Below Deck Spray Foam Insulation for Existing Roofs

Last Updated: 11/12/2015

Scope

Insulate an attic in an existing home by installing spray foam (open cell or closed cell) on the underside of the roof deck. This measure will convert a vented attic to a nonvented attic. The installation steps are as follows:

Inspect the existing roof shingles or roofing membrane for any deficiencies. If there is any history or evidence of leakage at the roof, this must be corrected since the assembly depends on the existing roof for the water control function. If the roof is at or near the end of its service life, roof replacement should be considered to ensure acceptable water control.

Install spray foam insulation (and additional loose-fill insulation if desired) in the roof cavity to levels that meet or exceed the current adopted building and energy codes.

Install thermal or ignition barrier (coating, gypsum board, or other material) over spray foam insulation as required by code.

See the following Building America Solution Center guides for more information:

- **Pre-Retrofit Assessment of Attics, Ceilings, and Roofs**
- **Pre-Retrofit Assessment of Hazardous Materials**

See the U.S. Department of Energy's Standard Work Specifications (SWS) for more on installing **spray polyurethane foam in unvented attics**.

See the **Compliance Tab** for related codes and standards requirements, and criteria to meet national programs such as DOE's Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.

Description

Many older homes have little or no attic insulation. Attic insulation can be installed on the attic floor if the attic will be a vented attic. Or insulation can be installed along the underside of the roof deck, which converts the attic to an unvented, sealed, conditioned attic that can provide a protected environment for HVAC equipment and storage.

An unvented attic assembly should be considered if the attic will be used for habitable space, if the attic contains mechanical equipment or ductwork, if the roof structure is complex (i.e., difficult to vent due to obstructions), and/or if the ceiling plane is difficult to air seal (complex geometry or difficult access). It is possible create a vented assembly with insulation at the roof deck and spray foam, but this additional step adds cost and is not required for moisture-safe performance.

If the roof has a low slope, there may not be sufficient space for the required insulation and ventilation space needed for a vented attic assembly, especially at the eaves, where insufficient insulation can contribute to ice damming. Therefore, low roofs are good candidates for conversion to an unvented attic with insulation along the roof line.

This unvented attic retrofit assembly applies all of the insulation to the interior side of the roof. Most roof cladding and water control materials (asphalt shingles, asphalt papers, self-adhered roof membranes, etc.) are vapor impermeable. In cold and mixed climates, this is effectively a vapor barrier on the “wrong side” of the assembly. Therefore, to address interstitial (within-the-cavity) condensation risks, special attention should be paid to the type and the levels of insulation in the roof assembly.

The building codes (e.g., §R806.4 in 2009 IRC) specify a minimum R-value requirement for “air impermeable” insulation in a roof assembly, such as rigid insulation or spray foam, to control wintertime condensation. In colder climate zones, the amount of air- and vapor-impermeable insulation required to control condensation increases. If using a hybrid approach, it is important to meet or exceed the required ratio of air- and vapor- impermeable insulation to air- and vapor-permeable insulation within the roof assembly.

For this assembly, replacement of the roofing is not required (unless it is at end of service life), but it is vital that the existing roof system provides robust protection from bulk water (precipitation), and that proper flashing is in place. The low permeance of the roof exterior (cladding and water control layer) combined with the reduced drying due to spray foam means that the sheathing is more vulnerable to damage due to bulk water penetration.

In Figures 1 through 3, the roof cladding is represented as shingles, but other roof claddings would be acceptable provided that the attachment of the roof cladding does not result in horizontal obstructions on the water control layer beneath the cladding.

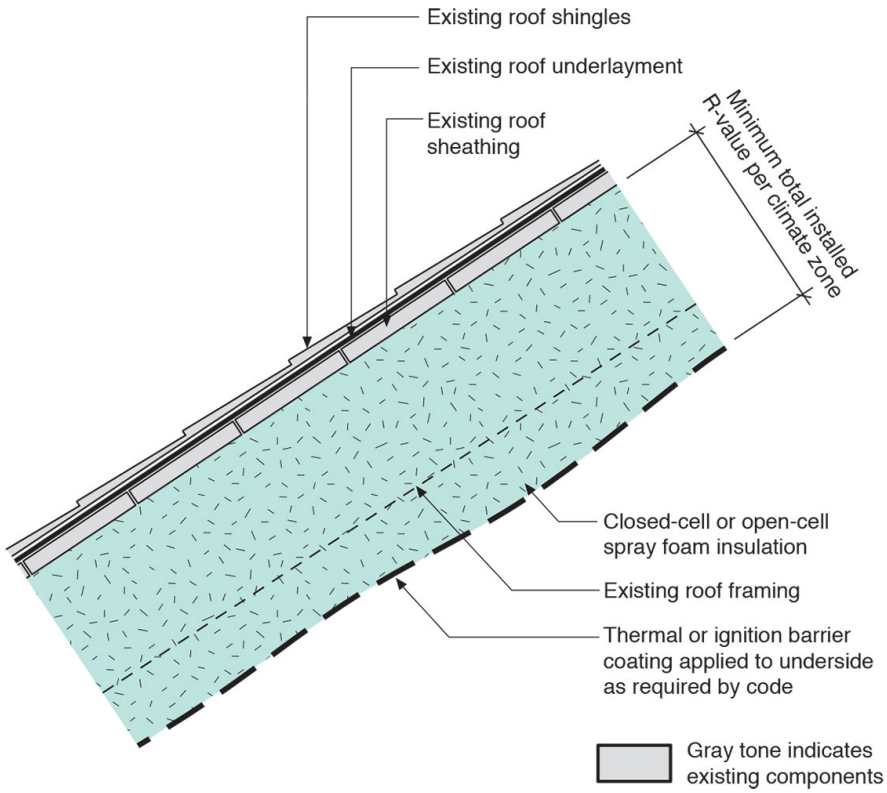


Figure 1. Sloped roof with cavity spray foam insulation sprayed on underside of roof deck and covered with sprayed-on thermal or ignition barrier coating.

