] or 13+5[g]	13/17	30[f]	10/13	10, 2 ft	10/13
North (6)	0.30	0.55	NR	49	23, 20+5[g], , or 13+10[g]	15/20	30[f]	10/13	10, 4 ft	10/13

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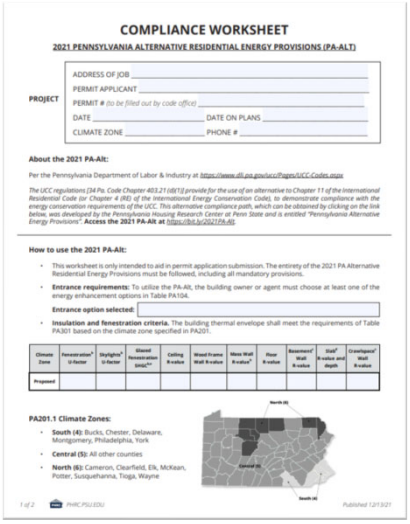
PA Alt Worksheet



COMPLIANCE WORKSHEET

2021 PENNSYLVANIA ALTERNATIVE RESIDENTIAL ENERGY PROVISIONS (PA-ALT)

PROJECT

ADDRESS OF JOB

PERMIT APPLICANT

PERMIT # (to be filled out by code office)

DATE ____ DATE ON PLANS

CLIMATE ZONE ____ PHONE #

About the 2021 PA-Alt:

Per the Pennsylvania Department of Labor & Industry at https://www.dli.pa.gov/ucc/Pages/UCC-Codes.aspx

The UCC regulations [34 Pa. Code Chapter 403.21 (d)(1)] provide for the use of an alternative to Chapter 11 of the International Residential Code (or Chapter 4 (RE) of the International Energy Conservation Code), to demonstrate compliance with the energy conservation requirements of the UCC. This alternative compliance path, which can be obtained by clicking on the link below, was developed by the Pennsylvania Housing Research Center at Penn State and is entitled "Pennsylvania Alternative Energy Provisions". Access the 2021 PA-Alt at https://bit.ly/2021PA-Alt.

How to use the 2021 PA-Alt:

- This worksheet is only intended to aid in permit application submission. The entirety of the 2021 PA Alternative Residential Energy Provisions must be followed, including all mandatory provisions.
- **Entrance requirements:** To utilize the PA-Alt, the building owner or agent must choose at least one of the energy enhancement options in Table PA104.

Entrance option selected:

- **Insulation and fenestration criteria.** The building thermal envelope shall meet the requirements of Table PA301 based on the climate zone specified in PA201.

Climate Zone	Fenestration* U-factor	Skylights* U-factor	Glazed fenestration SHGC**	Ceiling R-value	Wood frame Wall R-value	Mass Wall R-value*	Floor R-value	Basement* Wall R-value	Slab* R-value and depth	Crawlspace* Wall R-value
Proposed										

PA201.1 Climate Zones:

- **South (4):** Bucks, Chester, Delaware, Montgomery, Philadelphia, York
- **Central (5):** All other counties
- **North (6):** Cameron, Clearfield, Elk, McKean, Potter, Susquehanna, Tioga, Wayne

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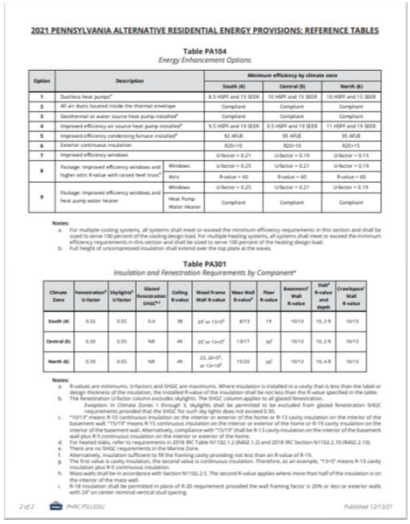

