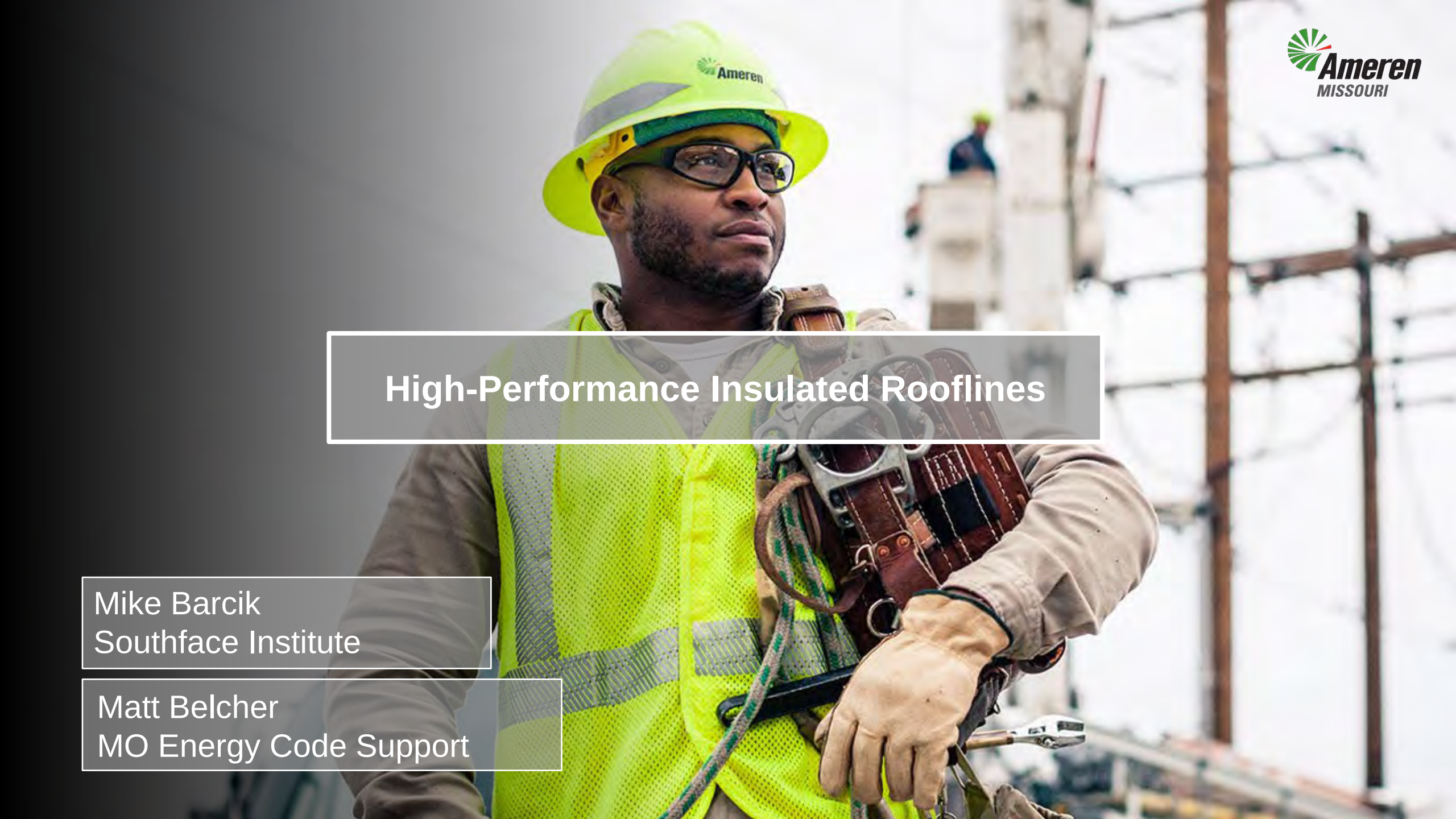

High-Performance Insulated Rooflines

Mike Barcik
Southface Institute

Matt Belcher
MO Energy Code Support


Ameren
MISSOURI

ENERGY CODE RESOURCES

Technical assistance or training requests:

Matt Belcher, Energy Code Consultant
Matt@moenergycodesupport.org
314.749.4189

Energy Code Resources

Missouri Residential Building Energy Code Construction Practices Study:
https://energy.mo.gov/energy-codes/missouri-residential-building-codes-study
For additional information on other DOE Field Studies and participating states, please visit https://www.energycodes.gov/compliance/energy-code-field-studies.
Additional education resources are available at www.southfaceonlinetraining.org.

www.southface.org => Resources => GA Energy Code Resources

mikeb@southface.org

ABOUT SOUTHFACE

- *Building a Regenerative Economy, Responsible Resource Use & Social Equity Through a Healthy Built Environment for All*

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- Weatherization
- HERS Rater
- Code official
- Designer / Engineer
- Contractor / Trades
- Utility
- Manufacturers / Product Rep
- Policy / Government
- Building Manager
- Home Inspector

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BUILDING CERTIFICATION | WATER | POLICY | INDOOR AIR QUALITY | COMMUNITY DEVELOPMENT | **CODE**

RESIDENTIAL | BUILDING SCIENCE | COMMERCIAL | ENERGY

Retrofit spray foam roofline

A properly installed foam coverage at the roofline, although expensive, offers exceptional thermal and comfort performance and provides significant energy savings (especially if ductwork is brought inside the thermal envelope). After average depth has been consistently verified, the foam will likely require an **intumescent coating** which provides a fire "thermal" barrier (it may also serve as an ignition barrier). Ideally the verifier should confirm the proper foam application before the coating is applied.

In general, a properly foamed roof retrofit will involve the following:

Assessment Toolkit | Guide

Energy and Water Efficiency Project Implementation Verification Checklist

Language contained in this document is intended to serve as a general template and should be copied, pasted and edited for each specific project. Providing clear expectations of what should be installed and how it will be inspected and verified...

Read More

Access the IECC and IRC codes at the **ICC Digital Codes Library:**

https://codes.iccsafe.org/

IMPORTANCE OF ENERGY CODES

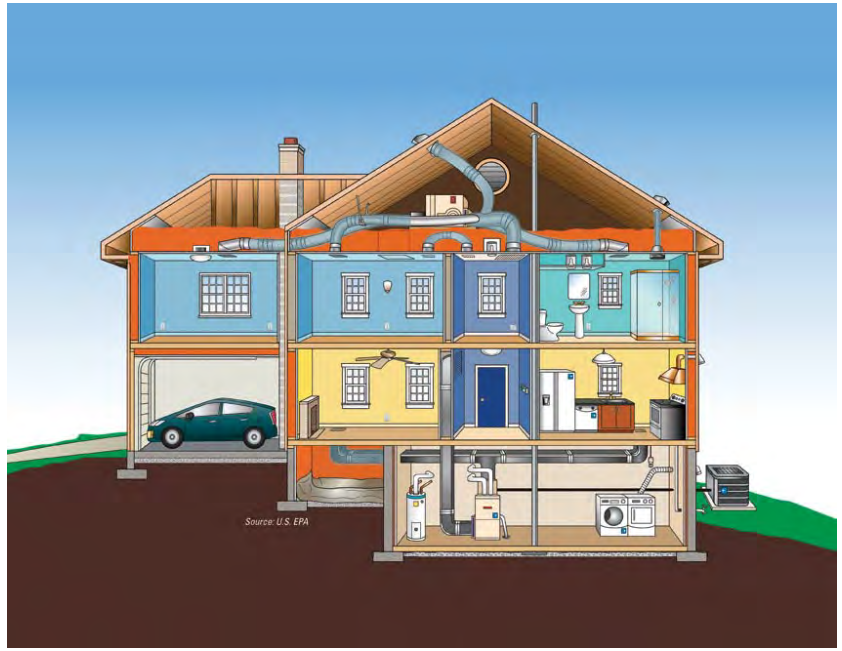
- **Saves energy** - Buildings consume 40% of energy in U.S. (more than half is homes)
- **Saves money** - Energy costs continue to escalate and energy codes help keep money within local economy
- **Additional benefits:**
  - Increases comfort, health and durability of homes
  - Increases value of homes in local community
  - Reduces liability for builders and subcontractors

SCOPE OF RESIDENTIAL ENERGY CODE

- Focus is on building envelope
  - Ceilings, walls, windows, floors, foundations
  - Sets insulation and fenestration levels, and solar heat gain coefficients
  - Infiltration control – caulk and seal to prevent air leaks, and test
- Ducts, air handlers, filter boxes – seal, insulate, and test
- Limited space heating, air conditioning, and water heating requirements
  - Federal law sets most equipment efficiency requirements, not the I-codes
- No appliance requirements
- Lighting equipment – 90% of lamps to be high-efficacy lamps or 90% of lighting fixtures to have only high-efficacy lamps

WHY BUILDING SCIENCE?

- Employ scientific principles from a variety of fields that govern building performance
- Optimize building performance and understand, prevent and correct building failures
- Systems approach to houses
- Physics of
  - Heat
  - Air
  - Moisture



All efficiency measures should take occupants into account (e.g., air sealing & ventilation)

THE HOUSE AS A SYSTEM

A house is a system made up of interrelated parts:

- The building thermal envelope
- Space conditioning
- Ventilation
- Lighting, appliances, plumbing

LEARNING OBJECTIVES

- Recall building science concepts
- Apply knowledge of the building thermal envelope to home design
- Interpret the energy code's treatment of insulated rooflines
- Choose best materials and methods for insulated and air sealing attic rooflines

Knowledge Check

HEAT TRANSFER PROBLEM

Your Choices:

Radiation

Conduction

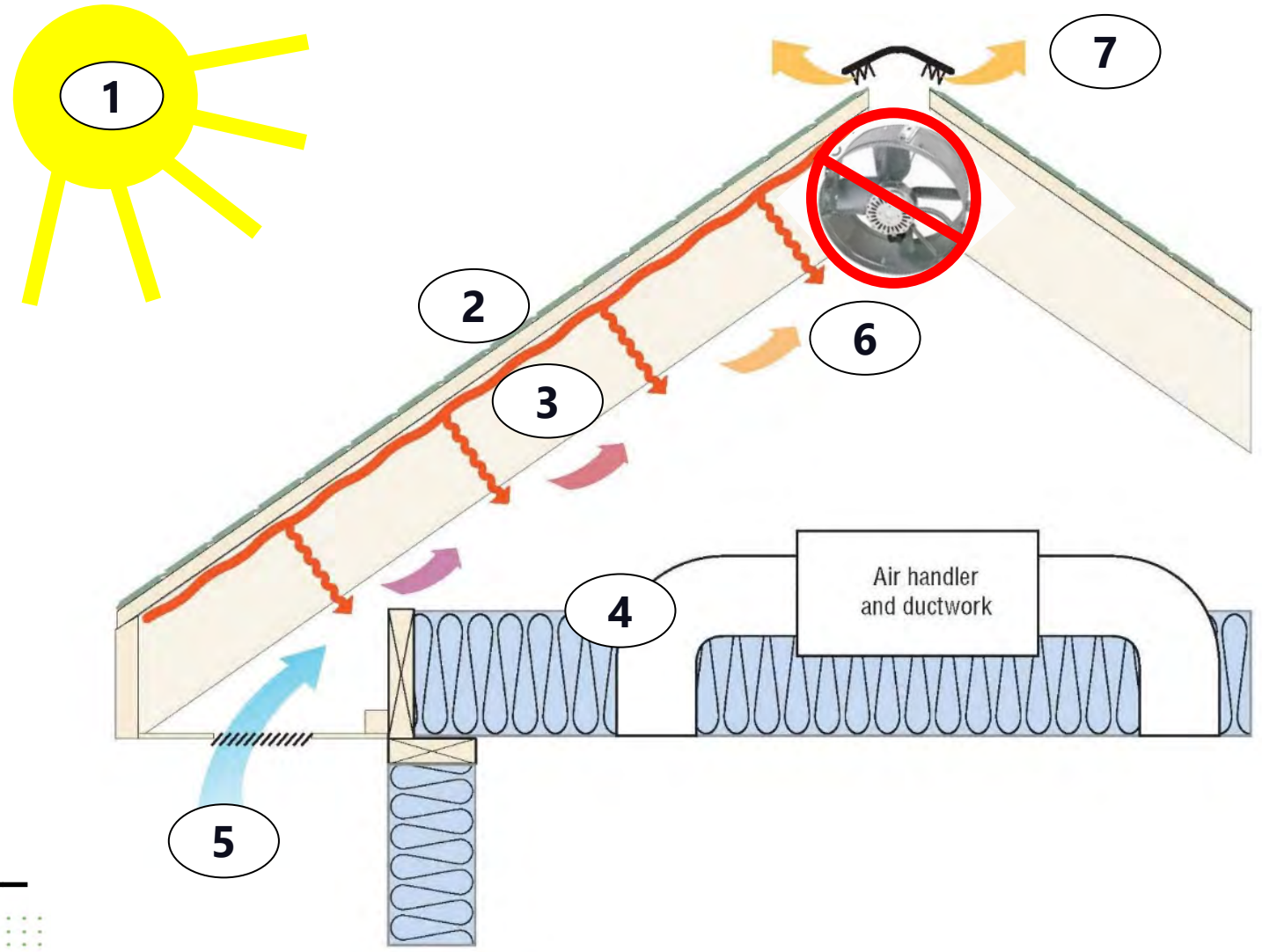
Convection

1 → 2 = Radiation

2 → 3 = Conduction

3 → 4 = Radiation

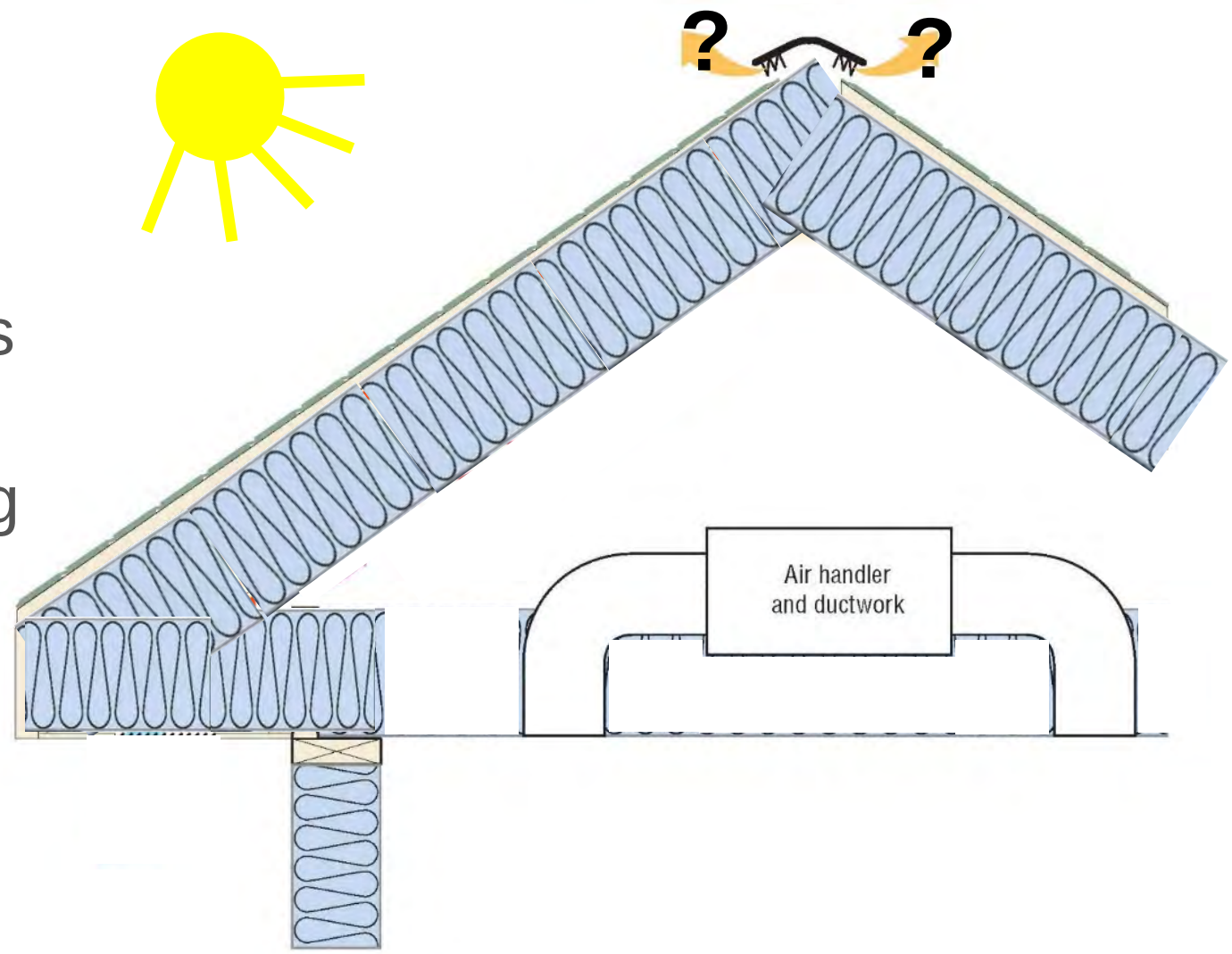
5 → 6 → 7 = Convection



ATTIC HEAT TRANSFER

3 methods of heat transfer:

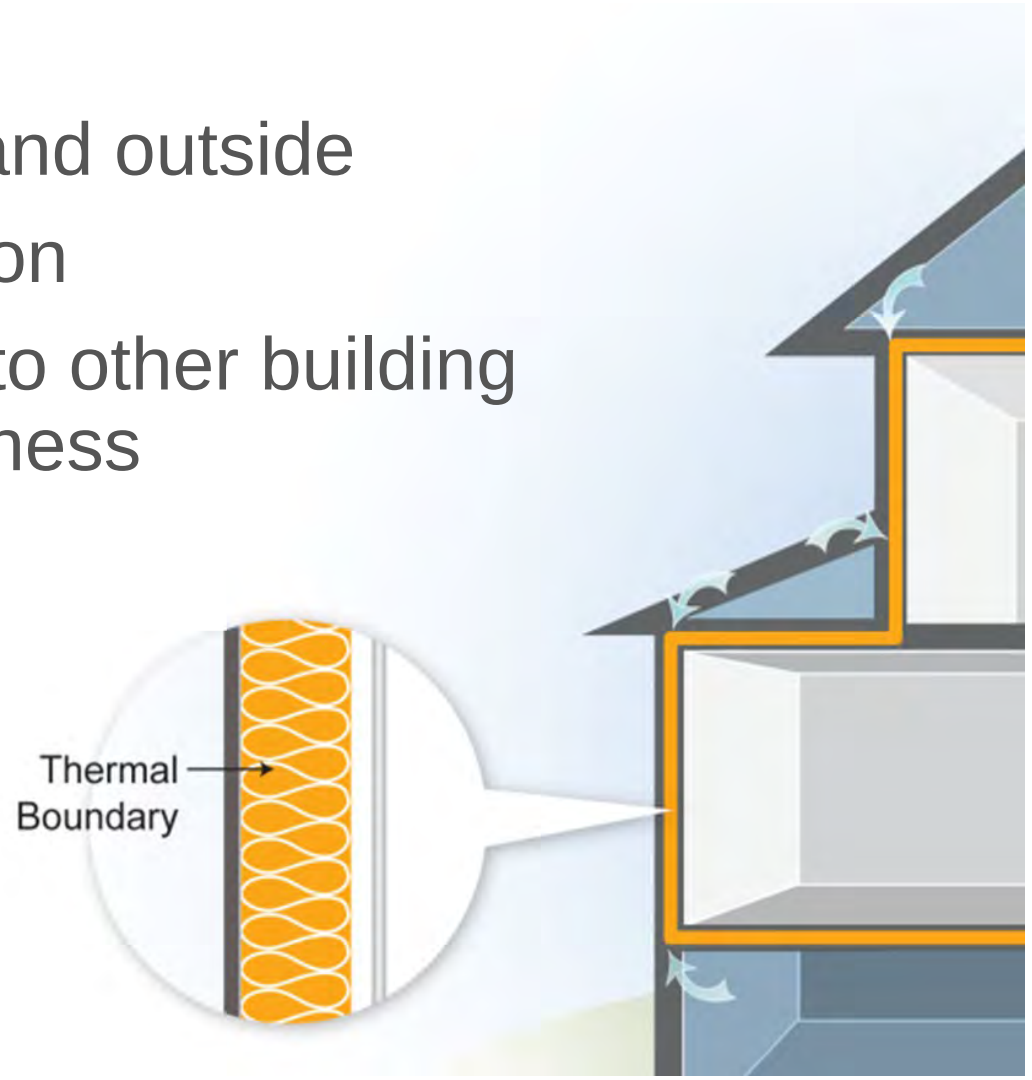
- **Radiation:**
  Sun to shingles; underside of decking to other attic surfaces
- **Conduction:**
  Through shingles and decking
- **Convection:**
  Soffit vents through attic to ridge