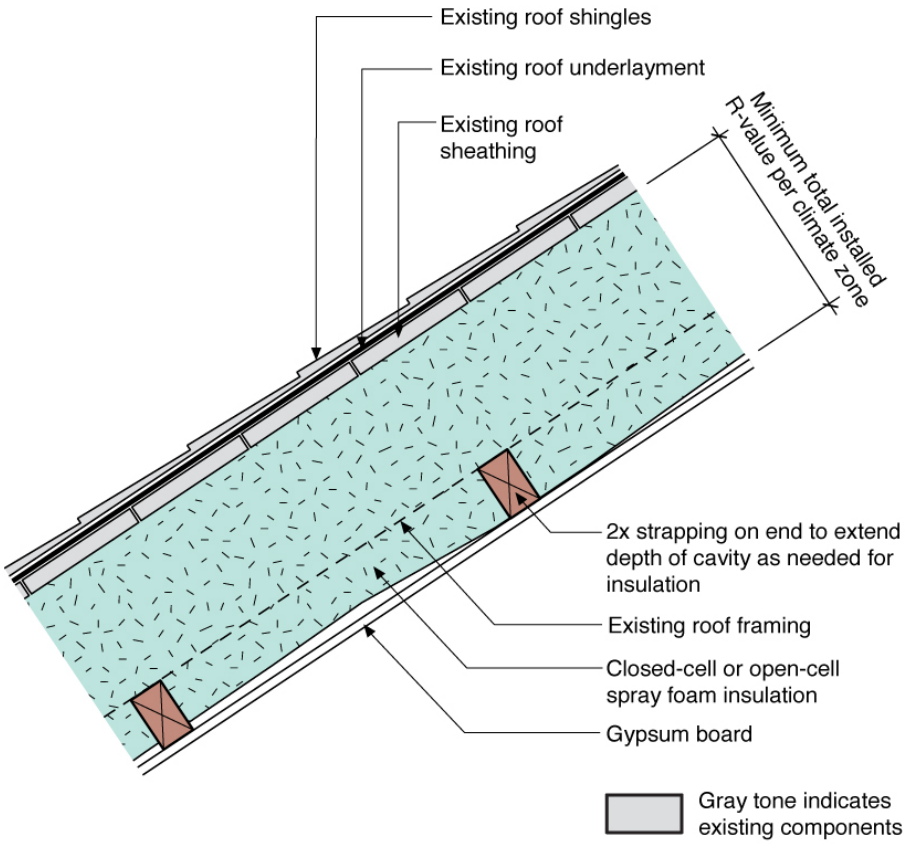


Figure 2. Sloped roof with cavity spray foam insulation, strapping, and gypsum board thermal barrier.

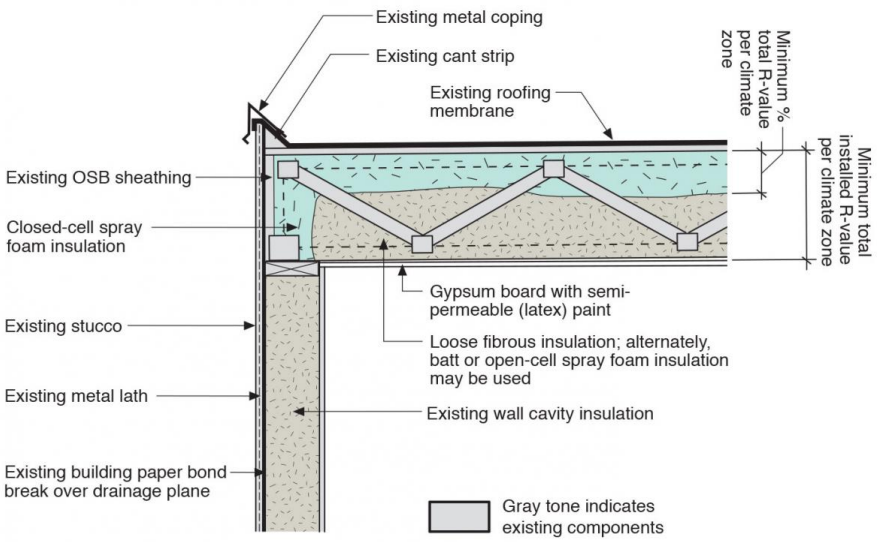


Figure 3. Flat roof with cavity spray foam plus loose-fill insulation and gypsum board thermal barrier.

How to Insulate a Roof from the Interior

1. Inspect the integrity of the roof system (roofing membrane or shingles). Check for any deficiencies, water damage, active leaks, etc. Proceed only if needed repairs are performed.
2. If there is an interior finish at the roofline (cathedral ceiling), remove the interior finish (plaster or gypsum board). Check the roof framing for any deficiencies, rot, water damage, active leaks, insect damage, etc. Proceed only if needed repairs are performed. Based on the findings, revise the roof assembly and review specific detailing as needed. Follow the minimum requirements of the current adopted building code regarding the wood roof framing construction.
3. Block the soffit vents; a typical detail is to provide 2x blocking or extended wall sheathing at the exterior wall line, to provide a substrate for the spray foam (see **WM354 Roof Eave Upgrade**).
4. Apply spray foam at the underside of the roof sheathing and at the wall perimeter to create an air barrier connecting the wall to the roof, and to provide adequate thermal resistance to prevent condensation. All attic gable end walls now separate interior from exterior conditions and must be insulated and air sealed. A typical approach is to insulate the gable end walls with the same spray foam used at the roofline. The area should be free of debris and dust prior to spraying for adequate adhesion. Install loose-fill insulation with netting over a layer of spray foam in wall cavities if desired.

5. Install a spray-on ignition barrier or gypsum board thermal barrier over the spray foam as required by code. (See **AY-126 Thermal and Ignition Barriers For The SPF Industry**).

Ensuring Success

Inspect the existing roof system, including the roofing membrane or shingles and framing, for any deficiencies and make any corrections if necessary. Consider roof replacement if roof is near end of service life.

Monitor the moisture content of the roof sheathing, when possible, during the construction process. Take measurements before the installation of the air-impermeable insulation to help ensure that the roof deck is dry enough to be covered with spray-foam insulation.