2021 PENNSYLVANIA ALTERNATIVE RESIDENTIAL ENERGY PROVISIONS: REFERENCE TABLES

Table PA104

Energy Enhancement Options

Option	Description		Minimum efficiency by climate zone		
			South (4)	Central (5)	North (6)
1	Ductless heat pumps[a]		8.5 HSPF and 15 SEER	10 HSPF and 15 SEER	10 HSPF and 15 SEER
2	All air ducts located inside the thermal envelope		Compliant	Compliant	Compliant
3	Geothermal or water source heat pump installed[a]		Compliant	Compliant	Compliant
4	Improved efficiency air source heat pump installed[a]		9.5 HSPF and 15 SEER	9.5 HSPF and 15 SEER	11 HSPF and 15 SEER
5	Improved efficiency condensing furnace installed[a]		92 AFUE	95 AFUE	95 AFUE
6	Exterior continuous insulation		R20+10	R20+10	R20+15
7	Improved efficiency windows		U-factor = 0.21	U-factor = 0.19	U-factor = 0.15
8	Package: Improved efficiency windows and higher attic R-value with raised heel truss[b]	Windows	U-factor = 0.25	U-factor = 0.21	U-factor = 0.19
		Attic	R-value = 60	R-value = 60	R-value = 60
9	Package: Improved efficiency windows and heat pump water heater	Windows	U-factor = 0.25	U-factor = 0.21	U-factor = 0.19
		Heat Pump Water Heater	Compliant	Compliant	Compliant

Notes:

a. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

b. Full height of uncompressed insulation shall extend over the top plate at the eaves.

Table PA301

Insulation and Fenestration Requirements by Component[a]

Climate Zone	Fenestration[b] U-factor	Skylights[b] U-factor	Glazed fenestration SHGC[b,c]	Ceiling R-value	Wood frame Wall R-value	Mass Wall R-value[d]	Floor R-value	Basement Wall R-value	Slab[e] R-value and depth	Crawlspace[e] Wall R-value
South (4)	0.32	0.55	0.4	38	20 or 13+5[f]	8/13	19	10/13	10, 2 ft	10/13
Central (5)	0.30	0.55	NR	49	20 or 13+5[f]	13/17	30[f]	10/13	10, 2 ft	10/13
North (6)	0.30	0.55	NR	49	20, 20+5[f], or 13+10[f]	15/20	30[f]	10/13	10, 4 ft	10/13

Notes:

a. R-values are minimums. U-factors and SHGC are maximums. Where insulation is installed in a cavity that is less than the label or design thickness of the insulation, the installed R-value of the insulation shall be not less than the R-value specified in the table.

b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration.

c. The SHGC requirements shall not apply to glazing that is not part of the building envelope, or to glazing excluded from glazed fenestration SHGC requirements provided that the SHGC for such sky lights does not exceed 0.30.

d. "13/17" means R-13 continuous insulation on the interior or exterior of the home or R-13 cavity insulation on the interior of the basement wall. "15/19" means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation on the interior of the basement wall. Alternatively, compliance with "15/19" shall be R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home.

e. For heated slabs, refer to requirements in 2018 IRC Table N1102.1.2 (R402.1.2) and 2018 IRC Section N1102.2.10 (R402.2.10).

f. There are no SHGC requirements in the Marine Zone.

g. Alternatively, insulation sufficient to fill the framing cavity providing not less than an R-value of R-19.

h. "13+5" means R-13 cavity insulation, the second value is continuous insulation. Therefore, as an example, "13+5" means R-13 cavity insulation plus R-5 continuous insulation.

i. Mass walls shall be in accordance with Section N1102.2.5. The second R-value applies where more than half of the insulation is on the interior of the mass wall.

j. R-18 insulation shall be permitted in place of R-20 requirement provided the wall framing factor is 20% or less or exterior walls with 24" on center nominal vertical stud spacing.

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Links

- 2021 PA Alternative Residential Energy Provisions
  - https://bit.ly/2021PA-Alt
- 2021 PA Alternative Worksheet
  - https://bit.ly/2021PA-Alt Worksheet
- Note: we recommend using these links if posting/linking the documents on your own website
  - This will ensure future revisions are automatically linked.

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Questions?

www.phrc.psu.edu

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