Hmmm…

THERMAL BOUNDARY

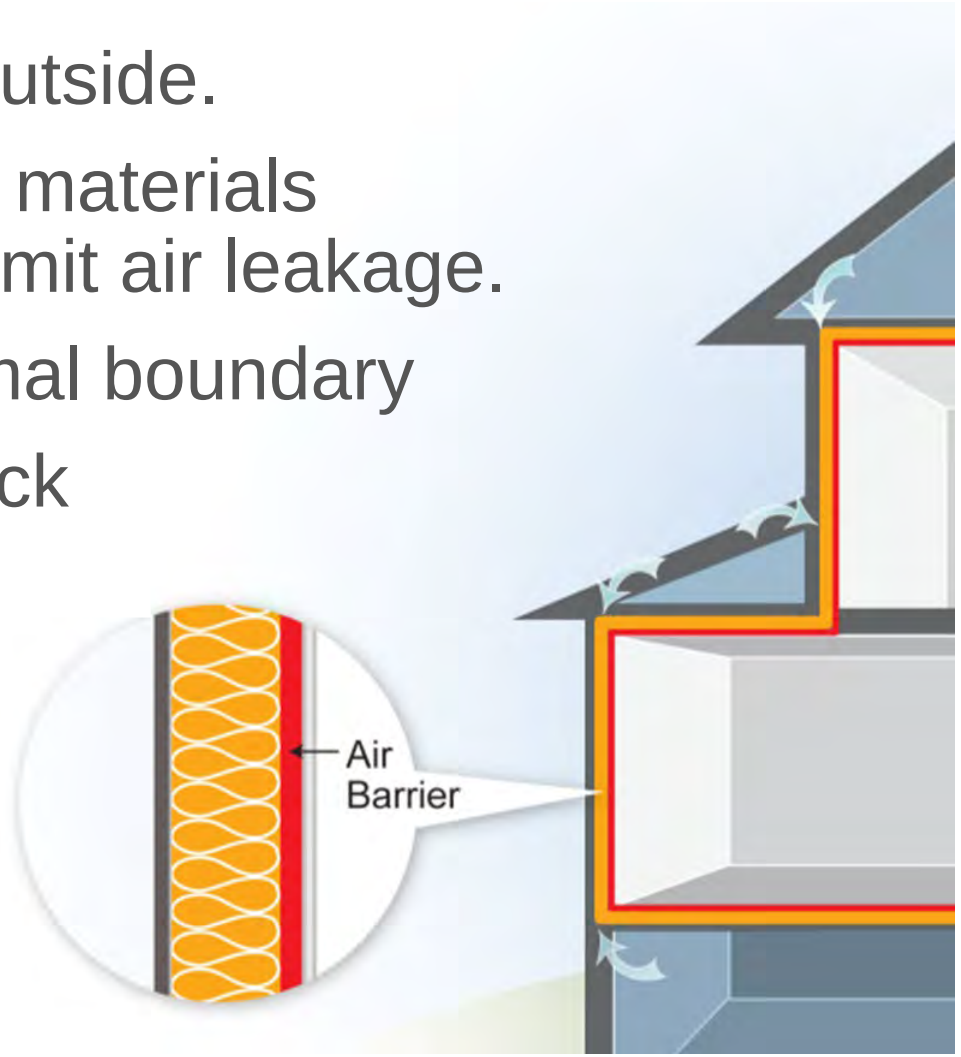
- Limits heat transfer between inside and outside
- Identified by the presence of insulation
- The location of insulation in relation to other building components is critical to its effectiveness
- Even small areas of missing insulation are very important
- Voids of 7% can reduce effective R-value by half



Graphic developed for the US DOE WAP Standardized Curricula

AIR BARRIER

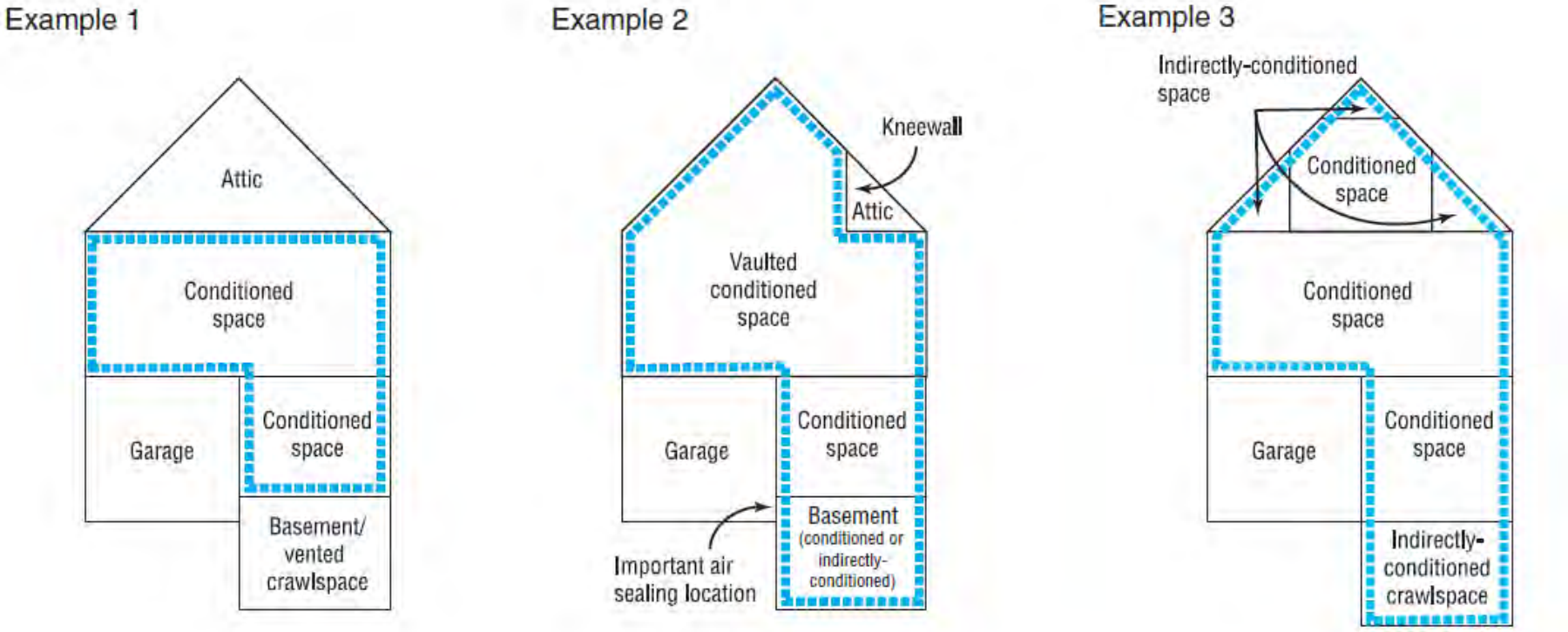
- Limits airflow between inside and outside.
- The IECC defines the air barrier as materials assembled and joined together to limit air leakage.
- Should be collocated with the thermal boundary
- Can be the attic floor or the roof deck



Graphic developed for the US DOE WAP Standardized Curricula

BUILDING THERMAL ENVELOPE

- Although these three homes look identical from the outside, each has defined the building thermal envelope differently
- This results in significantly different conditioned volumes



CODE CONSIDERATIONS

R402.2.1 CEILINGS WITH ATTIC SPACES

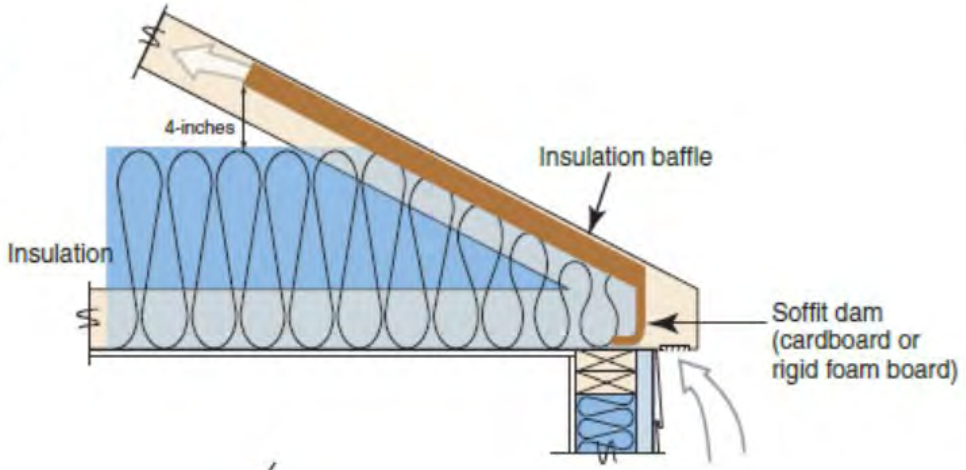
- R-49 is prescriptive requirement, for CZ4-8
- Complete coverage of continuous R-38 is deemed to comply
- Rulers required every 300 s.f. for blown attic insulation (R301.1.1)

R402.2.1 CEILINGS WITH ATTIC SPACES

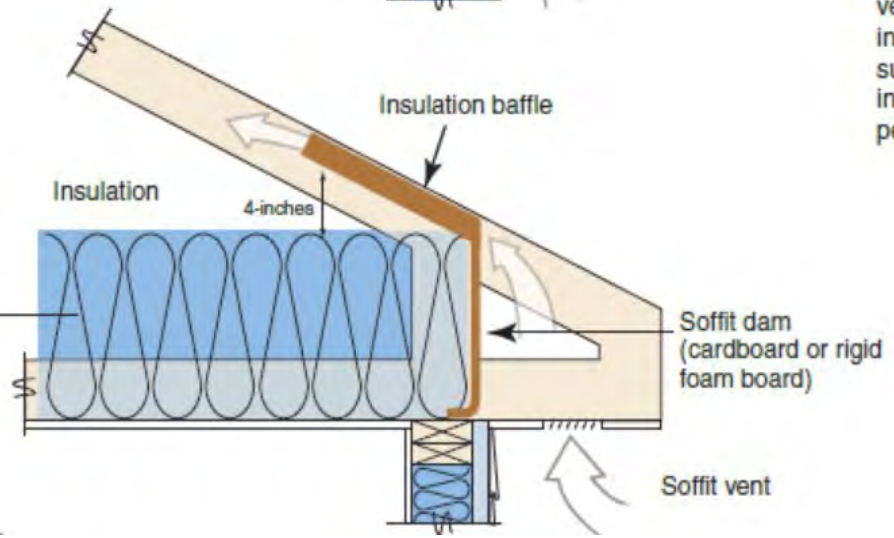
R402.2.1 Ceilings with attic spaces. Where Section R402.1.2 requires R-38 insulation in the ceiling, installing R-30 over 100 percent of the ceiling area requiring insulation shall satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Where Section R402.1.2 requires R-49 insulation in the ceiling, installing R-38 over 100 percent of the ceiling area requiring insulation shall satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the Total UA alternative in Section R402.1.5.