Spray foam is a material that is essentially “manufactured” when applied at the building site. Given the importance of this material’s performance, quality control measures should be set in place. Some key issues include moisture content and temperature of the substrate, applied spray foam layer or “lift” thickness, ratios of the two spray foam components during application, and storage/handling of spray foam components. Further information is available at the Spray Polyurethane Foam Alliance (**http://www.sprayfoam.org/**)

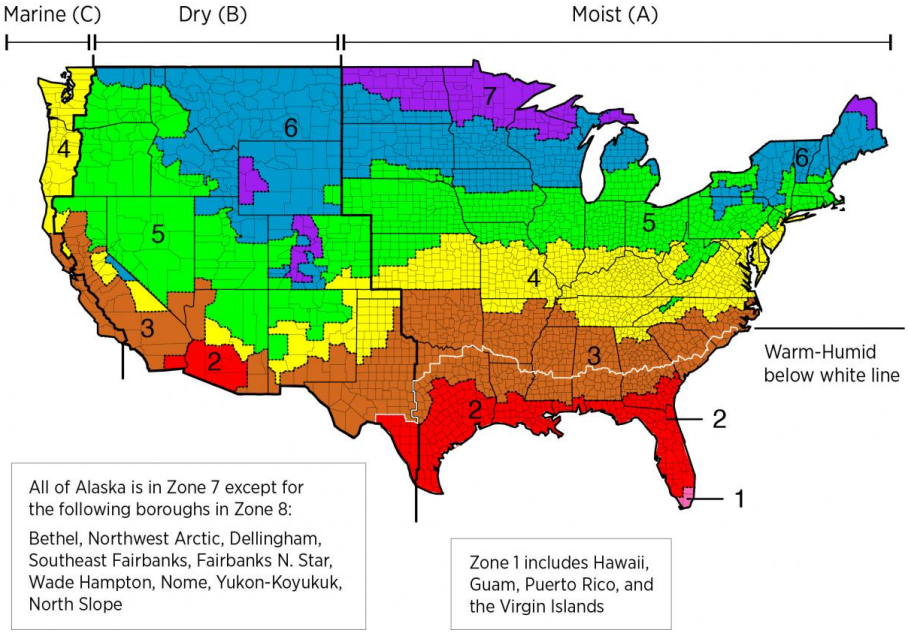
Apply insulation to a debris- and dust-free surface to provide adequate thermal resistance to prevent condensation.

Apply insulation to the levels specified in the current adopted building and energy codes.

Given the increased airtightness associated with this retrofit, combustion safety and controlled mechanical ventilation upgrades are required to maintain acceptable indoor air quality.

Climate

The roof assembly should be designed for a specific hygrothermal region, rain exposure zone, and climate. The climate zones are shown on the map below, which is taken from Figure C301.1 of the 2012 IECC.



IECC Climate Zone Map

The design should be based on the minimum requirements for the currently adopted building code and energy code. The table below provides the minimum thermal resistance (R-value) requirements specified in the 2009 IECC (ICC 2009b) and the 2012 IECC (ICC 2012b) based on climate zone for roof assemblies.

	Framed Roof Minimum R-Value	
Climate Zone	2009 IECC	2012 IECC
1	30	30
2	30	38
3	30	38
4 except Marine	38	49
5 and Marine 4	38	49
6	49	49
7 and 8	49	49

Table 1. Attic Insulation Requirements per the 2009 and 2012 IECC

It is important to maintain a sufficient ratio of air- and vapor-impermeable insulation to air- and vapor-permeable insulation within the roof assembly. In colder climate zones, the amount of air- and vapor-impermeable insulation needed to control condensation increases. The table below provides information on minimum levels of air-impermeable insulation for condensation control specified in Table R806.4 Insulation for Condensation Control of the 2009 IRC (ICC 2009a) and Table R806.5 Insulation for Condensation Control of the 2012 IRC (2012a). For further explanation, see **IRC FAQ: Conditioned Attics**.

Climate Zone	Minimum R-Value
2B and 3B tile roof only	0
1, 2A, 2B, 3A, 3B, 3C	5
4C	10
4A, 4B	15
5	20
6	25
7	30
8	35

Table 2. Insulation required for Condensation Control per the 2009 and 2012 IRC.

Where open-cell spray foam is used, the attic space must be “conditioned” by supplying 50 cfm of air from the occupiable space for every 1000 sq.ft. of attic area in climate zones 1, 2, 3, and 4. This is done to control humidity build-up in the attic spaces (see **BSI-077: Cool Hand Luke Meets Attics**).

Training

Right and Wrong Images

Display Image: Slide1.jpg

CAD

None Available

Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

ENERGY STAR Certified Homes

ENERGY STAR Certified Homes (Ver 3.0, Rev 07) requires that ceiling, wall, floor, and slab insulation levels meet or exceed those specified in the 2009 International Energy Conservation Code (IECC).

If the state or local residential building energy code requires higher insulation levels than those specified in the 2009 IECC, you must meet or exceed the locally mandated requirements. Some states have adopted the 2012 IECC. Visit the U.S. **DOE Building Energy Codes Program** to see what code has been adopted in each state. For states that have adopted the 2012 IECC or an equivalent code, EPA intends to implement the ENERGY STAR Certified Homes Version 3.1 National Program Requirements for homes permitted starting one year after state-level implementation of the 2012 IECC or an equivalent code. However, EPA will make a final determination of the implementation timeline on a state-by-state basis. Some states and regions of the country have ENERGY STAR requirements that differ from the national requirements. Visit ENERGY STAR's Regional Specifications page for more information on those region-specific requirements.

The ENERGY STAR Thermal Enclosure System Rater Checklist (Ver 3, Rev 07) specifies:

2.1 Ceiling, wall, floor and slab insulation levels shall comply with one of the following options:

2.1.1 Meet or exceed 2009 IECC levels, OR

2.1.2 Achieve <= 133% of the total UA resulting from the U-factors in 2009 IECC Table 402.1.3, excluding fenestration and per guidance in note "d" below, AND home shall achieve <= 50% of the infiltration rate in Exhibit 1 of the National Program Requirements.

