

**CONSTRUCTION GUIDE**

# **NEXT GENERATION HIGH PERFORMANCE WALLS**

**CLIMATE ZONES 3-5**

**PART 2: 2X4 Walls with 1"-1.5"  
Exterior Insulative Sheathing**

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Home Innovation Research Labs

June 2017



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Insulative sheathing**

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# CONSTRUCTION GUIDE

## NEXT GENERATION HIGH PERFORMANCE WALLS

### CLIMATE ZONES 3-5

### PART 2: 2X4 WALLS WITH 1"-1.5" EXTERIOR INSULATIVE SHEATHING

#### STRAIGHTFORWARD AND COST-EFFECTIVE STRATEGIES TO CONSTRUCT DURABLE, ENERGY EFFICIENT WALLS

The addition of exterior insulation to standard 2x4 framing enables a straightforward transition from conventional 2x4 wall construction to a more energy efficient wall system. In addition to increasing the wall's R-value, continuous exterior insulation minimizes thermal bridging of framing members and helps control condensation within walls during heating seasons. With the maximum 1.5 in. foam thickness addressed by this Guide, only minimal changes to detailing and cladding attachments are needed. Such wall systems have been used with various approaches to cavity insulation, air sealing, and moisture control across various climate zones and have a history of successful performance.

#### SCOPE

The Guide addresses walls constructed with 2x4 wood frame studs, wood structural panel (WSP) sheathing as wall bracing and added backing for foam sheathing, a layer of rigid foam sheathing insulation up to 1.5 in. thick over the WSP, and a cladding system installed over the foam sheathing in low-rise residential buildings up to three stories in height (Figure 1). The primary application for this wall system is in Climate Zones 3-5 (Figure 2). The Guide is aligned with the provisions of the 2012/2015 International Residential Code (IRC) as indicated throughout the document within specific sections.



#### MOISTURE PERFORMANCE

Adding exterior insulation triggers a change in moisture management strategy and requires different vapor control methods and flashing details. Exterior insulation keeps the wall cavity warmer in the winter reducing the risk of condensation inside the wall. Unlike walls with cavity-only insulation that rely on interior vapor retarders as the primary mechanism for condensation control, it is recommended in many cases that walls with exterior insulation use a more permeable interior vapor retarder to avoid the “double vapor barrier” effect – a condition where materials with low vapor permeance are installed on both sides of the walls. The primary drying path for any incidental moisture in walls with exterior foam sheathing is through the drywall to the inside of the building.

Table 1 outlines aspects of the wall design and construction addressed by this document. Walls constructed with 2x6 advanced framing without exterior continuous insulation are addressed in Part 1 of the Guide.

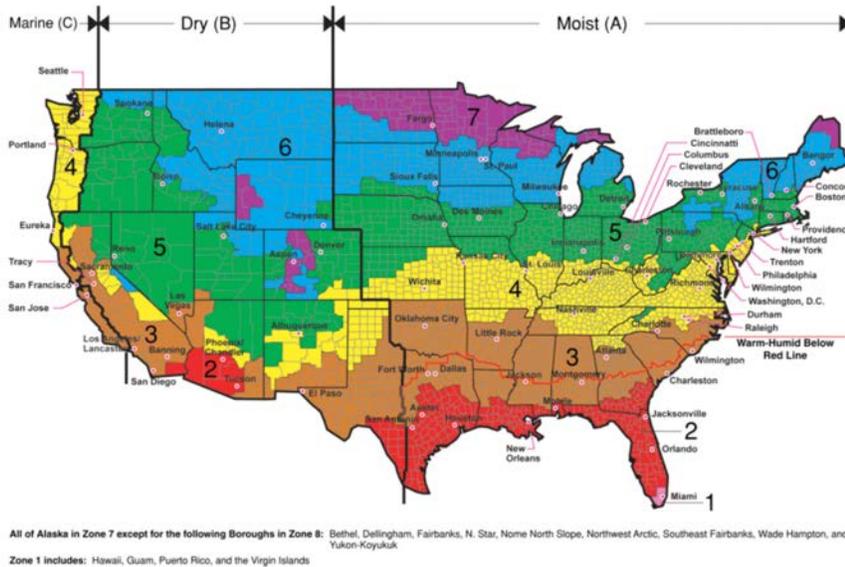


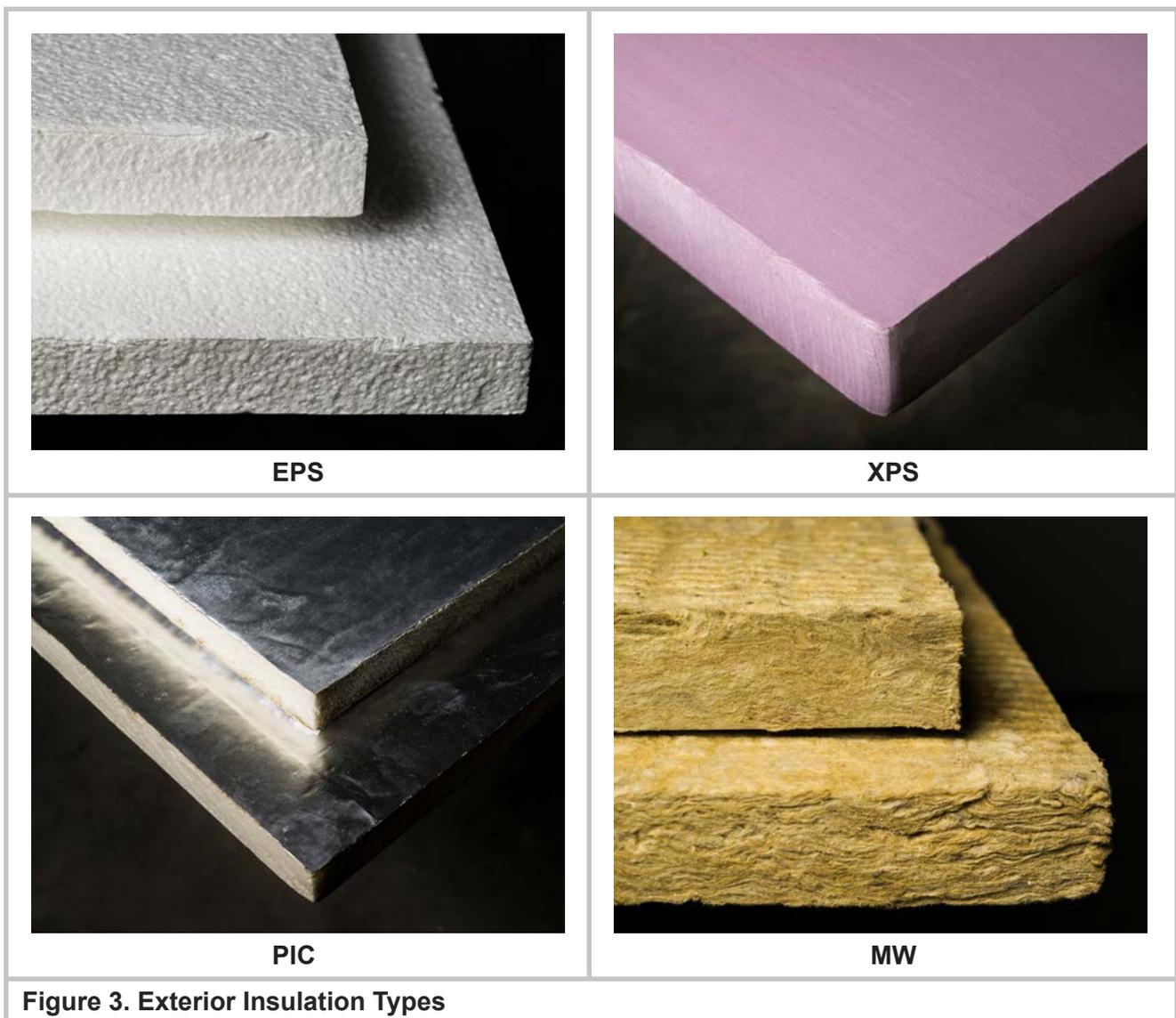
Figure 2. Climate Zone Map (Source: U.S. Department of Energy)

Table 1. Summary of Topics

WALL FEATURE	DESCRIPTION	PAGE
Exterior Insulating Sheathing Materials	Differences and commonalities between various types of exterior insulation, key properties and specifications	3
Thermal Performance	Benefits of continuous exterior insulation and performance compared to other wall types	7
Framing	Framing considerations in walls with exterior insulation	8
Exterior and interior sheathing	Considerations for exterior structural sheathing and interior gypsum drywall	8
Attachment of exterior foam sheathing	Installation, including attachments, of exterior insulating foam products	8
Water Resistive Barrier	Integration of exterior insulating sheathing with drainage plane and window & door openings	12
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# EXTERIOR INSULATING SHEATHING MATERIALS

There are three types of foam plastic insulating sheathing materials (foam sheathing) commonly used in exterior insulation applications in walls: expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate (PIC). All three types of foam sheathing are addressed in this Guide. Mineral wool (MW) can be also used in continuous exterior insulation applications and is listed in this section for comparative purposes. Applications of MW are not addressed by this Guide. Figure 3 shows examples of all four types of exterior insulation products.



Exterior insulating sheathing products vary in R-value, density, compression properties, vapor permeability, fire resistant characteristics, and other attributes – all of which should be considered when selecting exterior insulation for the specific residential project.

EPS, XPS, and PIC are more generally referred to as foam plastic insulating sheathing or rigid foam insulative sheathing or simply as foam sheathing, although variations in terminology are found in the

market. However, there are differences between these products that are discussed throughout this guide. In addition, manufacturers market their products under various brand names and sometimes build specific properties into their products to enhance certain performance attributes (R-value, fire rating, permeability, structural, etc.) Manufacturers often use a layer of plastic (polymeric) film or foil on one or both sides of the foam to achieve specific desired properties or to meet industry standard requirements. With a non-perforated polymeric film or foil layer, rigid insulation products become effectively impermeable to moisture diffusion (i.e., a Class I vapor retarder or vapor barrier). Table 2 summarizes key properties and specifications for exterior insulating materials.

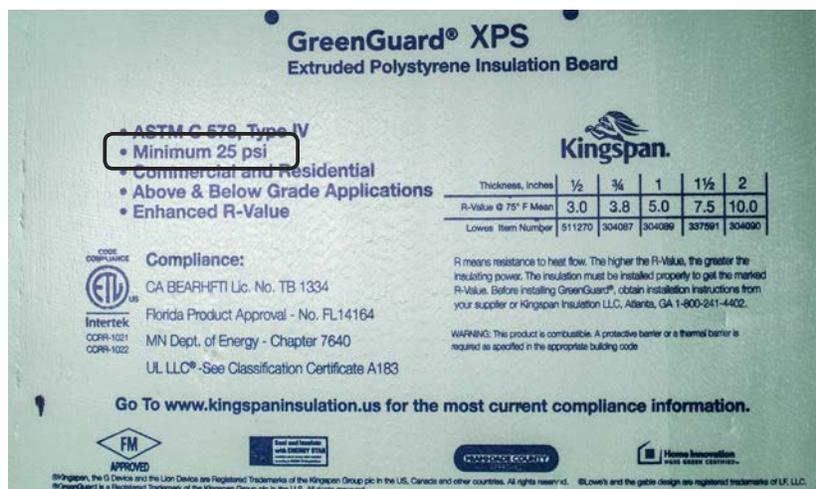
**Table 2. Exterior Insulation Types**

Insulation Type	Per in. R-value <sup>A</sup>	Minimum Density (pcf)	R5 thickness, in.	ASTM Standard	Compressive Strength <sup>B</sup> , psi
EPS Type II	4.0	1.35	1.25	ASTM C 578	15
EPS IX	4.2	1.80	1.19		25
EPS (proprietary)	4.3–4.6	Varies	Varies	ASTM C 578, proprietary specs	Varies
XPS Type X	5.0	1.30	1.00	ASTM C 578	15
XPS Type IV	5.0	1.55	1.00		25
PIC	6.5	1.70	0.77	ASTM C 1289	16
MW	4.0	8.00	1.25	ASTM C 665	5

<sup>A</sup> R-value provided in °F-ft<sup>2</sup>-h/Btu @75°F Mean Temperature.

<sup>B</sup> Minimum values for density and compressive strength, manufacturers' specifications may differ.

The reported compressive strength properties of foam sheathing materials have implications on installation of exterior finishes. For example, the IRC requires exterior foam sheathing insulation to have a minimum compressive strength of 15 psi in accordance with ASTM C 578 or ASTM C 1289. Other minimum compressive capacities may be required by specific industry standards for certain cladding applications (e.g., exterior insulated finish systems). Some foam sheathing products display the compressive strength directly on the panel as part of the product label (Figure 4). For other products, specifications should be reviewed for the compliance with the minimum compressive strength requirements.