R402.2.3 EAVE BAFFLES

Standard Truss
with tapered
insulation depth



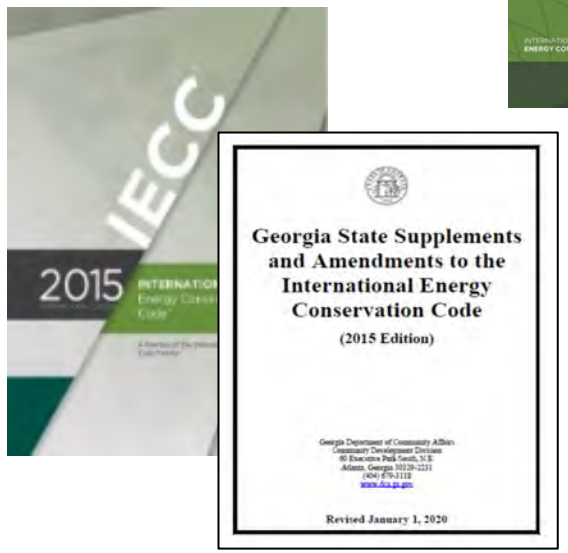
Energy Truss
with full height insulation
(recommended)



NOTE:

R-38 complete coverage is deemed equivalent to prescriptive R-49

Note: Wind wash baffle and air-permeable insulation dam. For air permeable insulation in vented attics, baffles shall be installed adjacent to soffit and eave vents. A minimum of a 1-inch of space shall be provided between the insulation and the roof sheathing and at the location of the vent. The baffle shall extend over the top of the insulation inward until it is at least 4 inches vertically above the top of the insulation. Any solid material such as cardboard or thin insulating sheathing shall be permissible as the baffle.

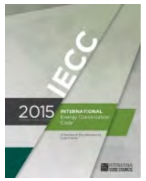


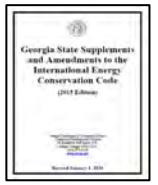
R402.2.3 Eave baffle. For air permeable insulation in vented attics, baffles shall be installed adjacent to soffit and eave vents. A minimum of a 1-inch of space shall be provided between the insulation and the roof sheathing and at the location of the vent. The baffle shall extend over the top of the insulation inward until it is at least 4 inches vertically above the top of the insulation. Any solid material such as cardboard or thin insulating sheathing shall be permissible as the baffle. (See Appendix RA for further clarification.)
(Effective January 1, 2020)

R402.2.2 CEILINGS WITHOUT ATTIC SPACES

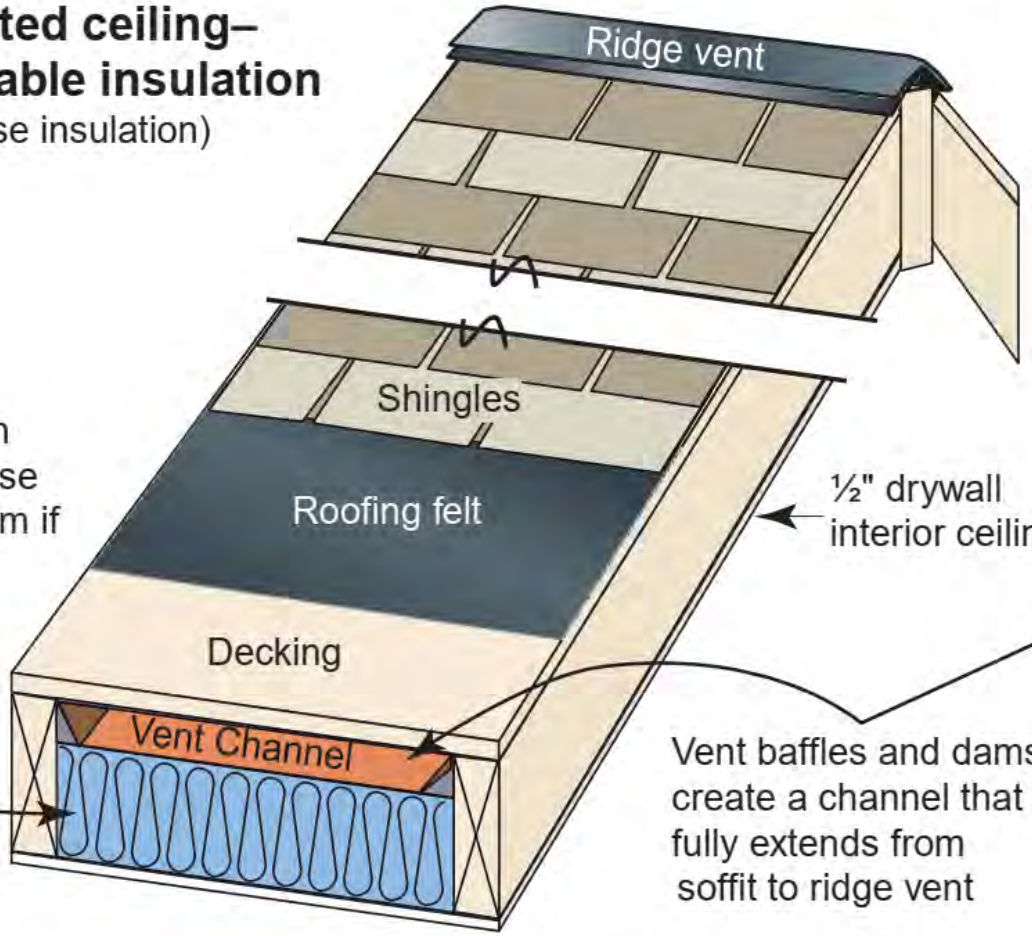
- If vaulted ceiling design does not allow sufficient space for required insulation, insulation can be reduced to R-30
- The area of the reduced insulation shall be limited to 500 sq ft or 20 percent of the insulated ceiling, whichever is less
- For prescriptive path only

OLD-SCHOOL VAULT WITH VENT





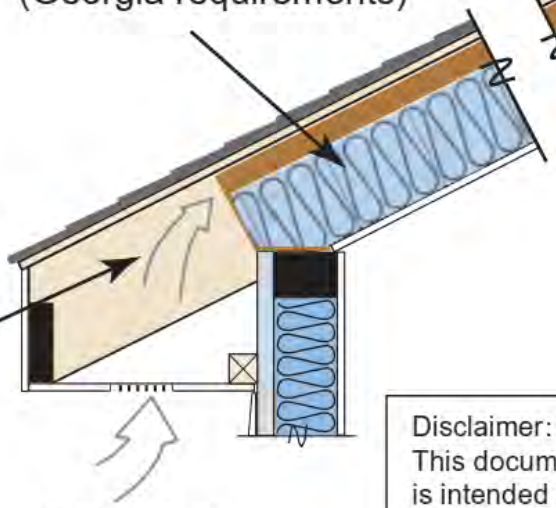
Cathedralized vented ceiling–roofline air-permeable insulation
(e.g., fiberglass, cellulose insulation)



Air-permeable insulation (e.g., fiberglass, cellulose insulation) R-20 minimum if trade-offs are used (Georgia requirements)

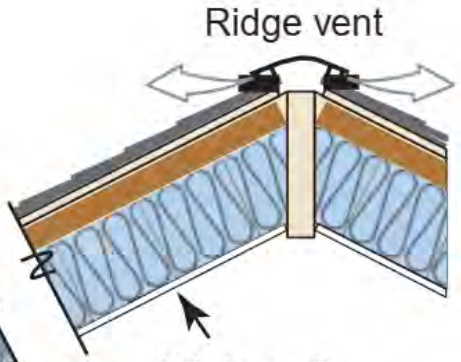
½" drywall interior ceiling

Vent baffles and dams create a channel that fully extends from soffit to ridge vent



Air-permeable insulation (e.g., fiberglass, cellulose insulation) R-20 minimum if trade-offs are used (Georgia requirements)

Soffit vent

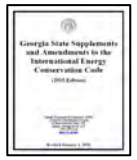


½" drywall interior ceiling

Disclaimer:
This document was created by Southface and is intended solely to help graphically demonstrate the air leakage and insulation provisions of the 2015 IECC (2020 Georgia Energy Code). It does not cover all air sealing locations, materials or techniques. Other code provisions may be applicable as well.

Georgia International Energy Conservation Code Supplements and Amendments 2020

UNVENTED VAULT WITH SPF

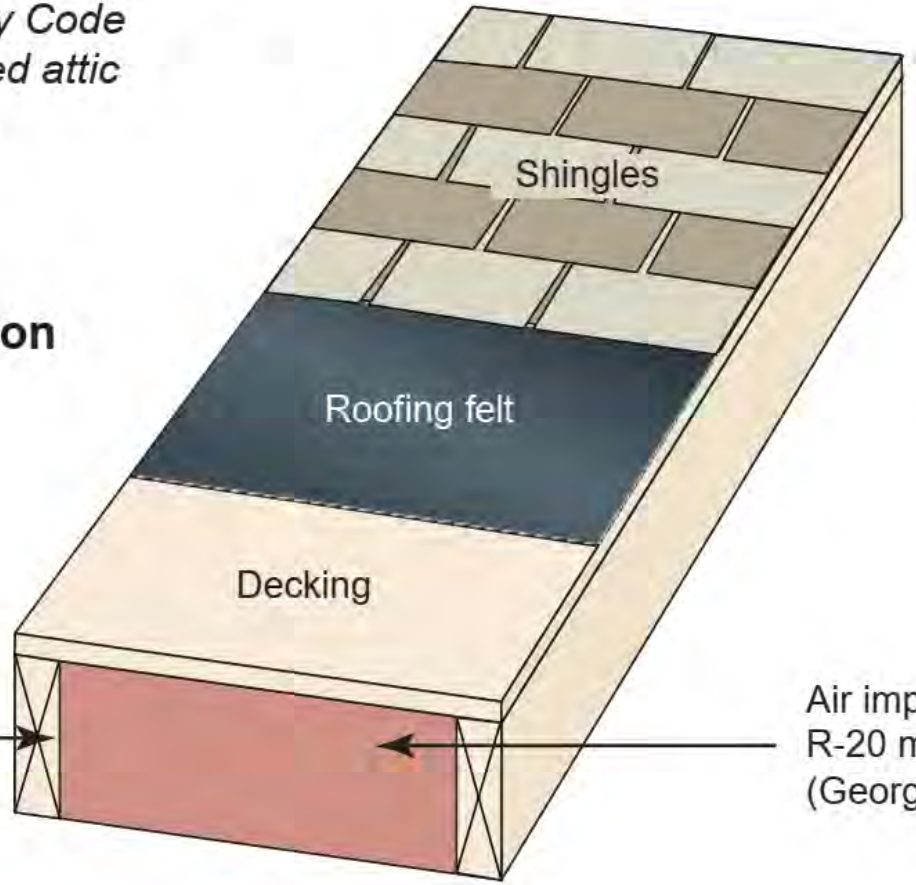



Appendix RA

Roofline Installed Insulation Options

Reference Table 402.1.1 and 402.1.6 in the Georgia Energy Code amendments to the 2015 IECC and Section 806.5 "unvented attic assemblies" in the Georgia Amendments to the 2012 IRC

Vaulted unvented attic –
roofline air-impermeable insulation
(e.g., spray foam insulation)



IRC 806.5 UNVENTED ROOF ASSEMBLIES

To reduce risk of condensation, install a certain amount of “air-impermeable” insulation before using an “air- permeable” product in an unvented roof assembly

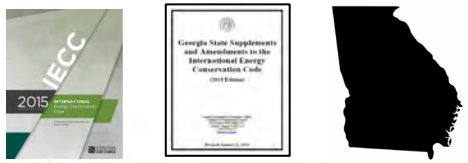
TABLE R806.5
INSULATION FOR CONDENSATION CONTROL

CLIMATE ZONE	MINIMUM RIGID BOARD ON AIR-IMPERMEABLE INSULATION *R*-VALUE[a, b]
2B and 3B tile roof only	0 (none required)
1, 2A, 2B, 3A, 3B, 3C	R-5
4C	R-10
4A, 4B	R-15
5	R-20
6	R-25
7	R-30
8	R-35

a. Contributes to but does not supersede the requirements in Section N1102.

b. Alternatively, sufficient continuous insulation shall be installed directly above the structural roof sheathing to maintain the monthly average temperature of the underside of the structural roof sheathing above 45°F (7°C). For calculation purposes, an interior air temperature of 68°F (20°C) is assumed and the exterior air temperature is assumed to be the monthly average outside air temperature of the three coldest months.