(3) Insulation levels in a home shall meet or exceed the component insulation requirements in the 2009 IECC - Table 402.1.1. The following exceptions apply:

1. 1.
    a. Steel-frame ceilings, walls, and floors shall meet the insulation requirements of the 2009 IECC Table 402.2.5. In CZ 1 and 2, the continuous insulation requirements in this table shall be permitted to be reduced to R-3 for steel-frame wall assemblies with studs spaced at 24 inch on center. This exception shall not apply if the alternative calculations in "d" below are used;
    b. For ceilings with attic spaces, R-30 shall satisfy the requirement for R-38 and R-38 shall satisfy the requirement for R-49 wherever the full height of uncompressed insulation at the lower R-value extends over the wall top plate at the eaves. This exemption shall not apply if the alternative calculations in "d" are used;
    c. For ceilings without attic spaces, R-30 shall satisfy the requirement for any required value above R-30 if the design of the roof/ceiling assembly does not provide sufficient space for the required insulation value. This exemption shall be limited to 500 square feet or 20% of the total insulated ceiling area, whichever is less. This exemption shall not apply if the alternative calculations in "d" are used;
    d. An alternative equivalent U-factor or total UA calculation may also be used to demonstrate compliance, as follows: An assembly with a U-factor equal or less than specified in 2009 IECC Table 402.1.3 complies. A total building thermal envelope UA that is less than or equal to the total UA resulting from the U-factors in Table 402.1.3 also complies. The insulation levels of all non-fenestration components (i.e., ceilings, walls, floors, and slabs) can be traded off using the UA approach under both the Prescriptive and the Performance Path. Note that fenestration products (i.e., windows, skylights, doors) shall not be included in this calculation. Also, note that while ceiling and slab insulation can be included in trade-off calculations, the R-value must meet or exceed the minimum values listed in Items 4.1 through 4.3 of the ENERGY STAR Checklist to provide an effective thermal break, regardless of the UA tradeoffs calculated. The UA calculation shall be done using a method consistent with the ASHRAE Handbook of Fundamentals and shall include the thermal bridging effects of framing materials. The calculation for a steel-frame envelope assembly shall use the ASHRAE zone method or a method providing equivalent results, and not a series-parallel path calculation method.

The ENERGY STAR Water Management Checklist specifies:

Water-Managed Roof Assembly

3.1 Step and kick-out flashing at all roof-wall intersections, extending ? 4" on wall surface above roof deck and integrated with drainage plane above.

3.2 For homes that don't have a slab-on-grade foundation and do have expansive or collapsible soils, gutters & downspouts provided that empty to lateral piping that deposits water on sloping final grade ? 5 ft. from foundation or to underground catchment system ? 10 ft. from foundation.

3.3 Self-sealing bituminous membrane or equivalent at all valleys & roof deck penetrations.

3.4 In 2009 IECC Climate Zones 5 and higher, self-sealing bituminous membrane or equivalent over sheathing at eaves from the edge of the roof line to > 2 ft. up roof deck from the interior plane of the exterior wall.

DOE Zero Energy Ready Home

The U.S. Department of Energy Zero Energy Ready Home National Program Requirements specify as a mandatory requirement (Exhibit 1, #2.2) that, for all labeled homes, whether prescriptive or performance path, ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels. See the guide **2012 IECC Code Level Insulation – DOE Zero Energy Ready Home Requirements** for more details.

2009 IECC

Section 101.4.3 Additions, alterations, renovations or repairs. Portions of an existing building that are altered in the course of additions, alterations, renovations or repairs must be brought into conformance with the code with the following exceptions applicable to attic/roof retrofit: existing ceiling wall or floor cavities that are exposed provided the cavities exposed are filled with insulation; addition, alteration, renovation or repair projects that do not expose the existing roof, wall or floor cavity; reroofing that does not expose the insulation nor the sheathing.

Section 101.4.5 Change in space conditioning. This section states that spaces must be brought into full compliance with the new construction requirements if the addition, alteration, renovation or repair changes that space from unconditioned to conditioned space.

Section 402 Building Thermal Envelope. Table 402.1.1 indicates the prescriptive requirements for building enclosure components.

Section 402.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IECC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

2012, 2015, and 2018 IECC

Section R101.4.3 (R501.1.1/R503.1.1 in 2015 and 2018 IECC) Additions, alterations, renovations or repairs. Portions of an existing building that are altered in the course of additions, alterations, renovations or repairs must be brought into conformance with the code with the following exceptions applicable to attic/roof retrofit: existing ceiling wall or floor cavities that are exposed provided the cavities exposed are filled with insulation; addition, alteration, renovation or repair projects that do not expose the existing roof, wall or floor cavity; reroofing that does not expose the insulation nor the sheathing.

Section R101.4.5 (R503.2 in 2015 and 2018 IECC) Change in space conditioning. This section states that spaces must be brought into full compliance with the new construction requirements if the addition, alteration, renovation or repair changes that space from unconditioned to conditioned space.

Section R402 (R402.1.2 in 2015 and 2018 IECC) Building Thermal Envelope. Table R402.1.1 indicates the prescriptive requirements for building enclosure components.

Section R402.2.1 Ceilings with attic spaces. This section indicates that the prescriptive requirement for R-38 ceiling insulations is deemed to be met by R-30 insulation when the R-30 insulation extends over the wall top plate at eaves and when the insulation is at full loft and uncompressed over the wall top plate at eaves. Similarly, R-38 insulation is recognized to satisfy the requirement for R-49 insulation when R-38 insulation extends over the wall top plate at eaves and when the insulation is at full loft and uncompressed over the wall top plate at eaves.

Section R402.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IECC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

2009 IRC

R316.4 Thermal barrier. This section addresses the thermal barrier requirements when foam plastic is used and its installation.

R316.5.3 Attics. This section lists the exceptions to the use of a thermal barrier, including ignition barrier options for foam plastic insulation.

Section R806.4 Unvented attic assemblies. This section outlines the conditions for unvented attic/roof assemblies. Note that table R806.4 indicates the amount of insulation above the roof deck or air impermeable insulation below the roof deck required for condensation control assuming minimum required total insulation as indicated in Section N1102 Building Thermal Envelope. Higher R-value assemblies will require a proportionally larger amount of air impermeable insulation below the roof deck or insulation above the roof deck for condensation control.