**Figure 4. Compressive rating displayed on an XPS panel**

## EPS

Because EPS products are available in various densities, specific products (density, thickness, brand) must be selected and installed that meet the minimum required R-value for the building design. It may not be sufficient to specify exterior insulation only as “EPS” – the R-value of commercially available EPS products may vary by over 25 percent, with a typical value at approximately R-4.0 per inch. If provided without a film layer, EPS has the highest permeance among rigid sheathing insulating materials (typically 2-4 perms at 1 inch thickness), but not as high as MW. EPS foam sheathing products are available with and without film facings.

## XPS

XPS products provide R-value of 5.0 per inch, so 1.5-inch thick XPS provides an insulation value of R-7.5. The permeance of unfaced XPS material (typically 0.8 perm at 1 inch thickness) ranges between EPS (unfaced) and PIC (foil-faced) products. XPS products may also be available with a plastic film.

## PIC

PIC provides the highest R-value per inch (R-6.0 or greater) compared to other exterior insulating sheathing materials. As a wall sheathing product, it typically includes a layer of reflective film or foil on each side. Because of this added film, PIC wall sheathing has the lowest permeability (generally less than 0.1 perm). It is noted that there are PIC products with other types of facings (including glass fiber mat, fiberboard, OSB, and gypsum board) which increase the product’s permeability rating significantly (e.g., 4 to 8 perms).

## MW

MW typically has an insulation value between R-3.8 and R-4.3 per inch. MW boards are generally not considered a sheathing product and claddings are typically attached to furring strips. MW has superior fire characteristics and improved sound performance. MW also has highest permeance (~30 perm). MW is more commonly used in commercial applications, in part due to its premium cost and fire resistance characteristics

that are more applicable to commercial building code requirements. MW is water and air permeable and in all applications requires a separate water resistive barrier and an air-barrier.

## OTHER

R-5 continuous exterior insulation can also be achieved with a combination of an insulated siding product and foam sheathing. For example, insulated vinyl siding products are now recognized in the IRC and provide R-value typically in the range of R-2.5 (some products as high as R-4). Thus, a hybrid solution may combine insulated siding with a thinner insulated sheathing to achieve a total continuous insulation R-value of R-5 or more. The reader is referred to the manufacturers of the specific insulated vinyl siding products for applicable wall design and construction solutions.

## AT THE JOBSITE

Products used for exterior insulation typically arrive on the jobsite as panels or sheets 2- or 4-feet wide by 8- to 10-feet long. Rigid board edges may be square (butt joint), tongue-and-groove, or shiplap depending on the manufacturer or the product type.

Foam sheathing products are available as “scored” or “non-scored.” “Scored” products are delivered with a partial cut through the thickness of the panel to allow for easy snapping of the panel into narrower width sections (typically 16 or 24 inches wide). “Scored” products should never be used in installation directly over studs because these products do not provide the structural resistance required in such applications. In addition, non-scored products should be preferred in installation over WSP to avoid an excessive amount of joints, intended or not. The “scored” products are intended for use with masonry- or brick-veneer walls to allow closely spaced joints to be created to accommodate brick ties installed directly against the WSP. Alternatively, brick ties can be placed over the foam sheathing (non-scored) such that only the fastener penetrates the foam layer. Refer to section on Claddings for more information.

The IRC also requires that packages and containers of foam plastic insulation delivered to

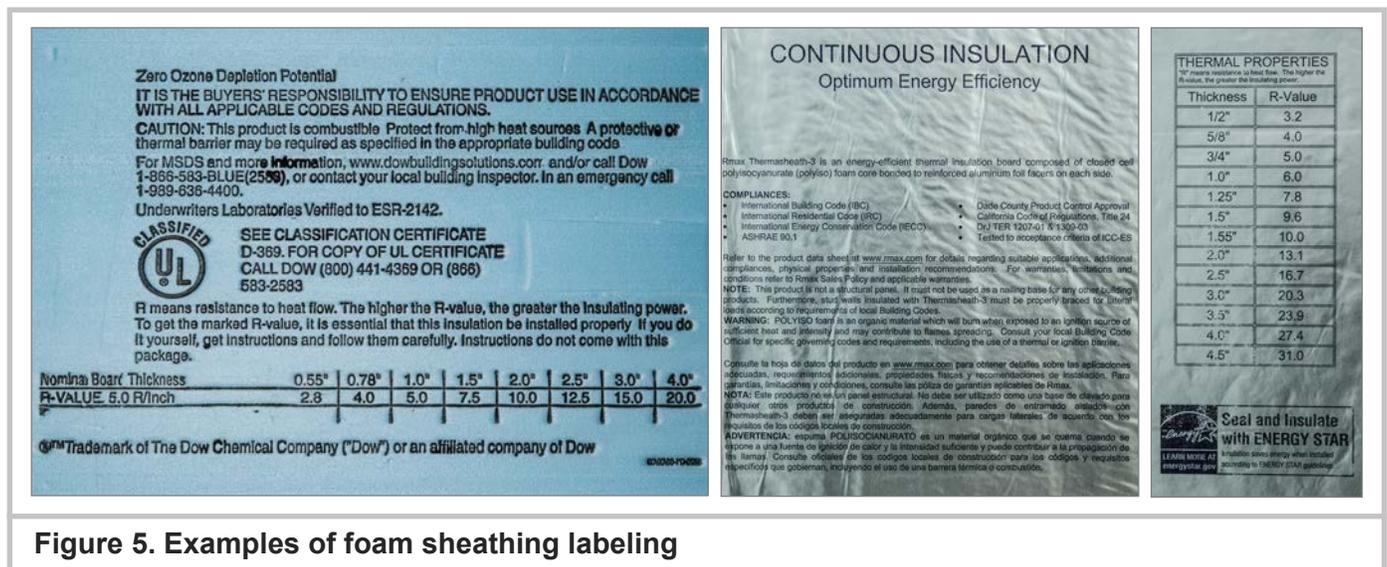
the job site bear the label of an approved third-party agency showing the manufacturer's name, the product listing, product identification, and other information sufficient for determining compliance of the end use of the product with the code requirements. Typical labeling and identification includes applicable ASTM standards and other applicable specifications, UL and/or ICC-ES listing, R-value, thickness, etc. (Figure 5).

## BOTTOM LINE

Each of the available foam sheathing products has individual advantages. The decision on selecting one of these products should always be made in the context of the wall system design for the specific climate zone and design objectives as part of the whole-building design process.

The insulating sheathing thickness applicable in this Guide ranges from 1 to 1.5 in. thick.

This range of insulation thickness is generally consistent with exterior continuous insulation requirements for 2x4 walls in Climate Zone 3-5. Also, for several cladding products, it is consistent with the maximum foam sheathing thickness where the exterior cladding can continue to be attached directly over the sheathing without triggering a change in the attachment requirements (refer to siding manufacturer instructions for specific requirements for installation over foam sheathing materials). Foam sheathing panels greater than 1.5 inches thick require other attachment considerations that will be covered in future Guides.<sup>1</sup> Similarly, foam sheathing products less than 1 inches thick, such as fan-fold, are commonly used and therefore not covered in this Guide. Foam sheathing products of less than 1 in. thick (less than R5) also generally do not comply with the prescriptive insulation requirements in CZ 3-5 for 2x4 walls and may require added consideration for vapor retarder strategies.



<sup>1</sup> For the first time, the 2015 IRC includes prescriptive provisions to install claddings directly over foam plastic insulating sheathing. Table 703.15.1 provides provisions for direct cladding attachment over insulating sheathing up to 4 in. in thickness. Always refer to manufacturer instructions for specific requirements.

# THERMAL PERFORMANCE

Continuous exterior insulation provides two primary thermal functions:

- **Added overall insulation level**
- **Reduced thermal bridging at framing members**

The combined effect is a better total system R-value than a traditional deeper cavity approach (see Figure 6 for comparison of the whole-wall R-value for various wall systems). The benefit of continuous insulation located to the exterior of the wall framing is that it provides a thermal break for all framing members in the wall. The IRC recognizes the value of continuous exterior insulation by listing R-13+5<sup>2</sup> as equivalent to R-20 cavity-only insulation.



**Figure 6. Whole Wall R-Values for Various Cavity/Exterior Insulation Combinations**

(Note that the same framing factor of 23 percent is used for all walls in the figure. The framing factor can be reduced to 16–18 percent for 2x6 walls if advanced framing practices are implemented – see the companion Part I Guide on 2x6 walls where advanced framing is implemented with R-20 cavity insulation. The whole-wall R-value for an R-20 2x6 wall with a framing factor of 17 percent increases from ~R-15.9 to R-17.1).

<sup>2</sup> First number is cavity insulation R-value and second number is exterior insulation R-value.

# FRAMING

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When transitioning from standard 2x4 wall construction to the more energy efficient option with exterior insulation of 1 to 1.5 inches thick, there are no direct implications on the framing layout. Thus, builders can continue with the standard framing practices for stud spacing, header sizing, etc. Information on advanced framing (optimum value engineering) for 2x4 applications can be found in several other resources. Information for 2x6 framing can be found in Part 1 of the Guide. Although the direct thermal benefit from using advanced framing measures in walls with exterior foam is less significant than in 2x6 walls with cavity-only insulation, there is always a direct cost savings benefit and construction efficiency advantages from the use of optimum quantities of materials.

## EXTERIOR STRUCTURAL SHEATHING AND INTERIOR GYPSUM WALLBOARD SHEATHING

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There are no changes to installation of exterior or interior sheathing compared to standard 2x4 wall construction when including exterior rigid insulation. Both exterior wood structural panel sheathing and interior gypsum wallboard are attached directly to framing using a standard fastening schedule for the application. A reverse installation where wood structural panel is to the outside of the insulative sheathing is not addressed in this guide because such systems are not rated by prescriptive IRC provisions to function as wall braced panels. It should be noted that there are proprietary products and innovative solutions that allow for the WSP to be installed to the exterior of the rigid foam sheathing, but these products/systems require different fastening schedules and include other considerations that are outside of the scope of this Guide.

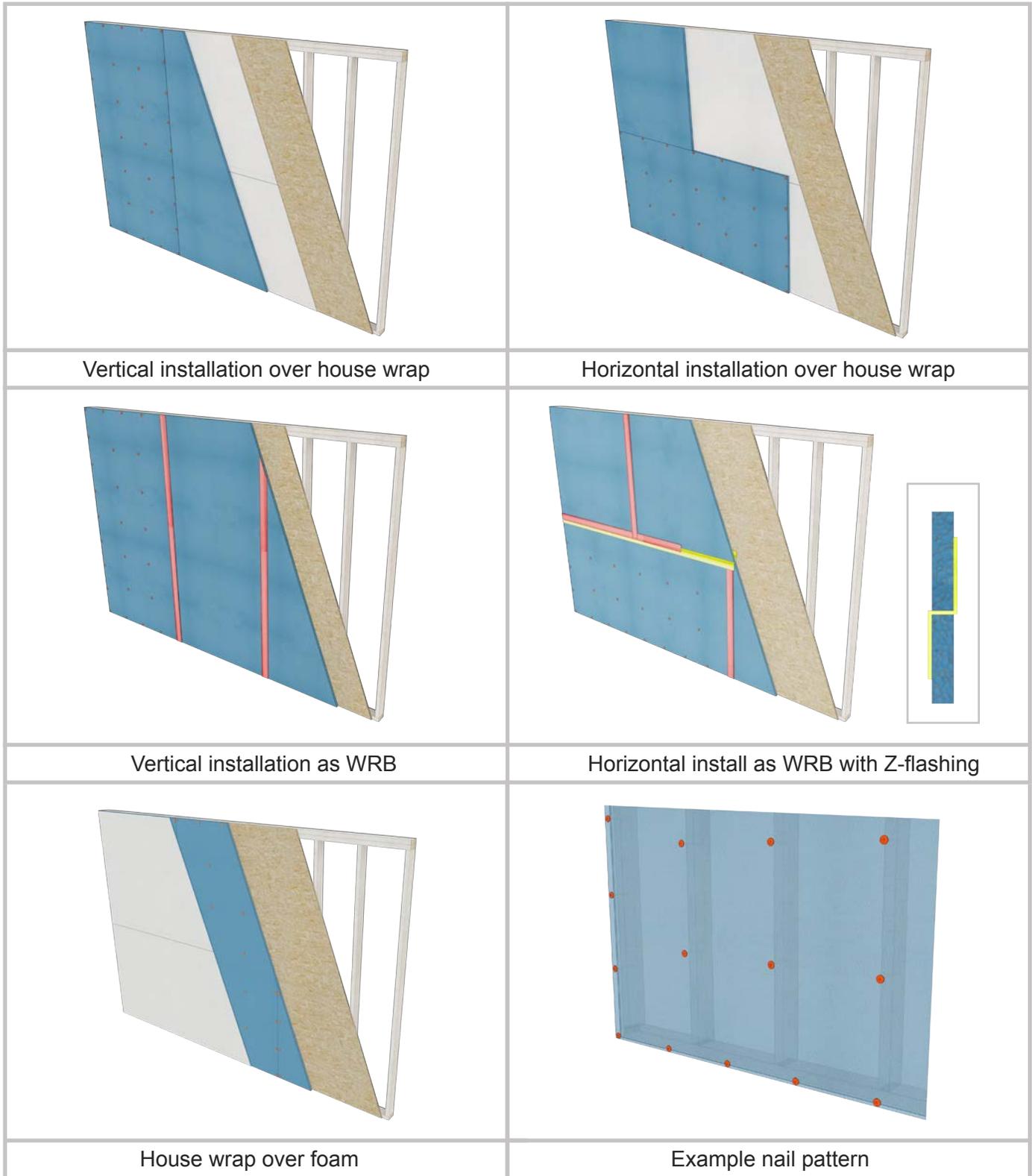
For certain wall configurations, it is permissible to install rigid foam sheathing directly over studs without wood structural panels for a portion of the wall length or the entire wall length. Wall bracing in these applications is provided by intermittently installed structural sheathing or other means (let-in bracing, diagonal metal bracing, proprietary shear panels, etc.) These bracing solutions are less common and are not addressed by this Guide.