HYBRID INSULATION APPROACHES



Vaulted unvented attic – roofline air-permeable insulation
(e.g., fiberglass, cellulose insulation)

Option 1
Air impermeable insulation continuous above rafters (e.g. rigid foam board) combined with air-permeable insulation (e.g., fiberglass, cellulose insulation)

Air impermeable insulation (e.g. rigid foam board)

Shingles

Roofing felt

Decking

R-5 minimum in climate zones 2 & 3
R-15 minimum in climate zone 4

Air-permeable insulation (e.g.. fiberglass, cellulose insulation) R-20 minimum if trade-offs are used (Georgia requirements)

Option 2
Air impermeable insulation between rafters (e.g. rigid foam board or spray foam) combined with air-permeable insulation (e.g., fiberglass, cellulose insulation)

Shingles

Roofing felt

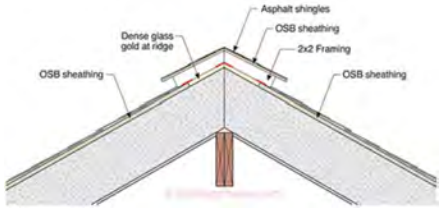
Decking

Air-permeable insulation (e.g., fiberglass, cellulose insulation) R-20 minimum if trade-offs are used (Georgia requirements)

5.3. Where preformed insulation board is used as the air-impermeable insulation layer, it shall be sealed at the perimeter of each individual sheet interior surface to form a continuous layer.

PEACHCREST COMMUNITY CENTER

IRC 806.5 VAPOR VENT – NEW FOR CZ1-3



5.2. In Climate Zones 1, 2 and 3, air-permeable insulation installed in unvented *attics* shall meet the following requirements:

5.2.1. An approved *vapor diffusion port* shall be installed not more than 12 inches (305 mm) from the highest point of the roof, measured vertically from the highest point of the roof to the lower edge of the port.

5.2.2. The port area shall be greater than or equal to 1:600 of the ceiling area. Where there are multiple ports in the attic, the sum of the port areas shall be greater than or equal to the area requirement.

5.2.3. The vapor-permeable membrane in the *vapor diffusion port* shall have a vapor permeance rating of greater than or equal to 20 perms when tested in accordance with Procedure A of ASTM E96.

5.2.4. The *vapor diffusion port* shall serve as an air barrier between the *attic* and the exterior of the building.

5.2.5. The *vapor diffusion port* shall protect the *attic* against the entrance of rain and snow.

5.2.6. Framing members and blocking shall not block the free flow of water vapor to the port. Not less than a 2-inch (51 mm) space shall be provided between any blocking and the roof sheathing. Air-permeable insulation shall be permitted within that space.

5.2.7. The roof slope shall be greater than or equal to 3:12 (vertical/horizontal).

5.2.8. Where only air-permeable insulation is used, it shall be installed directly below the structural roof sheathing.

5.2.9. *Air-impermeable insulation*, if any, shall be directly above or below the structural roof sheathing and is not required to meet the *R*-value in Table 806.5. Where directly below the structural roof sheathing, there shall be no space between the *air-impermeable insulation* and air-permeable insulation.

5.2.10. The air shall be supplied at a flow rate greater than or equal to 50 CFM (23.6 L/s) per 1,000 square feet (93 m^2) of ceiling. The air shall be supplied from ductwork providing supply air to the occupiable space when the conditioning system is operating. Alternatively, the air shall be supplied by a supply fan when the conditioning system is operating.

TRADE-OFFS

- Even if you've created a high-performance, insulated roofline, chances are you're still short on insulation
- R-20 < R-49

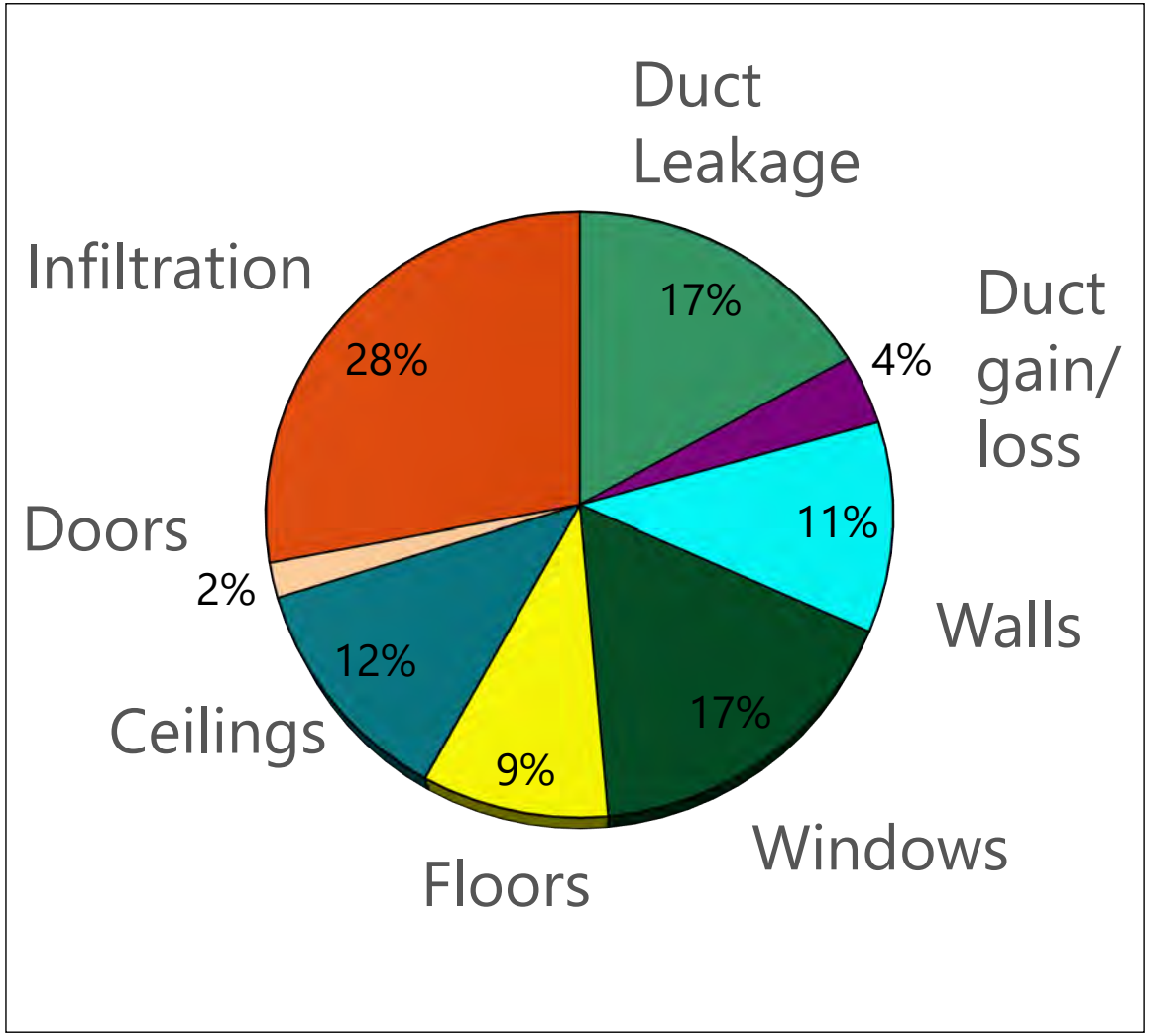
TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[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	0.32	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

LOAD CALCULATIONS

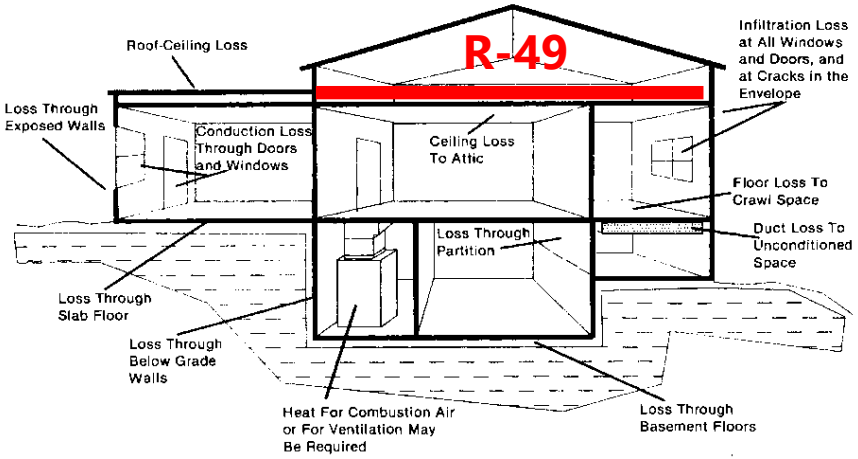
HOME HEATING & COOLING ENERGY

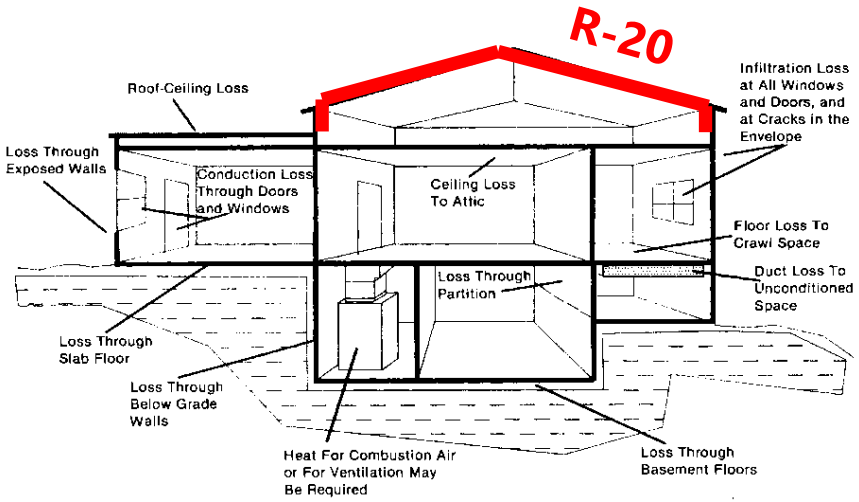
- This chart represents energy used to heat and cool an existing home
- A lot of this energy is gained/lost in the attic *(conduction through ceiling plus air and duct leakage)*
- Insulating and air sealing the attic is a high priority way to improve energy efficiency in a typical existing home