Section R807.1 Attic access. An attic access is required where the ceiling or roof construction is combustible and where the attic area is more than 30 sf and the height between the ceiling framing and roof framing is more than 30”. Refer to specific language of this section for required dimensions of the access.

Section R901 Roof Assemblies. This section outlines the design, materials, construction and quality of roof assemblies.

Section N1102 Building Thermal Envelope. Table N1102.1 indicates the prescriptive requirements for building enclosure components.

Section N1102.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IRC) must be sealed

to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

2012, 2015, and 2018 IRC

R316.4 Thermal barrier. This section addresses the thermal barrier requirements when foam plastic is used and its installation.

R316.5.3 Attics. This section lists the exceptions to the use of a thermal barrier, including ignition barrier options for foam plastic insulation.

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Section R901 Roof Assemblies. This section outlines the design, materials, construction and quality of roof assemblies.

Section N1102 Building Thermal Envelope. Table N1102.1.1 (N1102.1.2 in 2015 and 2018 IRC) indicates the prescriptive requirements for building enclosure components.

Section N1102.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IRC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

Retrofit: 2009, 2012, 2015, and 2018 IRC

Section N1101.3 (Section N1107.1.1 in 2015 and 2018 IRC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

Appendix J regulates the repair, renovation, alteration, and reconstruction of existing buildings and is intended to encourage their continued safe use.

Controlling Moisture in Unvented Attics - Code Compliance Brief

Overview:

The intent of this brief is to provide code-related information about controlling moisture in unvented attics by installing a vapor diffusion port/vent that would convey water vapor from an unvented attic to the outside when air-permeable insulation materials are installed and can be verified as being in compliance with the related codes and standards for residential construction. Providing consistent information to document compliance with codes and standards to all relevant parties responsible for verifying compliance (e.g., code officials, builders, contractors, designers, etc.) is expected to result in increased compliance and more timely, less challenging and more uniform plan review and field inspections.

In the early 1990s, construction of unvented attics became popular, especially for structures in warmer climates. The typical construction scenario involved the use of low-density, open-cell spray foam insulation for the thermal barrier at roof deck and duct work installed in the unvented attic space. Most of these attics stayed dry. "These were conditioned attics," said Joe Lstiburek, Building Science Corporation, CEO.[1] "The conditioning was happening because of leaky ductwork. The supply ducts were leaking, and there was a leaky ceiling." The attics were accidentally heated during the winter and accidentally cooled during the summer by air escaping through cracks in the duct seams. This type of conditioning kept attic moisture levels under control. Lstiburek continued, "Later, when the ductwork got tighter, we ended up with very high humidity in the attics, and we discovered sweating on the ducts and mold on the mastic."

In summary, Lstiburek's explanation was that moisture in the attic originated inside the house. Moisture ended up in the attic rather than in the lower floors of the house through a phenomenon known as "hygric buoyancy." This phenomenon occurs when moisture-laden air is lighter and less dense than dry air so the moisture-laden air collects in the attic.

After Dr. Lstiburek identified this moisture problem, further investigation revealed what the recent codes addressed or did not address and whether or not the codes needed to be changed. The study revealed that proper moisture, ventilation, and insulation requirements in climate zones 1, 2, and 3 for unvented attics and unvented enclosed rafter assemblies are not addressed in the 2015 International Energy Conservation Code (IECC). These measures are identified as code barriers because they are neither discouraged nor encouraged by the recent model codes (i.e., IECC). Moisture, ventilation, and insulation requirements are addressed for unvented attics in the International Residential Code (IRC), but only for *air-impermeable insulation*[2] or rigid board insulation installed above roof decks.

Through the Building America Program, new approaches have successfully been researched and validated. The Building America research team, Building Science Corporation, submitted separate proposals for the 2018 International Code Council (ICC) code hearings to address the moisture, ventilation, and insulation issues in unvented attics with interior insulation. The code proposals include new language about installing a *vapor diffusion port*/vent that would convey water vapor from an unvented attic to the outside when air-permeable insulation materials are installed. Some of the main

reasons for the new code changes are described below:

- The research supporting this code change is an outgrowth of the original research supporting unvented attic assemblies started in 1995 under the Department of Energy's Building America Program. The same technical team and the same technical rigor that supported the original code changes for unvented attics in the early 2000s is the basis for this proposed code change.
- Current code language is limited to climate zones 1, 2 and 3 for air-permeable insulation based on research and historic experience over the past decade. *Air-impermeable insulation* approaches and rigid insulation approaches installed above the roof deck are currently code allowed in all climate zones.
- *Vapor diffusion ports*/vents allow moisture in the attic to be removed by diffusion rather than by air change. This allows the attic assembly to remain airtight while providing a path for moving the moisture to the outside via vapor diffusion. Airtight attics also provide an energy-efficiency benefit.
- When equipped with *vapor diffusion ports*, unvented attics can be insulated with other insulation materials, such as fiberglass batts, blown cellulose, and blown fiberglass, rather than polyurethane spray foam and rigid board insulation.
- Adding new unvented attic options to existing options provides additional benefits. In regions where high wildfire occurrence, elimination of eave vents and air sealing the upper attic vents at ridges significantly decreases entry paths for embers that could start a house fire. In hurricane zones, eliminating roof vents reduces the entry way for rainwater during storms.

The next section of this Code Compliance Brief lists applicable code requirements and details helpful for Plan Review. The Field Inspection section that follows provides details regarding the inspection of unvented attics and unvented enclosed rafter assemblies. Refer to the last section of this brief for resources on technical validation, best practices, and measure guidelines.

These lists and provisions provided below in each section are intended to target the main code sections and provisions. There may be other references, code sections, standards, testing methods, etc., that affect the technology or other assemblies or functions of the building.

[1] High Humidity in Unvented Conditioned Attics, Green Building Advisor, **http://www.greenbuildingadvisor.com**.

[2] Air-impermeable insulation is defined in the 2015 IRC as an insulation having an air permanence equal to or less than 0.02 L/s-m^2 at 75 Pa pressure differential as tested in accordance with ASTM E 2178 or E 283.

Plan Review:

This section, provides current code sections and details in the 2015 IRC and IECC, and the language (underscored, struck-through, and highlighted in red) from code change proposals that were approved for the 2018 IRC.