## ATTACHMENT OF EXTERIOR FOAM SHEATHING

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Where the rigid foam sheathing is installed over a WSP backer, the primary role of the attachment is to hold the material in place until the permanent cladding or furring is installed and fastened to the structural framing and/or sheathing members. Installation guidelines for fastening requirements vary between foam sheathing manufacturers. Building codes do not provide a generic standard fastening schedule for this application because it is a construction process consideration rather than an integral structural feature of the wall. A typical example schedule for attachment of foam sheathing is shown in Table 3 as guidance.

Figure 7 provides an illustration of the attachment and orientation of foam sheathing panels for configuration where foam sheathing is installed over a house wrap or as the WRB. If house wrap is installed over foam sheathing, the foam sheathing panels can be also oriented vertically or horizontally and taping/flashing of foam joint is not required in this case because the foam sheathing is behind the primary (cladding) and secondary (house wrap) drainage planes.



**Figure 7. Illustration of Foam Sheathing Attachment and Orientation**

**Table 3. Example Attachment of Foam Sheathing Panels for Installation Over WSP Sheathing**

Fastener Type <sup>ABC</sup>	Spacing of fasteners	Minimum penetration into wood substrate	Minimum fastener length (L) based on foam sheathing thickness and 3/4-in. substrate penetration		
			1" Foam	1.25" Foam	1.5" Foam
Nail with a 1-in. min. plastic cap or 3/8-in. head nails or 1-in. crown staples	12" panel perimeter 12"–16" panel field	3/4" <sup>DEF</sup>	L = 1-3/4"	L = 2"	L = 2-1/4"

<sup>A</sup> There is no minimum nail diameter requirement.

<sup>B</sup> Nails can be smooth-shank or deformed-shank.

<sup>C</sup> Fasteners are galvanized.

<sup>D</sup> The minimum penetration depth includes the thickness of the WSP (i.e., where 7/16" OSB panel is used, the minimum penetration into the framing is 5/16").

<sup>E</sup> Where deformed-shank fasteners are used, the penetration into the WSP sheathing may be sufficient – consult with the foam sheathing manufacturer and fastener manufacturer.

<sup>F</sup> Maximum stud spacing is 24" on center.

To achieve the minimum 3/4-inch penetration requirements, the panel edges must occur over the framing. Where deformed-shank fasteners are used, the minimum penetration into the 7/16-inch WSP sheathing (without the framing) may be sufficient. It is recommended to contact the foam sheathing manufacturer for information on whether such practice is permitted and on the specific fastening schedule. Attachment to WSP sheathing simplifies the installation by eliminating the need for aligning foam sheathing panel edges with framing members and locating the studs behind two layers of sheathing. Where the foam sheathing is used as the WRB, the fastener locations are visible and, if located in studs, provides an easy visual cue to siding installers as to the location of siding fasteners. Alternatively, the WSP sheathing may be used as the nail base for siding connections as permitted by the siding manufacturer, the code, or by design (see section on Claddings). Newly added provisions to the 2015 IRC provide a means (with certain limitations) on the use of 7/16-inch WSP as a nail base sheathing suitable for siding and foam sheathing attachment, simplifying installation, particularly if a layer of house wrap is used in the assembly that will tend to mask the stud locations because its fasteners do not need to (and usually do not) penetrate into studs.

The use of cap-head nails helps avoid overdriving fasteners into the foam sheathing.

The foam sheathing panel edges may be offset from the WSP edges or occur directly over the WSP edges. Aligning foam sheathing edges with the WSP panels may help with locating the studs to facilitate fastening foam sheathing to wood framing. Where edges are offset, the nailing markings provided on most WSP sheathing products can be used to help align foam sheathing edges with studs.

Foam sheathing can be installed after the exterior walls are erected and braced (Figure 8) or it can be attached to wall panels before the panels are installed in place (Figure 9).



**Figure 8. Foam sheathing installation after walls are erected and braced**



**Figure 9. Foam Sheathing is Installed as Wall Panels are Framed**

The installation sequence may determine which trades are installing the foam sheathing. In the first scenario, commonly the siding crew would be installing exterior insulation and house wrap (if used) and would be motivated and able to keep track of the location of the framing members for attaching siding. In the second scenario, the exterior insulation is installed by the framing crew prior to the panel erection. It is recommended that the two trade crews have an opportunity for communication so that the siding crew understand the installation sequence for the foam sheathing and house wrap and has the ability to locate the framing members. As an alternative solution to locating each framing member, a cladding fastener option that relies on attachment to the WSP only can be used (refer to section on Claddings).

# WATER RESISTIVE BARRIER

Establishing a strategy for integrating exterior insulation with the wall's drainage plane is a key consideration for transitioning from a standard 2x4 wall to one that includes exterior rigid insulation.

Two primary strategies for installing exterior rigid foam sheathing insulation up to 1.5 in. thick are highlighted in this Guide and are defined by the location of the wall drainage plane, i.e., water resistive barrier (WRB):

1. **Drainage Plane Outboard of Exterior Insulation:**
  - A. A separate WRB installed over the foam sheathing OR
  - B. The outside surface of the foam sheathing serves as the WRB
2. **Drainage Plane Inboard of Exterior Insulation:**
  - A. A separate WRB installed between the WSP and the foam sheathing

Note: Cladding serves as the primary defense protecting the wall from the rain water. The WRB drains away any liquid water that finds a path behind the cladding.

The two strategies differ in the *flashing details for openings* – a critical aspect to the long-term performance of the wall system. Either strategy can be effectively implemented and is a matter of builder preference with regard to integration of various materials into an assembly and transition approach to installation sequencing for the trades. The graphics in this section show the essential steps for integrating the WRB with the window or door flashing; these examples align with installation guidelines from most product manufacturers.

The primary attribute of the **Outboard Method** is that the drainage plane is directly behind the cladding, immediately draining away any water that gets behind the cladding. Windows and doors are flashed to the exterior foam sheathing or house wrap installed over the foam sheathing. Windows are installed with the flanges over the insulating sheathing creating a conventional flat

façade appearance (window is the same plane with the wall) and the reveal of the window frame can be matched up with siding and trim materials as typically practiced.

The primary attribute of the **Inboard Method** is the drainage plane (WRB and flashing) remaining at the same location as in conventional 2x4 construction (at the WSP). In this case, the addition of exterior insulation only requires the use of longer fasteners for attaching the cladding. Other construction practices remain unchanged – windows and doors are installed before the foam and flashed to the WSP or the house wrap. The selected window type may have an exterior frame reveal (frame portion projecting exterior to the flange) that is able to accommodate the thickness of foam sheathing and siding or trim. Alternatively, additional detailing to maintain continuity of appearance and weather barrier function of the cladding and trim at the window perimeter may be required. Windows have a recessed appearance in this wall configuration. Figure 10 and Figure 11 show the appearance of the two window types.



Figure 10. Flat Facade Window — Outboard Drainage Plane Method



Figure 11. Recessed Windows — Inboard Drainage Plane Method

## OUTBOARD DRAINAGE PLANE

Table 4 summarizes three installation sequence options for the outboard drainage plane strategy based on the selection of the WRB and window installation. Figure 12 through Figure 14 illustrate each window detailing option.

**Table 4. Outboard Drainage Plane Installation Options**

INSTALLATION SEQUENCE			
Step	<b>Option 1:</b> Taped Foam Sheathing used as WRB (Figure 12)	<b>Option 2:</b> Windows installed after house wrap (Figure 13)	<b>Option 3:</b> Windows installed before house wrap (Figure 14)
<b>1</b>	WSP sheathing over framing		
<b>2</b>	Foam over WSP		
<b>3</b>	Foam seams taped with approved tape (typically acrylic-based adhered joint tape)	House wrap over foam	A piece of house wrap below the window (apron)
<b>4</b>	Pan flashing at window sill over foam	House wrap seams may be taped to improve air tightness (if part of the air sealing strategy)	Pan flashing at window sill over foam and over WRB apron
<b>5</b>	Windows with flanges over the foam sheathing	House wrap is prepared at window (fold in at jambs and fold up at head)	Windows with flanges over the foam sheathing
<b>6</b>	Jamb flashing over insulating sheathing and window flange	Pan flashing over foam and house wrap	Jamb flashing over insulating sheathing
<b>7</b>	Drip cap at window top flange (best practice, especially for mulled units or painted wood window)	Window with flanges over the house wrap	Drip cap at window top flange (best practice, especially for mulled units or painted wood window)
<b>8</b>	Head flashing over insulating sheathing and window head flange or drip cap vertical flange; lapped over jamb flashing	Jamb flashing over insulating sheathing and over window flange	Head flashing attached to insulating sheathing over jamb flashing
<b>9</b>	Counter flashing above head flashing (typically the sheathing joint tape is used)	Drip cap at window top flange (best practice, especially for mulled units or painted wood window)	House wrap shingle-style
<b>10</b>	Cladding	Head flashing over insulating sheathing and window head flange over jamb flashing and under top lap of house wrap	Integrate house wrap with apron and seal at jambs and head
<b>11</b>	-	Fold down house wrap and tape diagonal seams	Cladding
<b>12</b>	-	Cladding	-



**Figure 12. Option 1: Taped Foam Sheathing Used as WRB**

**Option 1:** Only approved foam sheathing products with all joints sealed using an approved tape can be used as a WRB surface. The product manufacturer will have an evaluation report from a third-party agency<sup>3</sup> with specific instructions for installations of foam sheathing as a WRB. The advantages of using foam sheathing as a WRB is that the foam serves multiple functions: provides insulation, acts as a drainage plane, contributes to the air barrier, and provides backing for the cladding. In addition, the foam sheathing fasteners when placed into studs provide a marker for location of siding fasteners. The effectiveness of the foam sheathing to act as a WRB relies on the taped joints. Therefore, only tape products specifically approved for this application can be used. Foam sheathing panels can be installed vertically or horizontally; however, the vertical installation practice will minimize the number of horizontal joints on multi-story walls. Use of Z-flashing at all horizontal seams is recommended as a best practice. As an alternative, the horizontal joints may be detailed as described for window head flashing (e.g., a layer of butyl-based adhered flashing tape over the horizontal joint with a termination strip of sheathing joint tape applied continuously along the top edge of the adhered flashing tape for a “double seal”).



**Figure 13a. Option 2: Windows Installed After House Wrap**

<sup>3</sup> As a standard industry practice, foam sheathing must meet the requirements established by an approved agency for code evaluations.



**Option 2:** Using a separate WRB membrane (house wrap) provides a drainage surface that relies on shingled, overlapped joints to divert any water that gets behind the cladding to the outside. A wide range of house wrap products is available for this application with varying water resistance and water vapor permeance properties. However, with the foam sheathing having a lower range of permeability (see section on Vapor Retarders), the permeability of the house wrap in this case is not a critical consideration for most applications. (For discussion on taping foam sheathing or house wrap in this application, refer to section on Air Barriers.) Installing fenestration after the house wrap is followed by standard flashing detailing.