LOAD CALCS & FOAMED HOUSES

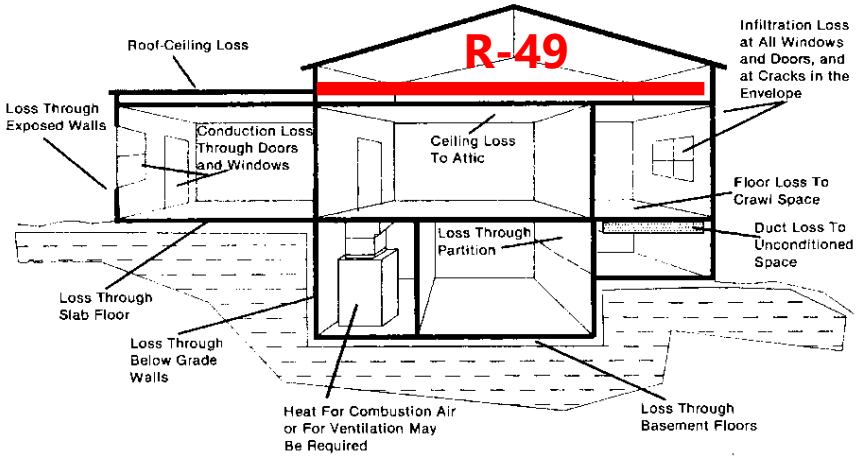
- **Foam insulation could increase the HVAC size because…**
  - Conduction occurs through surfaces and insulating the roofline involves more surface area than insulating the flat ceiling
  - R-value at roofline is usually only ~R-20
    but this is less than prescriptive R-49
  - Well-sealed houses will likely need ventilation which can add to load

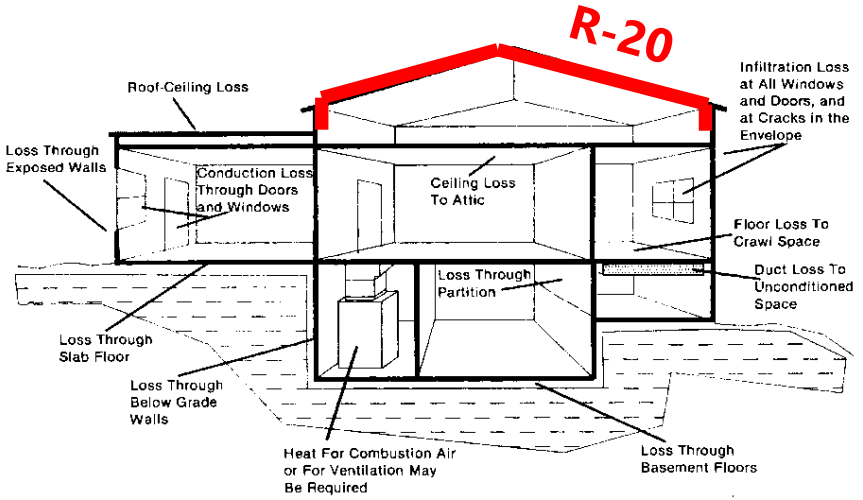




LOAD CALCS & FOAMED HOUSES

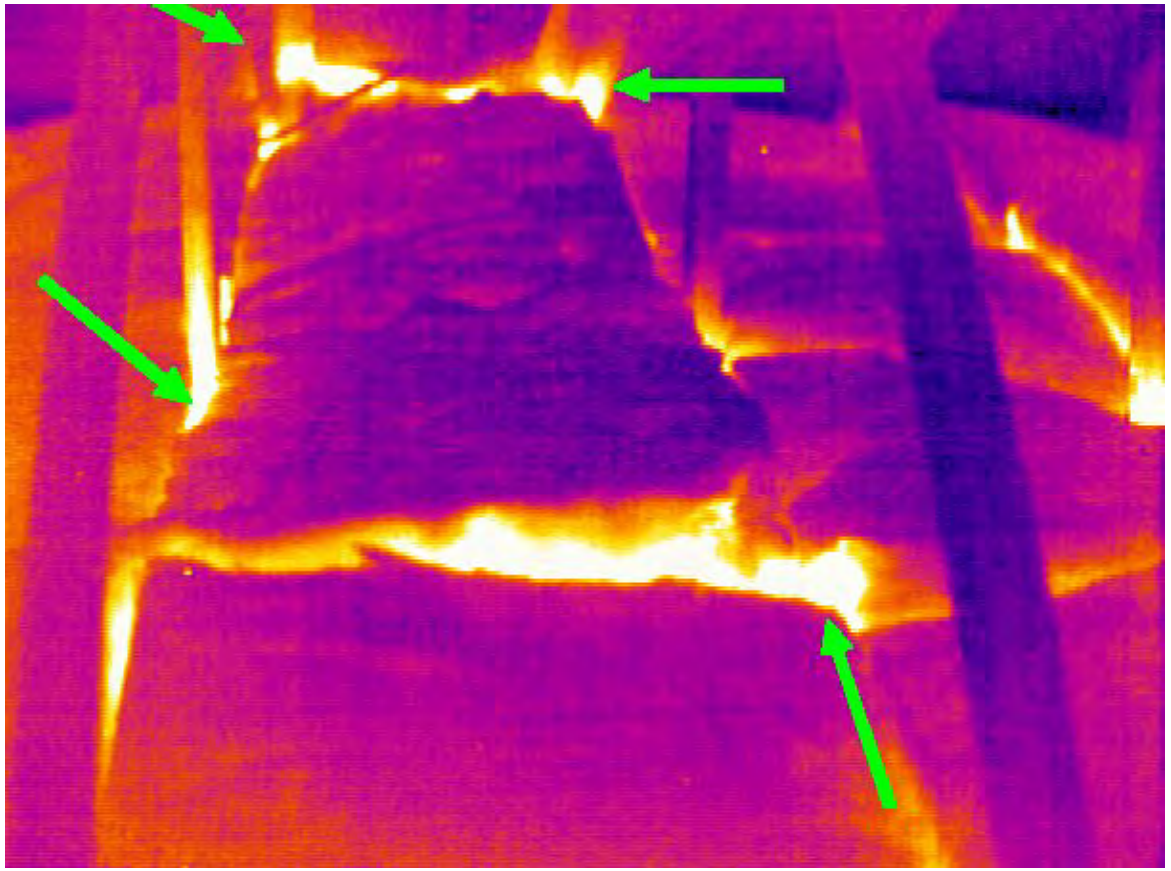
- **However, foam insulation should decrease the HVAC size because…**
  - Home is usually better airsealed (Lower ACH_{50} from blower door reading)
  - Insulation coverage is potentially better
  - Foam "holds its R-value" better over the actual temperature range
    - R-value is determined at 75°F but really should be measured at 0°F and 120°F – where it matters!
  - Ducts and equipment are inside thermal envelope
  - New, known ventilation cfm < random infiltration cfm





THE ATTIC FLOOR

- Insulation on the attic floor is often installed poorly
- The flat ceiling is difficult to make airtight
- This allows heat to flow freely from the attic (summer) or from the home (winter)



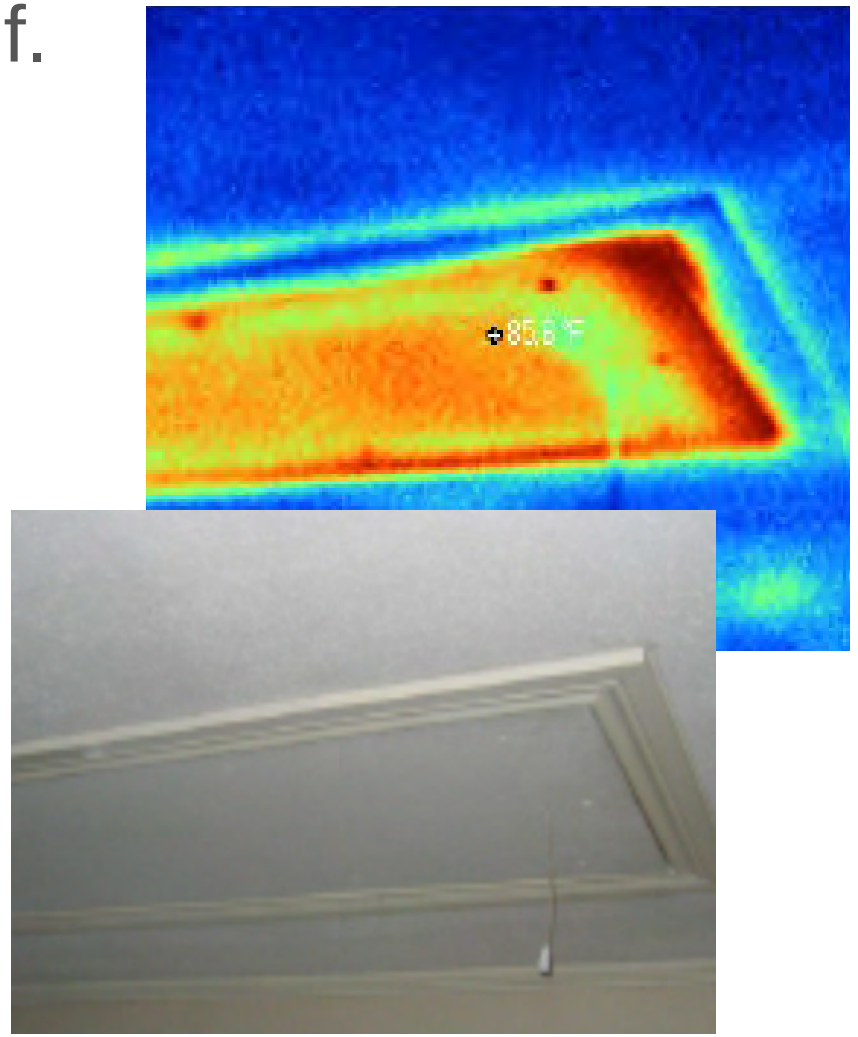
INSULATION COVERAGE IS KEY!