2015 IRC, Section R104 Duties and Powers of the Building Official

Section R104.1, General. The building official has authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be in conformance with the intent and purpose of this code.

2015 IECC/IRC, Section R102.1/R104.11, Alternative Materials, Design and Method of Construction and Equipment. The provisions of this code are not intended to prevent the installation of any material or prohibit any design or method of construction not specifically prescribed in the 2015 IECC/IRC, provided that any such alternative has been approved. The building official is permitted to approve an alternative material, design, or method of construction where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and the material, method, or work offered is for the purpose intended, not less than the equivalent of that prescribed in the code. Compliance with specific performance-based provisions of the International Codes is an alternative to the specific requirements of this code.

2015 IRC, Section R104.11.1, Tests. Whenever there is insufficient evidence of compliance with the provisions of this code, or evidence that a material or method does not conform to the requirements of this code, or in order to substantiate claims for alternative materials or methods, the building official has authority to require tests as evidence of compliance to be made at no expense to the jurisdiction. Test methods shall be as specified in this code or by other recognized test standards. In the absence of recognized and accepted test methods, the building official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the building official for the period required for retention of public records.

Construction Documentation. Review the construction documents for details describing roof ventilation, attic insulation, installation, air sealing, and construction techniques. (Bullet items underscored are based on the 2018 ICC code proposals.)

2015 IECC/IRC, Section R103.3/R106.3, Examination of Documents, the code official/building official must examine or cause to be examined construction documents for code compliance.

2015 IECC/IRC, Section R103.2/N1101.5, Information on Construction Documents. Construction documents should be of sufficient clarity to indicate the location, nature, extent of the work proposed, and show of sufficient detail pertinent data features. (Bullet items below that are underscroed and highlighted in red are based on the new provisions that will be published in the 2018 IRC. Construction documents should include:

- Roof assembly details.
- *Vapor diffusion port(s)*/vent(s) design and location.
- Moisture barrier material used for the *vapor diffusion port*(s)/vent(s).
- Insulation materials and their R-values.
- Details indicating how the insulation is to be applied.
- Where preformed insulation board is used as the *air-impermeable insulation* layer, confirm that the construction documents specify air sealing at the perimeter of each individual sheet interior surface to form a continuous layer.
- Air sealing details (joints, seams, penetrations).
- Confirm that the continuous air barrier is specified.
- Details of roof ventilation and moisture control.
- Design specifications of air supplied to the conditioned attic.

2015 IRC, Section R202, Definitions
Vapor Diffusion Port. A passageway for conveying water vapor from an unvented attic to the outside atmosphere.

Section R806.5, Unvented attic and unvented enclosed rafter assemblies. Unvented *attics* and unvented enclosed roof framing assemblies created by ceilings that are applied directly to the underside of the roof framing members and structural roof sheathing applied directly to the top of the roof framing members/rafters, shall be permitted where all the following conditions are met:

1. The unvented *attic* space is completely within the *building thermal envelope*. **[3]**
2. No interior Class I vapor retarders are installed on the ceiling side (*attic* floor) of the unvented *attic* assembly or on the ceiling side of the unvented enclosed roof framing assembly.
3. Where wood shingles or shakes are used, a minimum ¼-inch (6.4 mm) vented airspace separate the shingles or shakes and the roofing underlayment above the structural sheathing.
4. In climate zones 5, 6, 7, and 8, any *air-impermeable insulation* shall be a Class II vapor retarder, or shall have a Class II vapor retarder coating or covering in direct contact with the underside of the insulation.
5. Insulation shall ~~be located in accordance with the following with~~ comply with either 5.1 or 5.2, and additionally 5.3:

5.1. Item 5.1.1, 5.1.2, 5.1.3, or 5.1.4 shall be met, depending on the air permeability of the insulation directly under the structural roof sheathing.

5.1.1. Where only *air-impermeable insulation* is provided, it shall be applied in direct contact with the underside of the structural roof sheathing.

5.1.2. Where *air-permeable insulation* is provided inside the building thermal envelope, it shall be installed in accordance with Section 5.1. In addition to the *air-permeable insulation* installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing in accordance with the *R*-values in Table R806.5 for condensation control.

5.1.3. Where both *air-impermeable* and *air-permeable insulation* are provided, the *air-impermeable insulation* shall be applied in direct contact with the underside of the structural roof sheathing in accordance with Item 5.1.1 and shall be in accordance with the *R*-values in Table R806.5 for condensation control. The *air-permeable insulation* shall be installed directly under the *air-impermeable insulation*.

5.1.4. Alternatively, sufficient rigid board or sheet 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.

5.1.5. In climate zones 1, 2, and 3 air shall be supplied at a flow rate ?50 CFM (23.6 L/s) per 1000 ft^2 of ceiling. The air shall be supplied from ductwork providing supply air to the occupiable space when the conditioning system is operating.

Alternatively one of the following shall occur:

1. Air shall be supplied to the attic by a fan blowing air from the occupiable space into the attic.

2. Transfer air from the occupiable space shall be provided by a fan exhausting attic air to the outside.

3. Mechanical dehumidification shall be provided to the unvented attic air space.

5.2. In climate zones 1, 2, and 3 when air-permeable insulation is installed in unvented attics, it shall meet the following requirements:

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.

2) The port area shall be ?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.

3) The vapor permeable membrane in the *vapor diffusion port* shall have a vapor permeance rating of ?20 perms when tested in accordance with Procedure A of ASTM E96.

Confirm the vapor permeable membrane product specifications have been tested and rated accordingly.

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

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

6) Framing members and blocking shall not block the free flow of water vapor to the port. Not less than a 2-inch (50-mm) space shall be provided between any blocking and the roof sheathing. Air-permeable insulation shall be permitted within that space.

7) The roof slope shall be ?3:12 (vertical/horizontal).

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

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 in Table 806.5. When directly below the structural roof sheathing, there shall be no space between the air-impermeable and air-permeable insulation.

10) The air shall be supplied at a flow rate ?50 CFM (23.6 L/s) per 1000 ft2 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.

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.