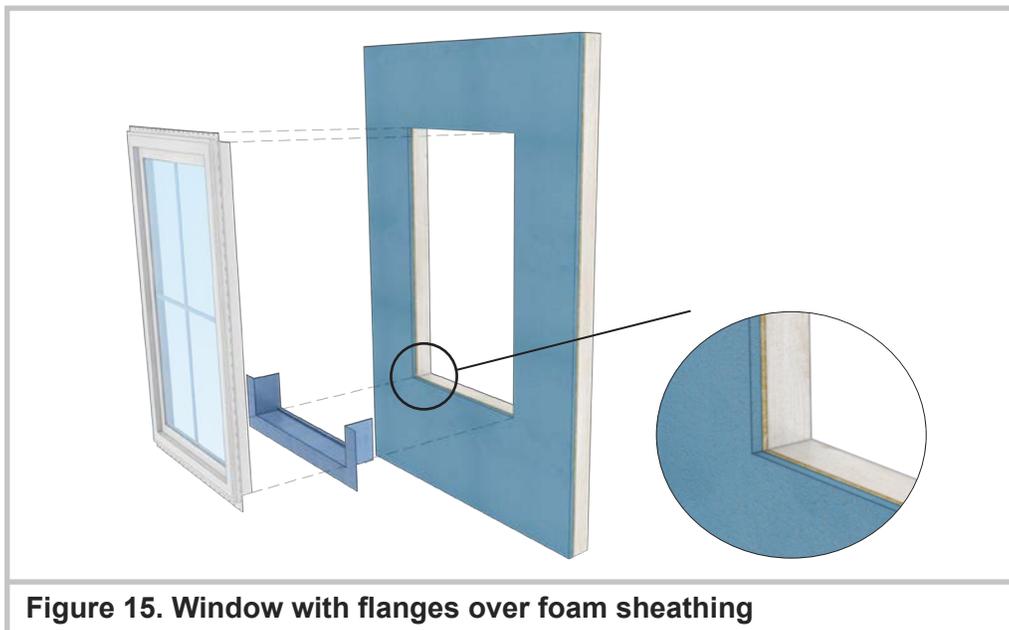
**Option 3** is different from Option 2 only in the flashing details. All other considerations discussed above apply to the configuration where the window is installed before the WRB. Note that the integration of the WRB apron should overlap the lower layer of the WRB.

## Window and Door Attachment (Outboard Drainage Plane)

Windows and doors must be supported through attachment to the wall. Several options are available for supporting and anchoring windows and doors in walls with exterior foam. The manufacturer should be contacted for specific attachment requirements for the window/door type and site location. Note that some window manufacturers may only permit installation directly over structural backing or may not provide specific instructions for installation over walls with foam sheathing. The following installation options are considered to be representative of accepted and successful construction practices for foam sheathing thicknesses that do not exceed 1.5 inches.

### *Flanges over foam sheathing:*

For walls with foam sheathing up to 1.5 inches thick<sup>4</sup>, the flange is fastened through the foam with the fasteners penetrating into the framing members around the window (see Figure 15). This is one of the simpler installation methods for windows over rigid foam sheathing that has been used for many years. Fasteners should be selected to sufficiently penetrate into the framing and should not be overdriven to avoid distorting the window frame and flanges. The requirement for the minimum compressive strength of the foam sheathing (15 psi for EPS and XPS, 16 psi for PIC) is important to this application and higher compressive strength foam sheathing products are available, if preferred, although not commonly specified in residential projects.

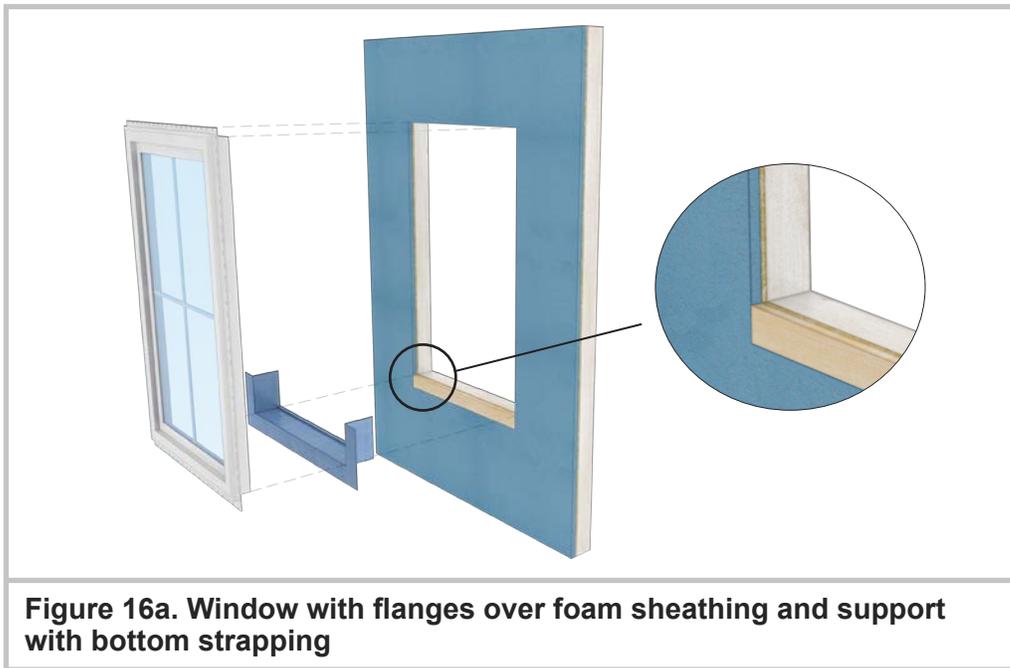


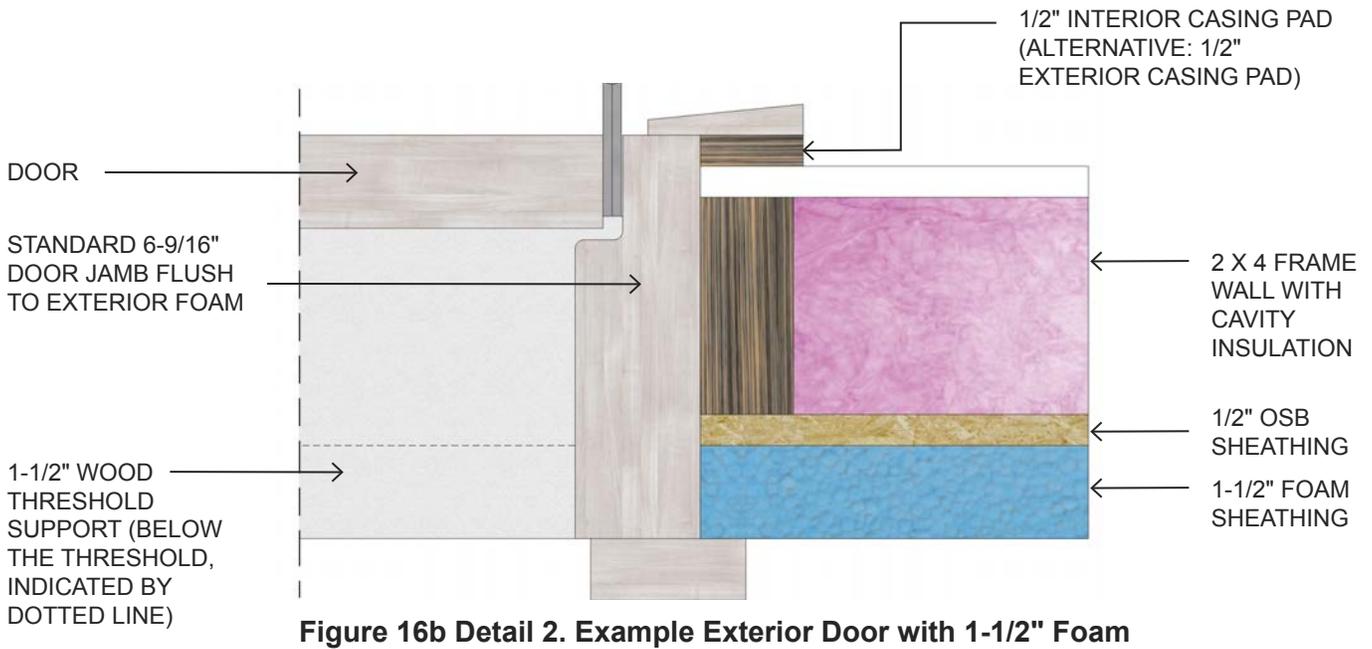
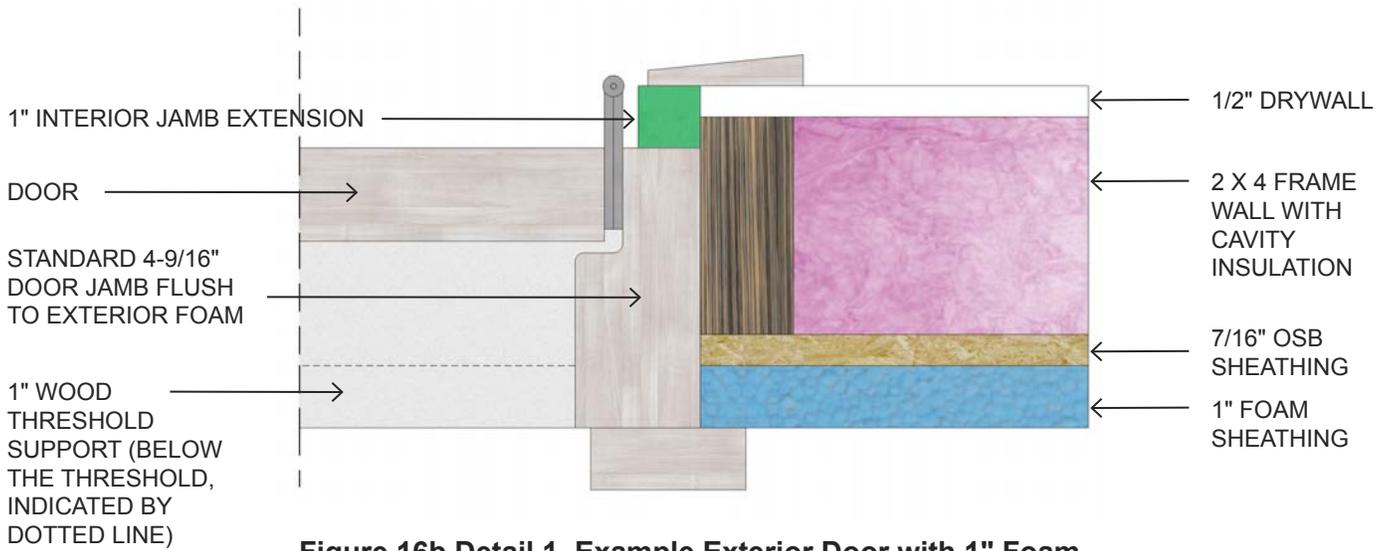
**Figure 15. Window with flanges over foam sheathing**

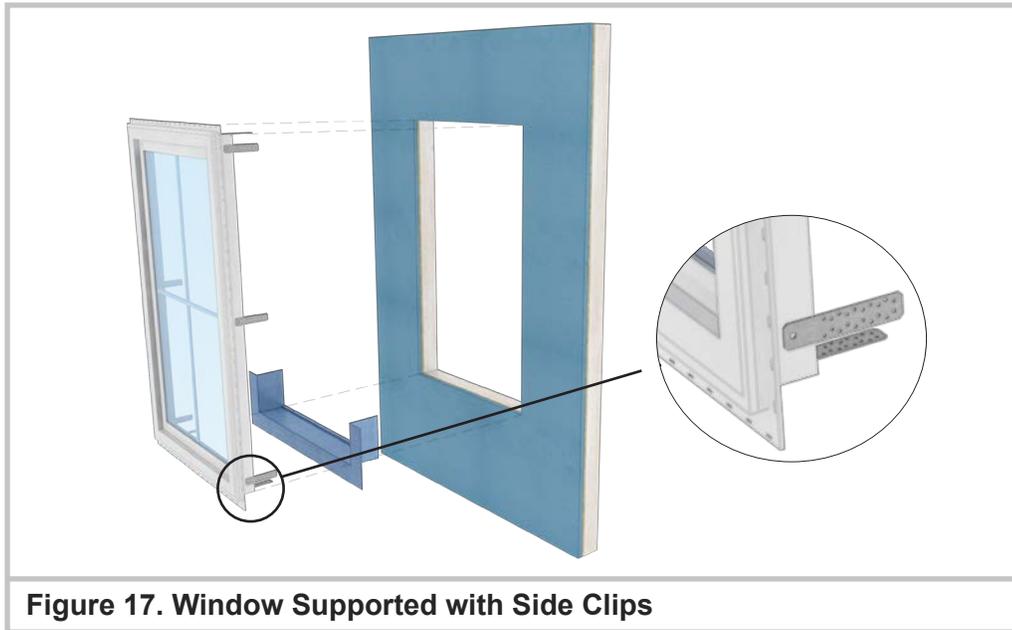
<sup>4</sup> Note that some manufacturers' literature may limit the thickness of the foam sheathing to less than 1.5 inches for direct attachment of the window flange. If clarification is needed, check directly with the manufacturer or follow an alternative designed solution.

*Supplemental support with bottom strapping:*

With the side and top flanges bearing on the foam sheathing, a horizontal wood member (sill blocking or strapping) added at the bottom of the window to provide additional support for the window sill (see Figure 16a). This is particularly suitable for windows that don't have a structural flange (i.e., the flange is simply meant as an installation aid and means of flashing) or in cases where the window frame is so narrow that it does not provide an overlap with the wood framing in the rough opening to allow for direct support or use of sill shims. The horizontal wood member is attached directly to the WSP and framing and the foam sheathing is installed around it. This option should also be considered for larger/heavier windows. For entry doors installed over foam, see Figure 16b and example details.