- If 1000 s.f. of R-49 is installed with 10 s.f. of uninsulated area (R-1), it effectively yields the same heat transfer as R-33!

$$U_{avg} = \frac{U_1 \times A_1 + U_2 \times A_2 + U_3 \times A_3}{A_{total}}$$

$$U_{avg} = \frac{0.0204 \times 990 + 1 \times 10}{1000}$$

$$U_{avg} = \mathbf{0.0302} \quad => \quad \mathbf{R\text{-}33}$$



- *If an attic has 970 s.f. at R-49, and 30 s.f. at R-1, Effective R-value is only **R-20**!*

THE ATTIC FLOOR

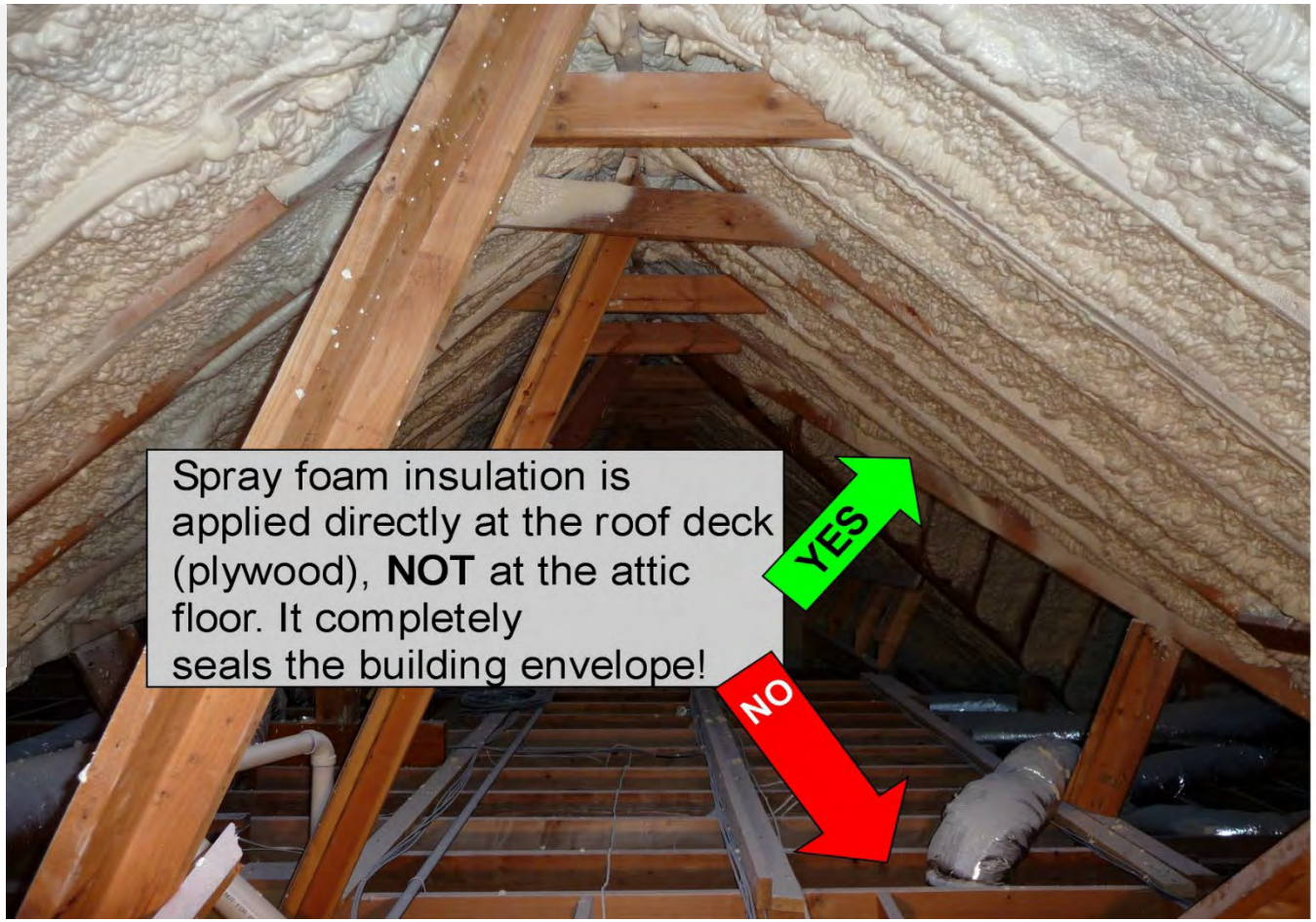
- The attic flow has many pathways for air to leak through
- Some of these pathways, such as duct chases, allow large volumes of air to move

SPRAY FOAMED ROOFLINES

SPRAY FOAM ROOFLINES

There are multiple ways of defining the building thermal envelope.

The performance advantage of defining the envelope by the roof is air-sealing, consistent insulation coverage and ducts brought inside the envelope



OPEN VS CLOSED CELL

- Spray Polyurethane Foam is made by combining two chemicals, an A (isocyanate) and B (catalyst, polyol resin, surfactant, blowing agent, fire retardant, coloring) chemicals in a spray application
- It is manufactured at the jobsite and is critical that the mix be correct and that the substrate be dry and warm enough

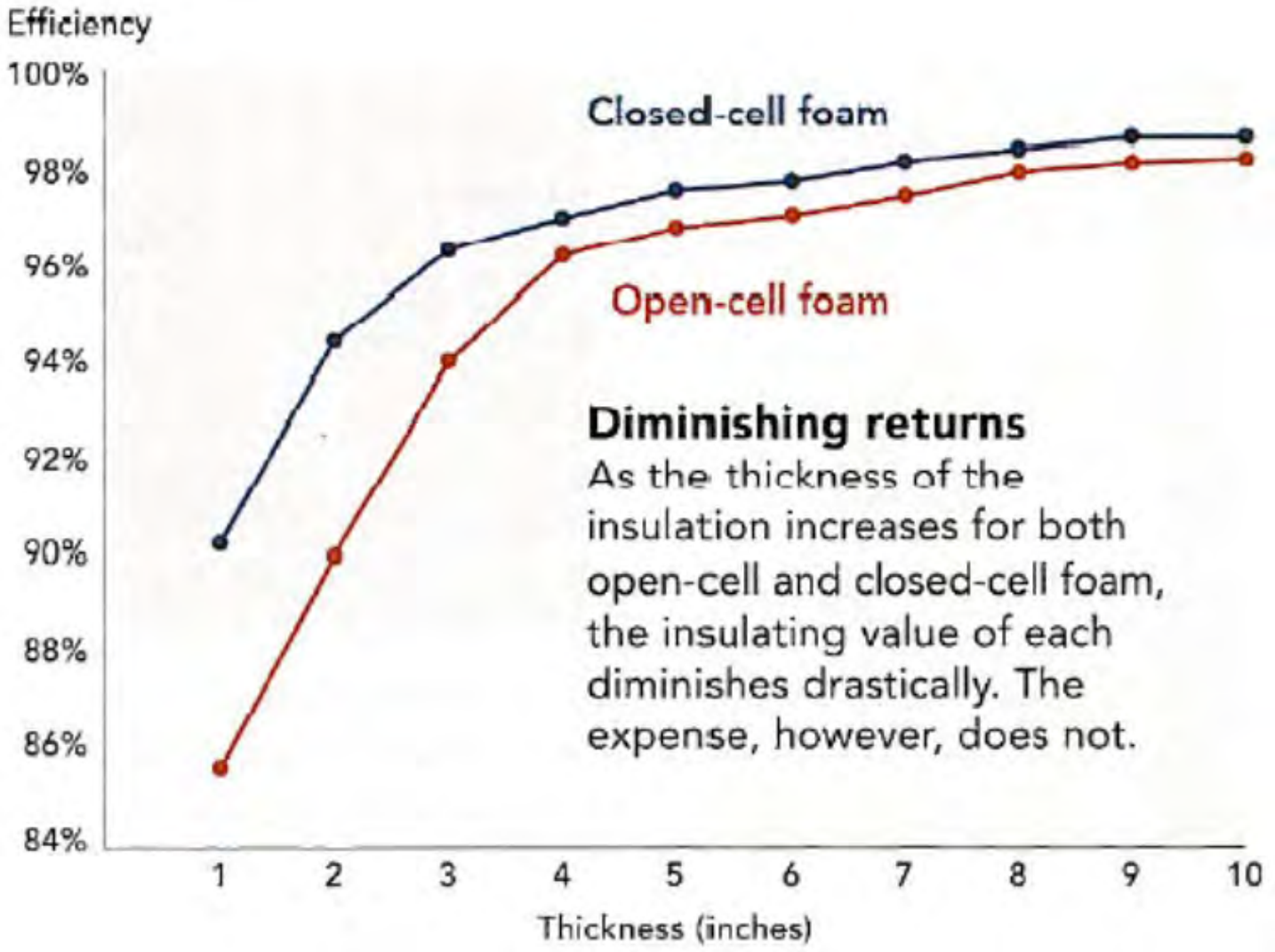
- **Open Cell**: low density (1/2 lb/ ft^3), ~R-3.7/inch, “squishy”, vapor open, water is blowing agent, lower cost
- **Closed Cell**: high density (2 lb/ ft^3), ~R-6-ish/inch, “solid”, lower vapor permeability (~0.5), HFC’s/other as blowing agent, higher cost but does add ~30% structural benefit

OPEN VS CLOSED CELL

- Both are considered air barriers at specified thickness
- Both generate heat during their application (exothermic) and there are limits of how little and how much can be installed in a lift (pass)
- Proper installation = minimal/no offgassing

- **Open Cell**: Walls (2x4-2x6), framed rafter roofline, framed floors
- **Closed Cell**: Above plus foundation, probably easier for hybrid approaches (flash and batt, etc.)

WHY NOT R-38 OR 49?