Excerpt from ***2015 IRC, Table R806.5 Insulation for Condensation Control***

Climate Zone	Minimum rigid Board on Air-Impermeable Insulation R-Value
1, 2A, 2B, 3A, 3B, 3C	R-5

***2015 IECC/IRC, Section R402.1.2/N1102.1.2*, Insulation Criteria.** The *building thermal envelope* must meet the requirements of Table R402.1.2/N1102.1.2, based on the climate zone specified in Chapter 3 and the building assemblies associated with the unvented attic assemblies that are considered part of the *building thermal envelope*.

2015 IECC/IRC, Section R402.1.3/N1102.1.3 or 2012 IECC/IRC, Section R402.1.2/N1102.1.2, R-Value Computation. Insulation material used in layers, such as framing cavity insulation, or continuous insulation **should be summed** to compute the corresponding component R-value. Computed R-values should not include an R-value for other building materials or air films.

Excerpt from the ***Insulation and Fenestration Requirements by Component Tables***

2015 IECC/IRC, Table R402.1.2/N1101.1.2 or 2012 IECC/IRC, Table R402.1.1/N1102.1.1

(R-values are the same for both versions of IECC/IRC.)

Climate Zone	Ceiling R-Value
1	30
2, 3	38

This means if air-impermeable insulation is installed in direct contact with the underside of the structural roof sheathing, a

minimum of R-5 rigid foam board is required, and the sum of air-permeable insulation directly below the air-impermeable insulation must meet a minimum R-value of R-25 in climate zone 1 and R-33 in climate zones 2 and 3.

2015 IECC/IRC, Section R402.1.4/N1102.1.4 or 2012 IECC/IRC Section R402.1.3/N1102.1.3, U-Factor Alternative. An assembly with a U-factor equal to or less than that specified in tables should be permitted as an alternative to the R-value in the Insulation and Fenestration Requirements by Component Tables of the IECC/IRC.

Excerpt from the ***Equivalent U-Factor Tables***

2015 IECC/IRC, Table R402.1.4/N1102.1.4 or 2012 IECC/IRC, Table R402.1.3/N1102.1.3. (U-factors are the same for both versions of the codes.)

Climate Zone	Ceiling U-Factor
1	0.035
2, 3	0.030

Air Sealing/Air Leakage Control

2015 IECC/IRC, Section R402.4./N1102.4, Air Leakage. The *building thermal envelope* should be constructed to limit air leakage.

- ***Section R402.4.1/N1102.4.1, Building Thermal Envelope***. The sealing methods between dissimilar materials should allow for differential expansion and contraction.
- ***Section R402.4.1.1/N1102.4.1.1, Installation***. The components listed in the Air Barrier and Insulation Installation Table [4] should be installed in accordance with the manufacturer's instructions and the criteria listed as the applicable method of construction. Below are the General Requirements and components from the table that are applicable to sealing and insulating unvented attics.

Air Barrier and Insulation Installation Table R402.4.1.1/N1102.4.1.1

- ***Continuous air barrier***[5] – Confirm that construction documents specify a continuous air barrier for the building components associated with the insulation. Air-permeable insulation should not be used as a sealing material.

2015 IECC/IRC, Section R501.1.1/N1107.1.1, Alterations - General. Alterations to an existing building or portion thereof should comply with Section R502/N1108, R503/N1109 or R504/N1110. Unaltered portions of the existing building are not required to comply.

- ***Section R503.1/N1109.1, General.*** Alterations to any building or structure should comply with the requirements of the code for new construction. Alterations should be such that the existing building or structure is no less conforming to the provisions of this code than the existing building or structure was prior to the alteration. Alterations should not create an unsafe or hazardous condition or overload existing building systems. Alterations should be such that the existing building or structure uses no more energy than the existing building or structure prior to the alteration.
- ***Section R503.2/N1103.2, Change in space conditioning.*** Any non-conditioned or low-energy space that is altered to become conditioned space should be required to be in full compliance with this code. (This means not only the altered assembly is brought into compliance but the entire space or building also would need to be brought into compliance.)
- ***Section R503.1.1/N1109.1.1, Building Envelope***. Building envelope assemblies that are part of the alteration must comply with Sections R402.1.2/N1102.1.2 (Insulation and Fenestration Table) or R402.1.4/N1102.1.4 (U-Factor Alternative), and Sections R402.2.1/N1102.2.1 through R402.2.12/N1102.2.12, R402.3/1/N1102.3.1, R402.3.2/N1102.3.2, R402.4.3/N1102.4.3 and R402.4.4/N1102.4.4.

Exception: The following alterations need not comply with the requirements for new construction provided the energy use of the building is not increased:

- Existing ceiling cavities exposed during construction, provided that the cavities are filled with insulation
- Construction where the existing roof cavity is not exposed
- Roof recover
- Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing should be insulated either above or below the sheathing.

[3] The term "*building thermal envelope*" is defined as the basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

[4] Table R402.4.1.1 of the IECC and Table N1102.4.1.1 of the IRC.

[5] The term "continuous air barrier" is defined as a combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

Field Inspection:

This section provides details for inspecting to the specific provisions for construction of unvented attics or enclosed unvented rafter assemblies, roof insulation, ventilation, and moisture controls where one or more specific types of inspection called for by the IECC or IRC may be necessary to confirm compliance. Framing and rough-in would be the typical type of inspection performed. (Bullet items underscored and highlighted in red are based on the new provisions for the 2018 IRC.)

Per the ***2015 IECC, Section R104 Inspections***, construction or work for which a permit is required is subject to inspection. Construction or work is to remain accessible and exposed for inspection purposes until approved. Required inspections include footings and the foundation, framing and rough-in work, plumbing rough-in, mechanical rough-in, and final inspection.

Per the ***2015 IRC, Section R109 Inspections***, for onsite construction, from time to time the building official, upon notification from the permit holder or his agent, can make or cause to be made any necessary inspections. Further details are provided for inspections regarding the foundation, plumbing, mechanical, gas and electrical, floodplain, frame and masonry, and the final inspection. Any additional inspections are at the discretion of the building official.