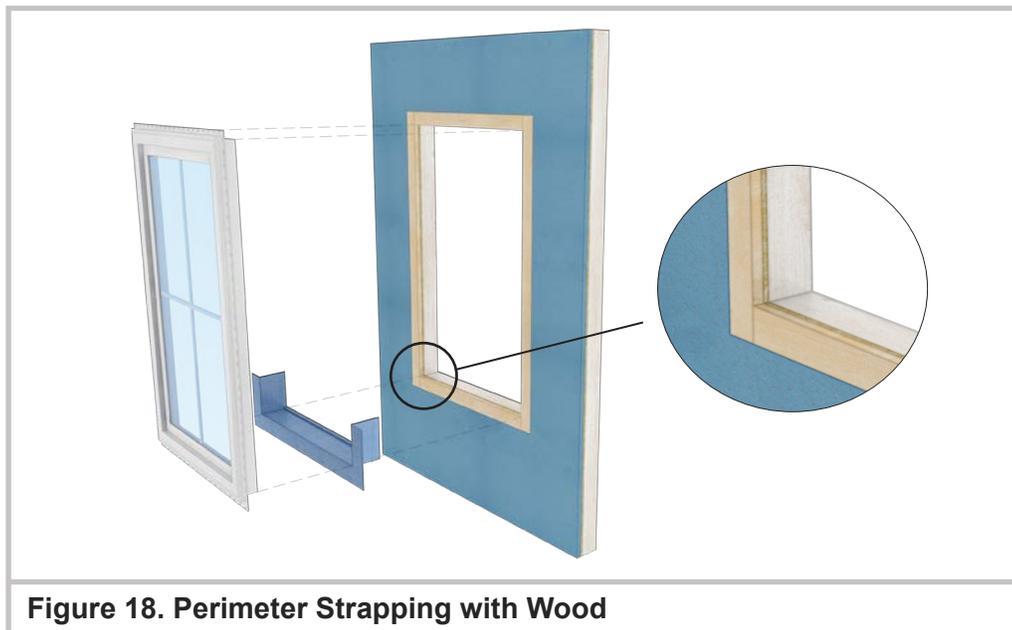




**Figure 17. Window Supported with Side Clips**

*Support with side clips:*

Metal or plastic side straps are used to attach the side of the window to the studs on the interior face of the rough opening (Figure 17). The flange is attached through the foam to secure the window in place, but the primary support for the window is provided by the side straps. Sill support may still be required for the window unit through use of shims between the window frame and rough opening. The side clips may be primarily intended to anchor the window unit against wind load when the window flange is not considered to be a structural flange.



**Figure 18. Perimeter Strapping with Wood**

*Perimeter strapping:*

Strapping (e.g., blocking, scabbing, etc.) around the window perimeter providing a solid nailing surface directly behind the window flange (see Figure 18). This approach is also referred to as a Rough Opening Extension Support Element, or ROESE. This type of installation is commonly used for thicker foam (2 inches and more) but can also be implemented for foam up to 1.5 inches thick where additional support is desired.

## INBOARD DRAINAGE PLANE

House wrap, windows and doors, and flashing are installed at the WSP sheathing following standard construction practices – a complete drainage plane is provided prior to installing the exterior rigid insulating sheathing. Insulating sheathing is then added over the drainage plane followed by the cladding.

As a best practice, it is recommended to use a house wrap product with enhanced draining channels to enable water shedding in the space between the foam sheathing and the house wrap. There are various commercially-available house wrap products with features (e.g., bumps, grooves, wrinkles) built-in to create a small air gap to promote drainage in these types of applications.

*(Note: This Guide does not provide information on the relative effectiveness of the various types of drainable house wraps.)*

As a practical matter, it is recommended to consider a siding product and siding attachment method compatible with the use of the 7/16-in. WSP sheathing as a nail base to simplify installation because of stud locations masked by the house wrap.

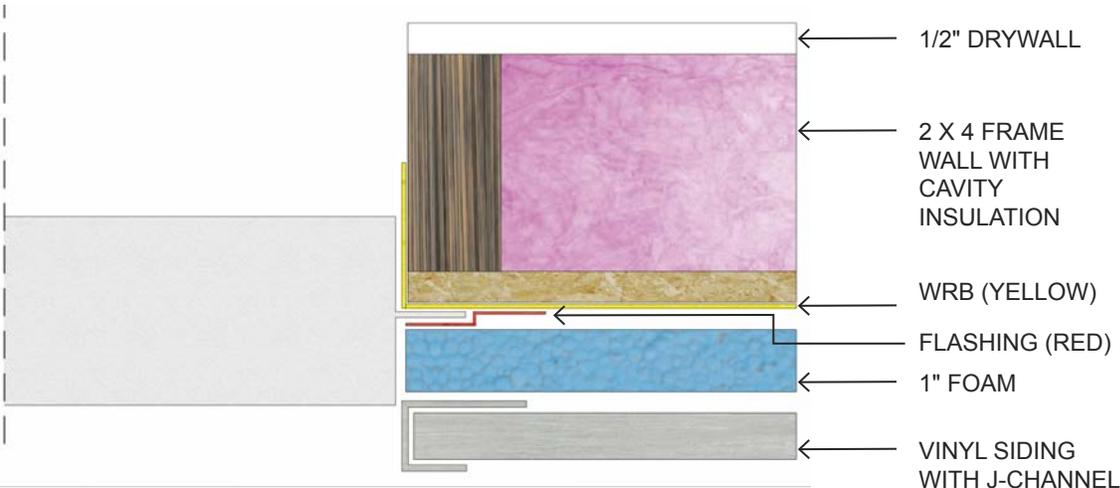
Table 5 summarizes two installation sequence options for the inboard drainage plane strategy. Figure 19 and Figure 20 illustrate both window detailing options.

**Table 5. Inboard Drainage Plane Installation Options**

INSTALLATION SEQUENCE		
Step	<b>Option 1: Window installed after WRB (Figure 19)</b>	<b>Option 2: Window installed before WRB (Figure 20)</b>
<b>1</b>	<b>WSP sheathing over framing</b>	
<b>2</b>	House wrap over WSP	A piece of house wrap below the window (apron)
<b>3</b>	House wrap joints can be taped if the WRB is the primary air sealing strategy or enhanced air sealing and water resistance is desired	Pan flashing at window sill over foam and over apron
<b>4</b>	House wrap is prepared at window (fold in at jambs and fold up at head)	Window installation
<b>5</b>	Pan flashing over house wrap	Jamb flashing
<b>6</b>	Window installation	Drip cap at window top flange
<b>7</b>	Jamb flashing	Head flashing
<b>8</b>	Drip cap at window top flange	House wrap shingle-style
<b>9</b>	Head flashing	Integrate house wrap with apron and seal at jambs and head
<b>10</b>	Fold down house wrap and tape diagonal seams	Exterior rigid insulating sheathing
<b>11</b>	Exterior rigid insulating sheathing	Cladding
<b>12</b>	Cladding	-



**Figure 19. Inboard Drainage Plane with Window Installed after House Wrap**



**Figure 19 Detail. Example Cladding Detail with Inboard Drainage Plane**



**Figure 20. Inboard Drainage Plane with Window Installed before House Wrap**

# AIR BARRIER STRATEGIES

Reducing air leakage through the wall is important to thermal and moisture performance of the wall. This section focuses on options for integrating exterior foam sheathing with the wall's air barrier.

An effective air barrier serves three primary functions:

- limit energy losses due to conditioned air leakage out of the home;
- limit air leakage pathways that can carry moisture-laden air to wall cavity condensing surfaces; and,
- maintain R-value levels of permeable insulation materials degraded by air movement.

The reduction of air leakage through the wall helps meet or exceed building code air tightness requirements and ensure the durability of the building envelope.

Wall air sealing measures are a major part of a whole-house air sealing package. As defined in the IRC, the air barrier consists of “*material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.*” Multiple layers of the wall system

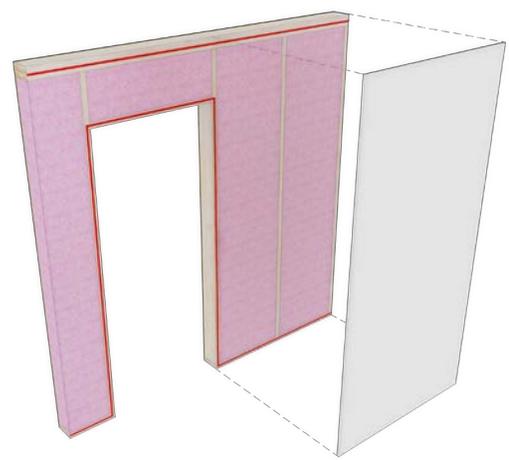
make up the air barrier system of the home.

For quality management purposes, it is recommended that the air barrier be detailed on the plans so that trades are familiar with the location of the air barrier when constructing walls. This is particularly important for complicated framing details. The building code provides specific requirements for air sealing to establish consistency for the trades and builders in identifying and creating an air barrier perimeter.<sup>5</sup>

***The air barrier for framed exterior walls may be located on the exterior, the interior, or a combination of both.*** Air barriers located to the exterior, for example taped exterior foam sheathing, limits air leakage from the outside (see Figure 21). Air barriers located to the interior, for example sealed gypsum board, limit air leakage into the cavity from the inside and limit air leakage into the attic space (see Figure 22). ***Ideally, a combination of air sealing strategies and materials are used to provide multiple benefits.*** The reader is referred to Part I of the Guide for a more detailed overview of interior air barriers. This section primarily focuses on the exterior air barrier – where the foam sheathing is located.



**Figure 21. Example Exterior Air Barrier (Taped Foam Sheathing)**



**Figure 22. Example Interior Air Barrier (Air sealed drywall)**

<sup>5</sup> 2012 IRC, TABLE N1102.4.1.1 (R402.4.1.1), AIR BARRIER AND INSULATION INSTALLATION

## **EXTERIOR FOAM SHEATHING: TAPE OR NO TAPE**

Foam sheathing with taped joints can be used to provide an exterior air barrier layer that contributes to the overall air tightness of the building. Yet, the decision whether to tape or not tape the foam panel joints is not an inevitable “yes” (*unless it is being used as the WRB*). While taping foam sheathing joints is often a good idea, the benefit does not always justify the effort. It depends on whether the foam sheathing is intended to serve as the drainage plane or is integrated with a separate drainage plane, as well as practical field installation considerations.

### ***Foam sheathing serves as the drainage plane***

In this configuration, all vertical and horizontal joints between adjacent foam sheathing panels are required to be taped and fenestration elements are sealed to the exterior surface of the foam sheathing. The foam sheathing layer will contribute to reduced air leakage, particularly in multistory construction.

Yet, unlike water that follows the direction of gravity (capillary action notwithstanding), air can enter from any direction and can travel in any direction and the top and bottom interfaces would need to be air sealed as well to provide the most complete air barrier. However, sealing foam sheathing at foundation and roof junctions may not always be the most practical or even correct solution. A belt-and-suspenders water management approach would be to not air seal the bottom edge of the foam to allow for any incidental water to drain out. Air sealing of the foam sheathing at the roof junction may be labor intensive and better results can be achieved by air sealing other parts of the wall from the interior. If desired, an air seal at the roof junction can be achieved using a bead of caulk between the top edge of the foam sheathing and the WSP sheathing.

### ***House wrap serves as the drainage plane***

Where house wrap is installed inboard or outboard of the foam sheathing to provide the primary drainage plane (see Figure 13, Figure 14, Figure 19, or Figure 20), using foam sheathing as air barrier becomes a less compelling value proposition from the standpoint of added labor and the required detailing. In fact, in some cases air barrier detailing may not be compatible with the WRB. For example, where the house wrap is installed between the foam and WSP sheathing (inboard drainage plane), it is recommended to maintain a small air space behind the foam and not seal at the top or bottom to allow for drainage.

## **AIR BARRIER - SUMMARY**

Foam sheathing can help improve air tightness of the wall and the house. The most practical and cost-effective solution will depend on the selected approach for drainage plane and the overall air sealing strategy for the walls and the climate zone.

# WATER VAPOR MANAGEMENT

Adding exterior insulation presents a different means of controlling water vapor transfer. Much of the conventional wisdom for selecting interior vapor retarders no longer applies. This section provides specific recommendations and solutions for selecting a foam-sheathed wall system design that manages interior water vapor and provides a drying path for any potential moisture accumulation.

Also refer to the Air Barrier section for information on importance of limiting air leakage paths on the wall's moisture performance. Both interior air leakage and vapor diffusion are significant sources of water vapor load that require attention in the wall design and construction process. Some vapor retarders (e.g., polyethylene) help control both air leakage and vapor diffusion. Others (e.g., Kraft facing) are more effective at controlling diffusion.