- From an economic standpoint, it is challenging to justify higher R-values after ~5-6” of SPF
- For example, 4” to 8” doubles the cost for only ~2% increase in efficiency
- Hybrid systems can offset this issue

SPRAY FOAM – BEST PRACTICE

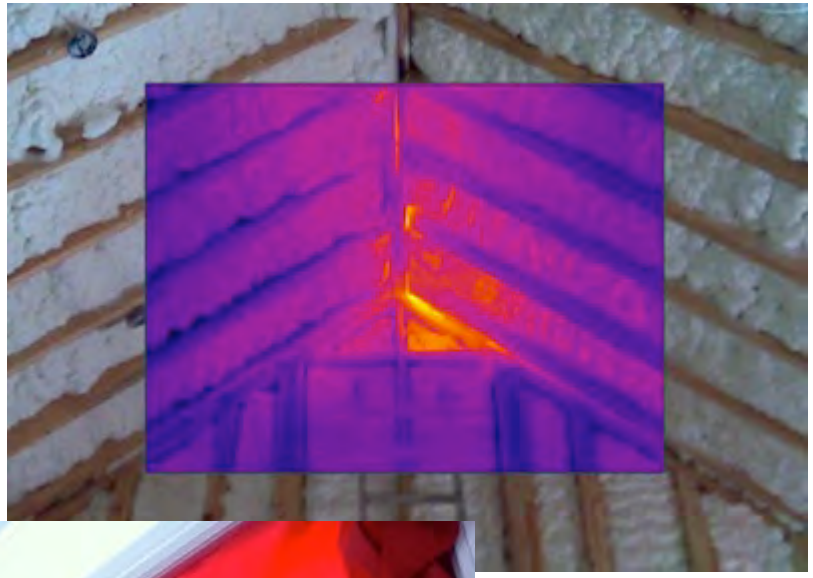
- Pay extra attention to the junctions (soffits, roof penetrations)
- Cover the rafter tails
- Use a straight wire to check for depth in multiple locations (minimum vs average)

DON’T FORGET THE FUNDAMENTALS

- Ducts still need to be sealed and installed properly
- No sharp turns
- Use appropriate support

TRUST BUT VERIFY

- Quality of installation critical that coverage is complete and proper substrate (OSB) temperature is maintained
- A blower door test and visual inspection should always be performed on foam houses
- Remove old ceiling insulation for IAQ reasons



SPRAY FOAM FAILS

- Inexperienced or poorly trained installers can lead to a poor end-product

- Improper ratio
- Temperature
- Substrate compatibility

FIRE CODE ISSUES

- Ignition barrier
  - Some open cell and all closed cell foams satisfy
- “Thermal” barrier
  - Basis is ½” drywall for separation between foam and occupants
    - Attic may not be used for storage but may be accessed and contain HVAC equipment
    - No drop ceilings
  - Otherwise, add sprayed-on intumescent coating (which adds cost)

COMBUSTION IN FOAMED HOUSES

- Do NOT use attic air as combustion air for **atmospheric** combustion appliances
  - Do not add high/low vents to unvented attic
  - Do not use “volume” of attic as combustion air

COMBUSTION IN FOAMED HOUSES

- Combustion equipment inside foamed attics should be sealed combustion, direct-vent (2-pipe systems)
- Not an issue in all electric homes!

ALTERNATIVES

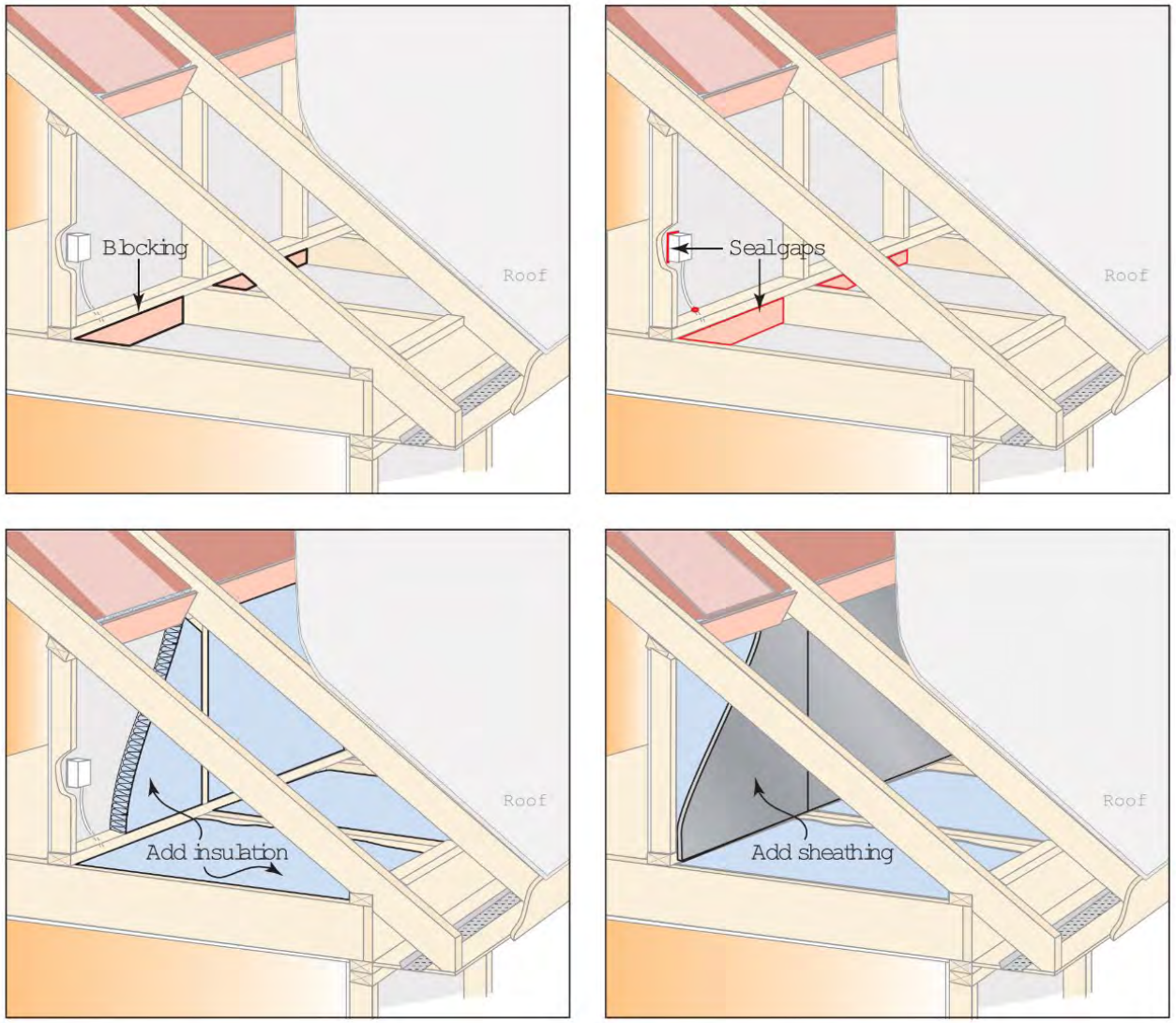
AIR-PERMEABLE INSULATION

- Materials like fiberglass, cellulose, and rockwool, can be used for rooflines
- They do not stop airflow!
- Batts must be secured, or they will slide down over time
- Follow IRC for condensation break (or vapor vent)

AIR-PERMEABLE INSULATION

- Fiberglass or cellulose can also be sprayed in
- A netting is used to secure the insulation
- Mind the knee wall!

KNEE WALLS


Blocking
Roof
Sealgaps
Roof
Add insulation
Roof
Add sheathing
Roof

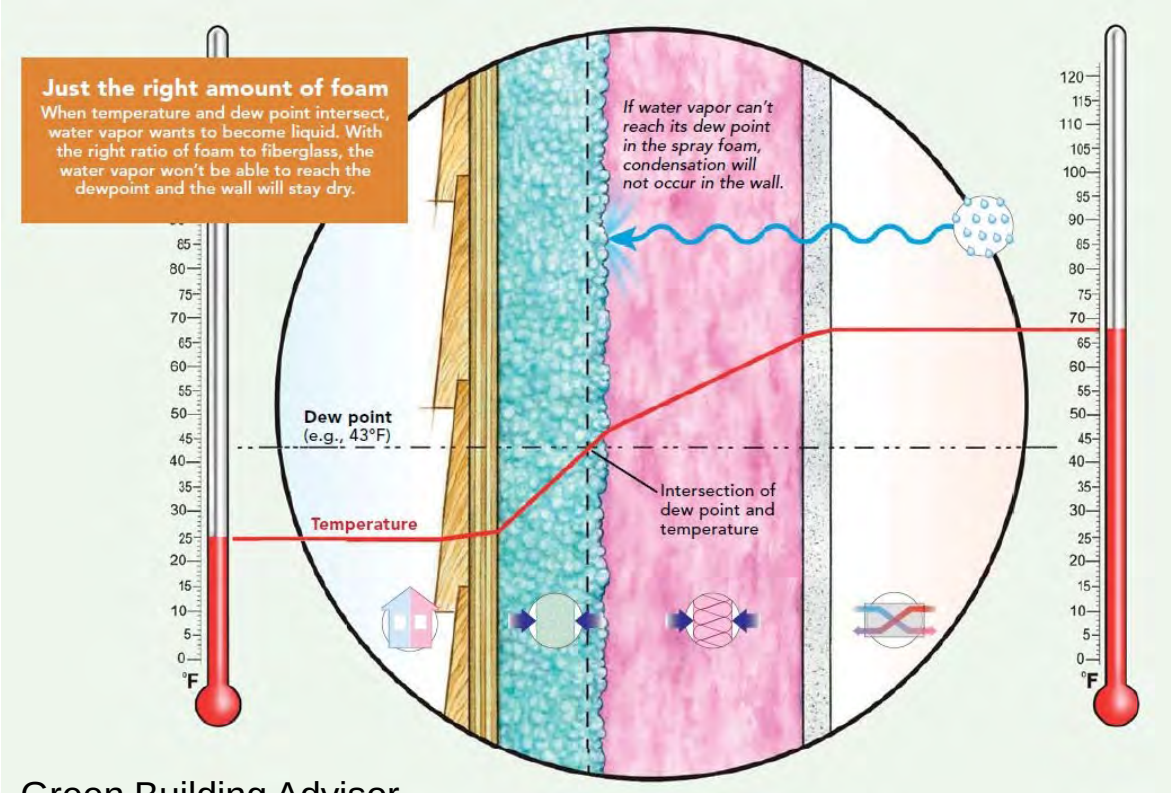

B1405142

HYBRID INSULATION APPROACH

- A thin layer of spray foam is applied, primarily for air sealing
- A fiberglass batt is used to fill the cavity

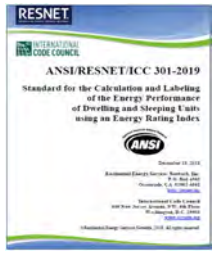
HYBRID APPROACH

- Closed-cell foam is recommended for this application
  - More dependable air barrier when applied (thin layer)
  - Closed-cell is less vapor permeable then open-cell
  - Open-cell cannot meet density requirements in shallow rafter bays



Green Building Advisor

MINIMUM SPECIFIC MATERIAL REQUIREMENTS: CLOSED-CELL POLYURETHANE FOAM (SPF)



- Installers shall meet the manufacturer's recommended training requirements and shall complete the online health and safety training for SPF provided by the Center for Polyurethanes Industry.
- Spray foam shall be well bonded to the substrate, including framing and sheathing.

- Closed-cell insulation, installed at a minimum thickness of **1.5 inches** and in contact with the substrate, shall be permitted to serve as a component of the continuous air barrier

SPRAYABLE CAULK / AERO-BARRIER

- A high-pressure sprayer applies a thin layer of latex, glycerin, and plasticizers
- Provides air sealing but no insulation
- Aerobarrier sprays while house is pressurized and seals where air leaks out

THE ROOF DECK CAN BE THE AIR BARRIER

- The roof deck can be used as an air barrier with proper materials and attention to detail

pro clima

THE ROOF DECK CAN ADD INSULATION

- The roof deck can also add R value with insulated sheathing or foam board

ACFoam® Nail Base
Nailable Roof Insulation

Thank you!

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