Inspections should provide verification with the following items if specifed and approved on the contruction documents and per manufacturer specifications and installation:

- Verify that joints, seams, holes, and penetrations are caulked, gasketed, weather-stripped, or otherwise sealed (assemblies part of the *building thermal envelope*).
- Ensure that the appearance of the insulation, as appropriate, in the field matches what is on the approved construction documents.
- If the R-value or U-factor approach for compliance was used in the documentation, ensure that the insulation installed meets the minimum R-value(s) specified for the assembly per climate zone based upon the approved construction documents.
- Confirm that the continuous air barrier is properly installed.
- Where preformed insulation board is used as the *air-impermeable insulation* layer, confirm that it is sealed at the perimeter of each individual sheet interior surface to form a continuous layer.
- Confirm that the *vapor diffusion port*(s) are installed per the approved construction documents.
- Confirm that the moisture barrier material used for the *vapor diffusion port*(s) is the same material specified on the approved construction documents.
- Confirm that the air supplied to the conditioned attic meets the approved construction documents.

Technical Validation(s):

This section provides additional related information and references to materials that are applicable to the provision.

- ***2015 IECC—International Energy Conservation Code***
  Author(s): ICC
  Organization(s): ICC
  Publication Date: May 2014
  This code establishes a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems, and service water heating systems in homes and commercial businesses.

- ***2015 IRC—International Residential Code for One- and Two-Family Dwellings***
  Author(s): ICC
  Organization(s): ICC
  Publication Date: May 2014
  This code for residential buildings creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy, and electrical provisions for one- and two-family residences.
- ***Understanding Attic Ventilation***
  Author(s): J. Lstiburek
  Organization(s): Building Science Corporation (BSC)
  Publication Date: October 2006
  This report provides guidance about whether to construct a vented or unvented attic based on hygro-thermal zone.
- *BSI-088: Venting Vapor*, Joseph Lstiburek, Building Science Corporation, July 2015, **http://buildingscience.com/documents/insights/bsi-088-venting-vapor**
- *BSI-077: Cool Hand Luke Meets Attics*, Joseph Lstiburek, Building Science Corporation, July 2015, **http://buildingscience.com/documents/insights/bsi-077-cool-hand-luke-mee...**
- *Moisture Risk in Unvented Attics Due to Air Leakage Paths,* D. Prahl and M. Shaffer, IBACOS, Inc., November, 2014, **http://www.nrel.gov/docs/fy15osti/63048.pdf**.

Related BASC Guides:

- Unvented Attic Insulation, **https://basc.pnnl.gov/resource-guides/unvented-attic-insulation**
- Ceilings, **https://basc.pnnl.gov/resource-guides/ceilings#quicktabs-guides=6**
- Spray Foam Applied to Existing Ceilings, **https://basc.pnnl.gov/resource-guides/spray-foam-insulation-applied-exis...**
- Above-Deck Rigid Foam Insulation for Existing Roofs, **https://basc.pnnl.gov/resource-guides/above-deck-rigid-foam-insulation-e...**
- Below-Deck Spray Foam Insulation for Existing Roofs, **https://basc.pnnl.gov/resource-guides/below-deck-spray-foam-insulation-e...**.

More Info.

Access to some references may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

Case Studies

1. **DOE Zero Energy Ready Home Case Study: Imery Group Proud Green Home, Serenbe, GA**
   Author(s): PNNL
   Organization(s): PNNL
   Publication Date: April, 2014
   Case study describing the first DOE Zero Energy Ready Home in Georgia that achieved a HERS score of 40 without PV and -10 with PV.

2. **Existing Whole-House Solutions Case Study: Habitat for Humanity South Sarasota County, Venice, Florida**
   Author(s): PNNL
   Organization(s): PNNL
   Publication Date: November, 2012
   Case study describing a deep energy renovation of a home in Florida.

3. **Existing Whole-House Solutions Case Study: National Grid Deep Energy Retrofit Pilot Program - Clark Residence**
   Author(s): BSC
   Organization(s): BSC
   Publication Date: March, 2010
   Case study describing a retrofit project in the cold and very-cold climate zones.

4. **New Whole-House Solutions Case Study: Lancaster Live/Work Townhome Prototype**
   Author(s): BSC
   Organization(s): BSC
   Publication Date: April, 2010
   Case study describing a building project in the marine climate.

5. **Technology Solutions Case Study: Application of Spray Foam Insulation Under Plywood and OSB Roof Sheathing**
   Author(s): BSC
   Organization(s): BSC
   Publication Date: November, 2013
   Case study describing research about spray foam roof insulation and moisture management.

References and Resources*

1. **2009 IECC - International Energy Conservation Code**
   Author(s): International Code Council
   Organization(s): ICC
   Publication Date: January, 2009
   Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

2. **2009 IRC - International Residential Code for One and Two Family Dwellings**
   Author(s): International Code Council
   Organization(s): ICC
   Publication Date: January, 2009
   Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

3.

2012 IECC - International Energy Conservation Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: January, 2012
Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

4. **2012 IRC - International Residential Code for One and Two Family Dwellings**
Author(s): International Code Council
Organization(s): ICC
Publication Date: January, 2012
Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

5. **BSI-077: Cool Hand Luke Meets Attics**
Author(s): Lstiburek
Organization(s): Building Science Corporation
Publication Date: April, 2014
Article describing correct ways to apply insulation to existing attics.

6. **IRC FAQ: Conditioned Attics**
Author(s): Building Science Corporation
Organization(s): Building Science Corporation
Publication Date: May, 2009
Report discussing how to create livable space in the attic that meets IRC code requirements by either creating a ventilated roof assembly, or and unvented attic assembly.

7. **Mass Save Deep Energy Retrofit Builder Guide**
Author(s): Pettit, Neuhauser, Gates
Organization(s): Building Science Corporation
Publication Date: July, 2013
Guidebook providing useful examples of high performance retrofit techniques for the building enclosure of wood frame residential construction in a cold and somewhat wet climate.

8. **Measure Guideline: Deep Energy Enclosure Retrofit (DEER) for Zero Energy House (ZERH) Flat Roofs**
Author(s): Loomis, Pettit
Organization(s): Building Science Corporation
Publication Date: May, 2015
This Measure Guideline provides design and construction information for a deep energy enclosure retrofit solution of a flat roof assembly.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

Contributors to this Guide

The following authors and organizations contributed to the content in this Guide.

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