## THE BASICS AND THE THEORIES

During the winter, the temperature inside the wall is lower than the indoor temperature leading to a potential for elevated relative humidity within the cavity and resulting in increased moisture content of the materials and condensation on cold surfaces. It is the water vapor in the warm indoor air of the house that is being driven into the colder wall cavity either by diffusion through the wall materials or by air leakage through cracks. This water vapor drive is addressed in different ways for conventional (cavity-only insulation) and foam-sheathed walls as contrasted below:

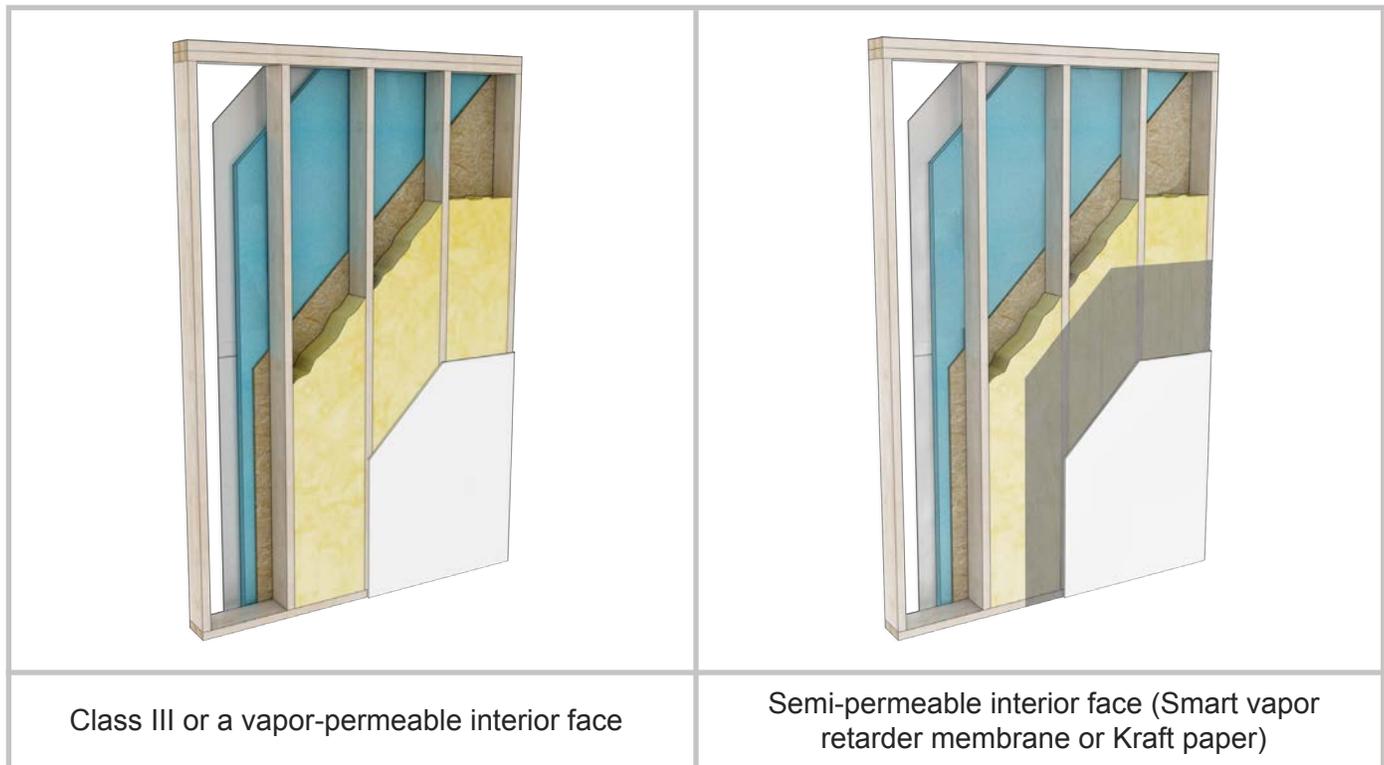
- (1) Conventional walls with cavity-only insulation rely solely on the interior vapor retarder (e.g., polyethylene, Kraft paper facing) to limit the transfer of water vapor from inside the house into the wall (see Figure 23). The control mechanism is to throttle moisture vapor on the interior side of the wall. The direction for drying is either to the outdoors or to the indoors or both. For outdoor drying, it is recommended that materials exterior to WSP sheathing have

a combined perm rating of 5 or greater. For drying to the indoors, a variable-perm vapor retarder is recommended such as a smart vapor retarder or Kraft paper.



**Figure 23. Conventional Walls**

- (2) In walls with foam sheathing, the winter vapor flow and moisture accumulation rate is reduced by keeping the wall cavity warmer and therefore the wall cavity RH lower. Conditions inside the cavity are somewhat closer to the conditions inside the building. A more permeable vapor retarder such as a Class III vapor retarder may be used to further moderate vapor flow and allow adequate drying to the interior. Figure 24 shows two variations of interior vapor retarders for walls with exterior foam sheathing.



**Figure 24. Walls with Exterior Foam**

In walls with exterior foam sheathing, the primary designed drying direction is to the inside because most exterior foam sheathing products generally have lower permeance. Therefore, certain vapor retarders (e.g., polyethylene sheeting) are not recommended in walls with exterior foam sheathing to avoid the potential for a double vapor barrier – a wall configuration where drying potential is substantially impeded in both directions. The primary reason is that such walls lack the ability to quickly recover from incidental moisture (e.g., window leak, air leaks at penetrations, etc.) that have the potential for occurring over the lifetime of a house. Therefore, this guide recommends the use of higher perm interior vapor retarders (e.g., Kraft paper, Class III latex paint, smart vapor retarder) in combination with the use of exterior foam sheathing.<sup>6</sup>

Another variable critical to the appropriate selection of a vapor retarder is the R-value provided by the exterior foam. For the 2x4 wall cavity to be sufficiently warm to effectively reduce

the rate of vapor flow from the interior toward the exterior, adequate thickness of foam sheathing should be provided. This Guide is based on the IRC that requires a minimum of R5 for 2x4 walls for Climate Zones 3-5<sup>7</sup>. Higher exterior insulating sheathing R-values help with water vapor management by further warming the wall cavity, but thicknesses in excess of 1–1.5 in. involve additional considerations for attachment of claddings and fenestration (not part of this Guide).

## VAPOR RETARDERS

Based on their effectiveness, vapor retarders are assigned into three classes as outlined in Table 6. Permeability of exterior sheathing products is summarized in Table 7.

<sup>6</sup> It is noted that other solutions are possible that would require a more targeted material selection and balancing vapor permeance of various layers. These approaches are beyond the scope of this document which is intended for more prescriptive solutions. It is also noted that for foam sheathing products without a facer (EPS and XPS products primarily), there is a secondary drying path to the outside.

<sup>7</sup> 2012 IRC or 2015 IRC Section R702.7.1.

**Table 6. Vapor Retarder Classification**

Class	Vapor permeability	Permeance Range	Example materials review
Class I	Low – impermeable	≤0.1 perm	Polyethylene sheet, aluminum foil, sheathing faced with a non-perforated foil or plastic film
Class II	Medium – semi-impermeable	>0.1 and ≤1.0	Kraft paper, XPS foam sheathing (un-faced, 1"–1.5" thick), ccSPF at ~1.5–2.5" thickness (see manufacturer product data)
Class III	Medium to High – Semi-permeable	>1.0 and ≤10	Latex or enamel paint (rated <sup>^</sup> ), EPS foam sheathing (un-faced, 1"–1.5" thick), Kraft paper at higher RH, OSB at <85% RH
N/A	High – permeable	>10	Gypsum (unpainted or non low-perm paint), smart vapor retarder at higher RH, OSB at >85% RH

<sup>^</sup> Paint should be tested to demonstrate permeability properties at application thicknesses. Standard primer/finish coat wall paint coverings may not consistently meet Class III permeance levels.

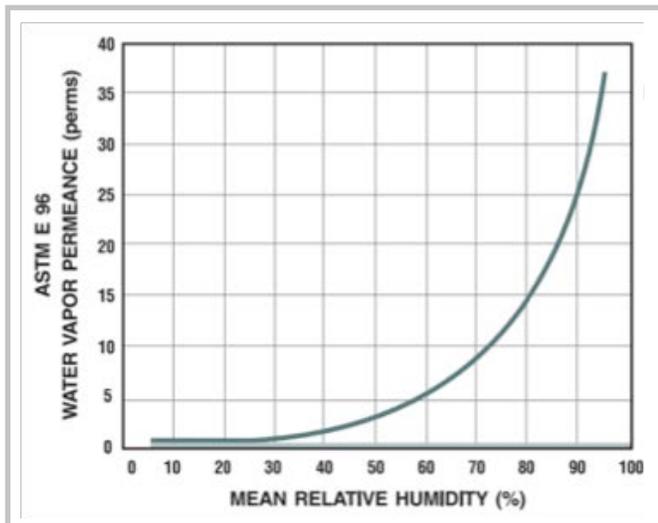
**Table 7. Vapor Permeance of Exterior Insulating Materials**

Exterior Insulation Product	Perm Rating (based on 1 inch thickness)	Classification for R-5
EPS	~2.8	Class III
XPS	~1.0	Class II
PIC	~0.1	Class I
EPS or XPS with film facing	Not published	Class I
Mineral Wool Board	~30	Vapor permeable

Perm is a measure of the amount of water vapor (in units of grain) transmitted through a square foot area of material per hour under a pressure equal to an inch of mercury. As a reference point, at interior conditions of 40% relative humidity and 70°F and exterior average monthly dew point temperature of 33°F, as much as 8.5 quarts of water can get through a 4x8 sheet of gypsum (50 perms) in a month. Replacing gypsum with kraft paper (1 perm) as the vapor retarder reduces that amount to 0.17 quarts of water.

Variable Vapor Retarders (aka Smart Vapor Retarders) are vapor retarders that change permeance in a manner that allows vapor diffusion to facilitate drying when elevated levels of moisture occur inside the wall and minimize vapor diffusion under normal conditions. Permeance in such materials is a function of relative humidity of the surrounding environment.

With elevated relative humidity the permeance increases, and vice versa. Some traditional materials (typically wood-fiber based) exhibit smart vapor retarder characteristics (e.g., Kraft paper which is a Class II vapor retarder that attains properties of a Class III vapor retarder at high levels of ambient relative humidity). There are proprietary materials with properties specifically engineered to respond as smart vapor retarders. When selecting a proprietary Smart Vapor Retarder, follow manufacturer’s guidance for the product for meeting the code provisions for vapor retarders for the specific application (i.e., climate zone, wall configuration.) These products are effective at reducing or throttling vapor flow into the wall during the winter (act as a Class II vapor retarder) while “opening up” in the summer to act as a Class II vapor retarder to allow moisture to more readily escape when vapor drives reverse (see Figure 25).



**Figure 25. Smart Vapor Retarder**

Source: <http://www.certainteed.com/resources/3028097.pdf>

## THE SOLUTION: VAPOR RETARDERS FOR 2X4 WALLS WITH EXTERIOR FOAM SHEATHING

The vapor retarder selection for 2x4 walls with exterior insulating sheathing are summarized in Table 8 based on the climate zone.

In **Climate Zone 3**, the IRC does not require an interior vapor retarder because the vapor drive from the interior to the outdoors during the colder season is not significant enough. Installing a Class

I interior vapor retarder is not recommended because of the substantial summer vapor drive in this climate zone from the outdoors to the indoors that can lead to potential for condensation on the cold interior surface (air-conditioned side of the wall).

**Climate Zone 4**, the IRC does not require an interior vapor retarder (except 4C, marine). Per this Guide, a complementary water vapor control measure is recommended for Climate Zone 4 such as a Class III vapor retarder or a Class II vapor retarder with adaptable permeance (e.g., Kraft paper). In addition, drywall air sealing measures on the interior of the wall can be implemented to minimize water vapor load delivered by bulk air leakage from the interior into the cavity.

In **Climate Zones 4C and 5**, the IRC requires an interior vapor retarder. Class I or II or III are permitted by the IRC. This Guide recommends a vapor retarder with adaptable permeance (e.g., Kraft paper) for Climate Zones 4C and 5 as the preferred strategy that provides added degree of vapor diffusion control yet it provides some drying ability. In addition, drywall air sealing measures on the interior of the wall can be implemented to minimize water vapor load delivered by bulk air leakage from the interior into the cavity.

**Table 8. Interior Vapor Retarders for 2x4 walls with Exterior Insulation (R-5 or higher) in Climate Zones 3–5**

Climate Zone	Code Requirements	Best-Practice Solution(s)
3	Vapor retarder not required by the IRC	No interior vapor retarder installed
4 (except 4C)	Vapor retarder not required by the IRC	Class III vapor retarder (e.g., drywall painted with a low-perm rated paint), OR Class II vapor retarder with “adaptable” permeance (e.g., Kraft paper)
4C	Class I, II, or III required by the IRC	
5	Class I, II, or III required by the IRC	

# CAVITY INSULATIONS

Cavity insulation is an integral part of the 2x4+R-5 wall's thermal resistance contributing over half of the R-value for the system. Table 9 summarizes various types of cavity insulation products available for this wall system. All listed insulation products meet the prescriptive IRC wall insulation requirements for Climate Zones 3-5.

In addition to the R-value, vapor permeability is important in selecting cavity insulation. An insulation with a low vapor permeance (e.g., Class I or II) is not recommended for this application (see Water Vapor Management section for more information). Insulation with high, moderate, or variable permeance can be used – all insulation products listed in Table 9 have acceptable permeability properties. Note that only fiber glass batts can be purchased with an integral vapor retarder (Kraft facing). Other cavity insulation products have a higher permeability (Class III or higher). Products such as closed-cell spray foam can be used in a hybrid application serving as an air barrier and partial insulation (e.g., 2-inch or thinner coat with permeance of 1 or greater) with a permeable insulation providing the balance of the cavity R-value.

**Table 9. Common Framed Wall Cavity Insulation Options for 2x4+R5 Walls**

Insulation	Total 3.5" cavity R-value	Approx. R-value/in.	Notes	Vapor Retarder <sup>B</sup>
Fiber glass batt <sup>A</sup> with or without Kraft facing <sup>B</sup>	13	3.7		Kraft facing is Class II vapor retarder
	15	4.3		
Spray-applied fiber glass	15	4.2	Follow installation instructions for drying before enclosing	It is recommended NOT to install an interior vapor retarder for water-based spray applications
Spray-applied cellulose	13	3.8	Follow installation instructions for drying before enclosing	It is recommended NOT to install an interior vapor retarder for water-based spray applications
Cellulose (dense pack)	13	3.7		Not a vapor retarder
Mineral wool batts	14	4.0		Not a vapor retarder
	15	4.4		
Open-cell spray foam (ocSPF)	13	3.7	Serves as an effective air barrier	Not a vapor retarder but less vapor permeable than other options (~15 perm in filled 2x4 cavity)
A coat of closed-cell spray foam (ccSPF) with another permeable insulation	15.7+ <sup>C</sup>	4.5+ <sup>C</sup>	Serves as an effective air barrier	Class II at limited thickness as indicated; verify with manufacturer

<sup>A</sup> Batt insulation is most effective with a Grade 1 installation. Grade 1 batt installation requires that the insulation material uniformly fill each cavity side-to-side and top-to-bottom, without substantial gaps, or voids around obstructions (such as blocking or bridging), and be split, installed, and/or fitted tightly around wiring and other services in the cavity. To attain a rating of Grade I, wall insulation shall be enclosed on all six sides, and shall be in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity.

<sup>B</sup> Refer to Section Water Vapor Management for more details on selecting a vapor retarder.

<sup>C</sup> Based on ccSPF R-6.5 per inch and another cavity insulation at R-3.7 per inch.

## BATT INSULATION OPTIONS

Exterior foam sheathing insulation minimizes the impact of imperfections in installation of batt insulation products. While Grade I cavity insulation installation is always preferable, the performance of Grade II cavity insulation has less of an impact on thermal performance where used in combination with continuous exterior foam sheathing.

## SPRAY-APPLIED OPTIONS

Spray-applied fiberglass or cellulose products can introduce moisture into the cavity during the construction process (does not apply to binder-based spray-applied insulations that do not rely on water or dry dense packed systems). Insulation manufacturer’s installation instructions specify either a drying time and/or target moisture content before the cavity can be enclosed with drywall or a separate vapor retarder. Most manufacturers of spray-applied cellulose insulation recommend the insulation moisture content at below 20-25 percent before installing drywall and even lower (as low as 12 percent) if an interior vapor retarder is specified.

While drying the bulk of this moisture out before

enclosing the wall is important for any wall assembly, it is increasingly important as the materials enclosing the wall cavity decrease in permeance. Thus, this particularly matters for walls with exterior foam sheathing (or other low perm exterior sheathing materials or membranes) because drying to the outside is limited. Installation instructions for spray-applied insulation typically do not contain provisions specific to walls with exterior foam sheathing or other low perm materials, but rather rely on the general guidelines for all wall types. Because drying rate is reduced, the target moisture content for cavity insulation may need to be lowered from the levels established for a standard wall without a vapor retarder. (It is noted that the drying rate also depends on the time of year.)

Because neither Class I nor Class II interior vapor retarders are required for 2x4+R-5 walls in Climate Zone 3–5, it is recommended to either install a Class III interior vapor retarder or NOT to install any interior vapor retarder (where permissible, e.g., CZ 3) in walls with spray-applied cavity insulation to facilitate drying to the inside.

After the cavity is enclosed with drywall, the drying will slow down significantly and the moisture will continue to be absorbed by the WSP sheathing

**Table 10. Installation of Spray-Applied Cavity Insulation in Walls with Exterior Foam Sheathing**

Season	Insulation Moisture	Construction Moisture
Winter	The direction of vapor drive in the winter is from the inside out. Therefore, after the insulation is enclosed, winter drying will nearly come to a halt. If the house is not heated and ventilated to reduce indoor RH, drying cannot take place	There can be a substantial source of construction moisture in the air from fuel burning heaters and from concrete and other construction materials. It is recommended to use electric heaters and supplemental ventilation (if house is already air sealed) to maintain a reduced indoor relative humidity in the house to facilitate drying.
Summer	The direction of the vapor drive is toward the interior of the house. This condition is preferred for accelerated drying.	There can be a substantial source of construction moisture in the air from concrete and other materials. It is recommended to control the RH inside the building to accelerate overall drying in the building via dehumidifiers and/or operating house AC. In humid or mixed-humid climates, the relative humidity load will be added from the outdoor conditions.
Spring/ Fall	During the seasonal transition period, the drying will slow down compared to the summer.	In many locations, the relative humidity during the transition period may be lower than during summer helping with the drying.

and framing and drywall. Because the moisture absorbed by the WSP does not have an immediate path for escape, any excessive moisture remaining in the insulation can result in WSP moisture contents above critical levels (20+ percent) and can lead to wood sheathing panel expansion and buckling. Sustained moisture levels above 20-24 percent can lead to durability issues in wood-based products. Table 10 summarizes considerations for installation of damp-spray-applied insulation in walls with exterior foam sheathing by the season.

## **OPEN-CELL SPRAY FOAM**

Open-cell spray foam cavity insulation can be used in walls with exterior foam sheathing because it has high permeability and allows drying to the interior. A benefit of the open-cell spray foam is that it is an effective air barrier that seals the cavity from outdoor air and prevents indoor air from reaching the sheathing (potential condensing surface). The use of exterior foam sheathing does not have an impact on installation practices for open-cell spray foam in wall cavities.

# **CLADDINGS**

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The fastening schedule for attaching cladding through the foam depends on the following factors:

- Fastener type and size
- Stud spacing
- Insulation thickness
- Cladding weight and thickness

Because of the added thickness of the foam material, a longer fastener is required to meet the minimum penetration into the framing. To compensate for the longer (more flexible) nail, a more stringent fastening schedule is typically required as compared to conventional walls that don't use foam. Fasteners should have a larger diameter or installed following a closer spacing or both.

Tables 11 through 17 provide attachment specifications for walls with exterior foam sheathing for a range of claddings including vinyl siding, fiber cement lap siding, wood siding, anchored veneer, and stucco.

**Table 11. Vinyl Siding Attachment over Foam Sheathing<sup>ABC</sup>**

Stud Spacing <sup>D</sup>	Min. Nail Diameter <sup>E</sup>	Min. Nail Length	Attachment to Stud
16" or 24"	0.113"	2-3/8 (1" foam sheathing) 2-5/8 (1.25" foam sheathing) 2-7/8 (1.5" foam sheathing)	One nail at each stud through the nail hem

<sup>A</sup> Siding panel width not to exceed 12 in. (i.e., maximum vertical spacing along the stud is 12 in.).

<sup>B</sup> Where siding manufacturer's installation instructions require a more stringent attachment schedule, the installation instructions must be followed.

<sup>C</sup> Use of staples must follow the schedule provided by the staple manufacturer and/or siding manufacturer, as applicable.

<sup>D</sup> Select the vinyl siding product rated for the stud spacing.

<sup>E</sup> Based on the minimum penetration of 1-1/4" into the wood (WSP plus stud) and 1/32" allowance to provide clearance between the vinyl siding and the sheathing required by the installation instruction to accommodate dimensional changes in the vinyl due to temperature swings and to avoid buckling. Minimum nail length is rounded up to the nearest 1/8" (and to allow for house wrap thickness if installed).

**Table 12. Vinyl Siding Attachment through Foam to WSP<sup>A</sup> – Stud Penetration Not Required<sup>B</sup>**

Vinyl Siding Width (Exposure), in.	Maximum Spacing of Fasteners <sup>CD</sup>				
	Ring shank roofing nail (0.120" min dia.)	#6 screw (0.138" min dia.)	Ring shank nail (0.148" min dia.)	#6 screw (0.164" min dia.)	Smooth shank roofing nail (0.120" min dia.)
7	20	20	25	27	5.0
8	18	18	22	24	4.5
9	16	16	20	21	4.0
10	14	14	18	19	3.5
12	12	12	15	16	3.0

<sup>A</sup> Thicker WSP is permitted.

<sup>B</sup> Other lap siding products up to 3 psf can be attached using the same schedule if permitted by the siding manufacturer.

<sup>C</sup> Fastener length must be sufficient to penetrate the back of the WSP panel by 1/4 in.

<sup>D</sup> Minimum fastener lengths based on 7/16" WSP:

- 1-7/8" (1" foam sheathing)
- 2-1/8" (1.25" foam sheathing)
- 2-3/8" (1.5" foam sheathing)

**Table 13. Fiber Cement Lap Siding Attachment over Foam Sheathing <sup>AB</sup>**

Stud Spacing	Min (Max) Nail Diameter	Min Nail Length <sup>DE</sup>	Max Nail Spacing (Along Stud)
16" or 24"	0.113" (0.131") <sup>C</sup>	2-5/8 (1" foam sheathing) 2-7/8 (1.25" foam sheathing) 3-1/8 (1.5" foam sheathing)	One nail at each stud at the top edge of the plank

<sup>A</sup> For fiber cement siding thickness 5/16" or less (or up to 3 psf).

<sup>B</sup> Where siding manufacturer's installation instructions require a more stringent attachment schedule, the installation instructions must be followed.

<sup>C</sup> Maximum diameter is based on the maximum nail diameter found in manufacturers' installation instructions for fiber cement lap siding. Larger diameter can be used if permitted by the siding manufacturer. The smallest diameter permissible should be preferred to avoid fracturing the siding material.

<sup>D</sup> Based on the minimum penetration of 1-1/4" into the wood (WSP plus stud) and 5/16" siding thickness. Minimum nail length is rounded up to the nearest 1/8".

<sup>E</sup> Longer nails may be required for trim installation.

**Table 14. Examples of Standard Nail Sizes (ASTM F 1667) for use with Siding over Foam Sheathing**

Nail Type	Designation	Shank Diameter, in.	Length, in.
Box (Style 4A)	9d	0.113"	2-3/4"
	10d	0.128	3"
	12d	0.128	3-1/4"
Cooler	9d	0.113"	2-3/4"
Sinker	10d	0.128	3"
Common (Style 10)	12d	0.128	3-1/4"

**Table 15. Vertical Furring Attachment over Foam Sheathing for Wood or Fiber Cement Lap Siding<sup>A</sup>**

Stud Spacing	Min Fastener Diameter	Max Fastener Spacing (Along Stud)	Min Fastener Length <sup>B</sup> for 1x (3/4") furring <sup>C</sup>	Min Fastener Length <sup>B</sup> for 2x (1-1/2") furring <sup>C</sup>
16" or 24"	0.131" nail	16"	3" (1" foam) 3-1/4" (1.25" foam) 3-1/2" (1.5" foam)	3-3/4" (1" foam) 4" (1.25" foam) 4-1/4" (1.5" foam)
16" or 24"	No.10 wood screw	24"	2-3/4" (1" foam) 3" (1.25" foam) 3-1/4" (1.5" foam)	3-1/2" (1" foam) 3-3/4" (1.25" foam) 4" (1.5" foam)

<sup>A</sup> For cladding weight up to 3 psf.

<sup>B</sup> Based on the minimum penetration depth into the wood (WSP plus stud) of 1-1/4" for nails, or 1" for screws, furring thickness, and foam thickness.

<sup>C</sup> Consult siding manufacturer instructions for fastener penetration requirements to determine the furring thickness required.

**Table 16. Anchored Veneer over Foam Sheathing<sup>ABCDEF</sup>**

Stud Spacing	Metal Tie Maximum Vertical Spacing (along stud) (see Figure 26)	
	Standard Conditions	High Seismic or High Wind Conditions
16"	24"	18"
24"	16"	n/a

<sup>A</sup> For the purpose of this table, high seismic is defined as SDC D0 or higher for one- or two-family dwelling, or SDC C or higher for townhouses.

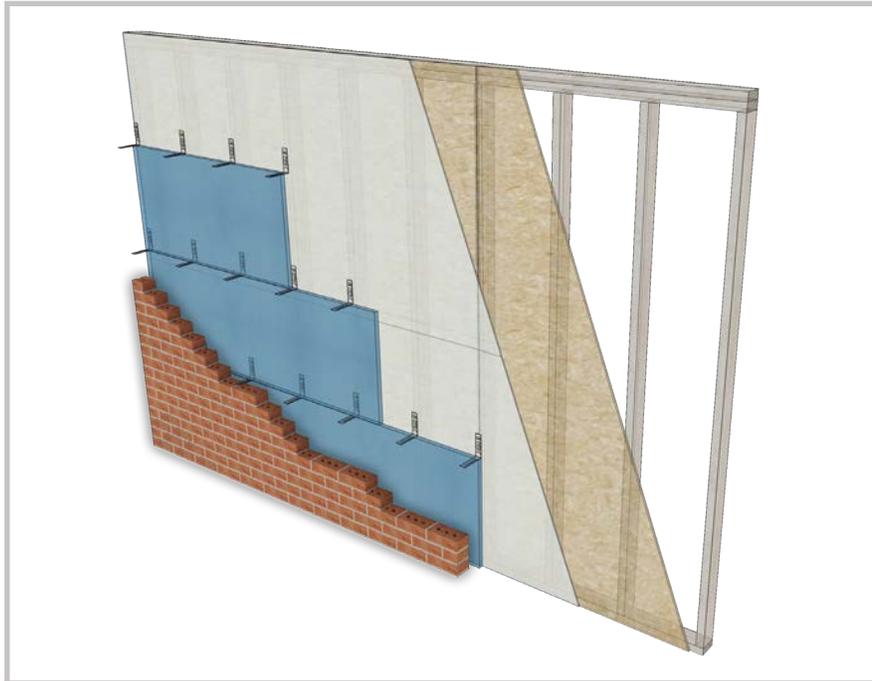
<sup>B</sup> For the purpose of this table, high wind is defined as wind pressure above 30 psf on the surface of the wall. Refer to 2015 IRC Table R301.2(2) for wind pressures. For Exposure B, 30 psf wall pressures occur at wind speeds above 110 mph.

<sup>C</sup> Metal ties are attached to WSP with the nail penetrating the framing. A minimum of one 8d common nail is used per each tie. Longer fasteners may be required to obtain equivalent penetration into framing when fastening metal ties through foam sheathing (ties mounted on top of the foam sheathing surface).

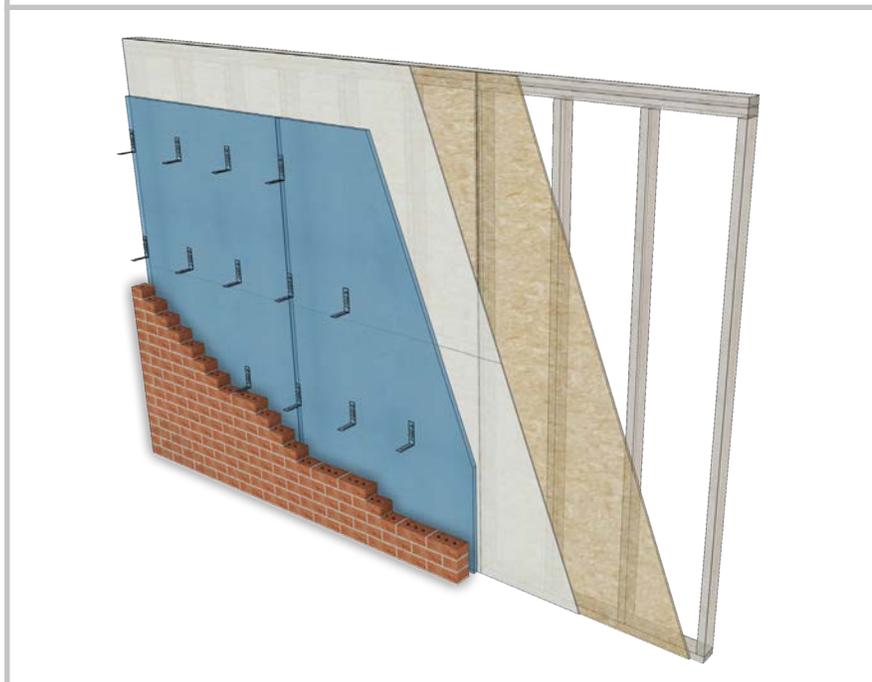
<sup>D</sup> Metal ties extend into the grout by no less than 1-1/2 in. with no less than 5/8-in. mortar cover to the outside.

<sup>E</sup> Follow tie manufacturer instructions for the selection of ties for the application.

<sup>F</sup> The 2018 IRC will allow metal ties attached to WSP only (not required to be attached to framing).



(a) Brick ties installed before foam sheathing



(b) Brick ties installed over foam sheathing

**Figure 26. Anchorage of brick veneer in walls with foam sheathing.**

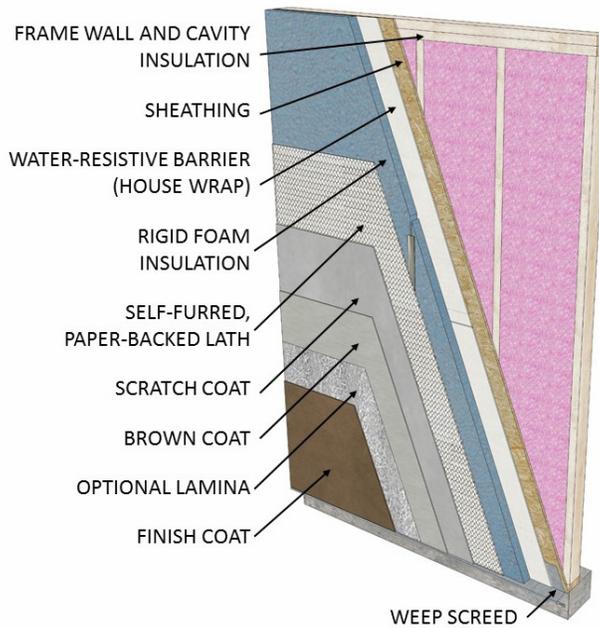
**Table 17. Stucco over Foam Sheathing – Metal Lath Attachment<sup>AB</sup>**

Stud Spacing	Min Nail Diameter	Max Nail Spacing (Along Stud)	Min Nail Length <sup>C</sup>
16"	0.113" (1" foam) 0.120" (1.25"–1.5" foam)	8" (1" foam) 6" (1.25"–1.5" foam)	2-1/2" (1" foam) 2-3/4" (1.25" foam) 3" (1.5" foam)
24"	0.131" (1" foam) 0.162" (1.25"–1.5" foam)	6" (1" foam) 8" (1.25"–1.5" foam)	

<sup>A</sup> For stucco cladding weight up to 11 psf.

<sup>B</sup> Follow manufacturer instructions where a more stringent attachment schedule is required.

<sup>C</sup> Based on the minimum penetration depth of 1-1/4" into wood (WSP plus stud), 1/4" for self-furred metal plaster base, and foam thickness; add length for rain-screen or drainable WRB as required.



**Figure 27. Example configuration of 3-coat stucco over foam sheathing**

# FIRE CONSIDERATIONS

In one- and two-family dwelling in the scope of the IRC, the following requirements apply to rigid foam sheathing materials in exterior wall applications installed over WSP sheathing:

1. **Flame-spread index of not more than 75**
2. **Smoke-developed index of not more than 450**
3. **Separated from the interior of a building by 1/2-inch gypsum board (or other acceptable thermal barrier material)<sup>8</sup>**

Standard wall assemblies using properly-labeled foam sheathing products meet these requirements without any special measures or detailing. It should be noted that 7/16-inch WSP backing is not sufficient to provide the required thermal barrier; therefore, 1/2-inch gypsum board (or other approved thermal barrier) is always required on the interior face where foam sheathing products are used in an exterior wall.

## FIRE SEPARATION DISTANCE LESS THAN FIVE FEET

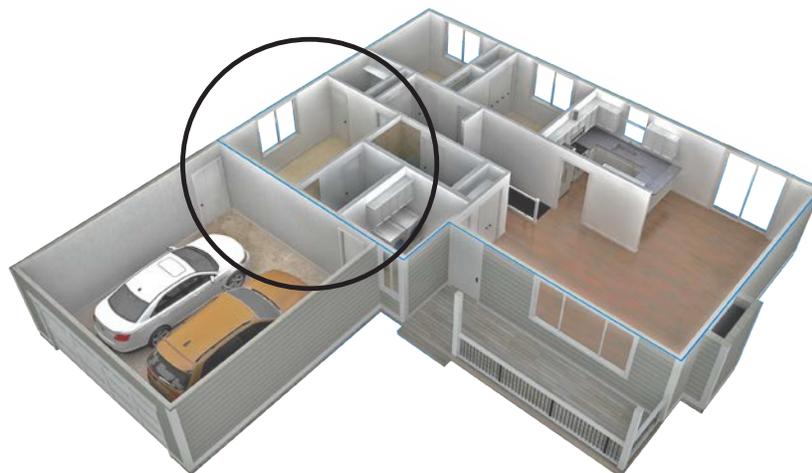
Where the fire separation distance between dwelling units is under 5 feet, the IRC requires

the exterior wall to have an exterior side 1-hour fire resistance rating. For dwellings with a code-compliant fire sprinkler system, the minimum fire separation distance requirement is reduced to 3 feet for requiring a 1-hour fire resistance rating. As with any other wall system, walls with exterior rigid foam will require an additional layer(s) of material(s) (e.g., gypsum sheathing) to achieve a 1-hour fire rating. Approved fire-rated assemblies can be found via websites for Underwriters Laboratories (UL), USG, Gypsum Association, and other industry organizations. Applicability of a specific wall system to meet the 1-hour fire rating should be evaluated by the local code official and the design professional of record, if required.

## DWELLING-GARAGE SEPARATION IN ATTACHED GARAGES

Where the house includes an attached garage, the IRC requires a 1/2-inch gypsum board or equivalent be applied on the garage side of the wall separating the garage from the dwelling unit (Figure 28).

If the attached garage is conditioned (garage is inside of the building thermal envelope), the exterior garage walls will provide the full insulation



**Figure 28. Dwelling-garage separation**

<sup>8</sup> In some applications such as a gable roof attic end-walls, an ignition barrier may be required and the same OSB sheathing used on the walls of the building can be used for that purpose. Also, some foam sheathing products have been tested and approved for certain applications without an ignition or thermal barrier; the foam sheathing manufacturer should be consulted for more information.

value and the wall separating the garage from the dwelling can be a standard 2x4 or 2x6 wall sheathed with 1/2-inch gypsum on both faces.

If the attached garage is outside of the building thermal envelope (garage is unconditioned), the separation wall must meet both requirements: (1) minimum R-value and (2) fire separation provision. In addition, the separation wall often serves as a braced wall and must meet requirements for sheathing type and sheathing attachment to framing. The following options are available to builders in this situation:

### Option 1 – The Separation Wall Includes Foam Sheathing

The separation wall is constructed in the same manner as the exterior walls except gypsum is added on the garage side in lieu of siding (see Figure 29). **Wall Construction:**

- o 1/2" Gypsum Wallboard (dwelling side)
- o 2x4 Stud Spacing at 16" oc and cavity insulation
- o 3/8"-1/2" WSP
- o 1" Foam Sheathing
- o 1/2" Gypsum Wallboard (garage side)

On the garage side, gypsum is attached to framing through foam sheathing using longer fasteners. The attachment should follow the same pattern and minimum penetration into



Figure 29. Garage wall with exterior foam

framing used for interior gypsum board. The provisions for attachment of cladding of the appropriate weight over the foam can be followed instead (refer to section on Claddings). The attachment of gypsum using adhesive (to the surface of the foam sheathing) is not applicable for this wall configuration because it will negate the fire-resistance rating of the gypsum finish. Furthermore, the attachment of foam sheathing to the wall is not intended to resist the additional load from the gypsum. Finally, where the separation wall is not required to serve as braced wall, the WSP layer can be omitted and the foam sheathing can be attached directly to framing.

### Option 2 – The Separation Wall is Cavity-Insulation-Only

A standard 2x6 wall with cavity insulation and gypsum wallboard attached directly to framing on both faces of the wall is another practical option for complying with the separation wall requirements (see Figure 30). The double sided gypsum wall will act as an interior braced wall, provide the fire separation, and reach a nominal R-value of R-20 or higher. For more information on 2x6 walls, refer to Part I of the Guide. **Wall Construction:**

- o 1/2" Gypsum Wallboard (dwelling side)
- o 2x6 Stud Spacing at 16" oc and cavity insulation
- o 1/2" Gypsum Wallboard (garage side)

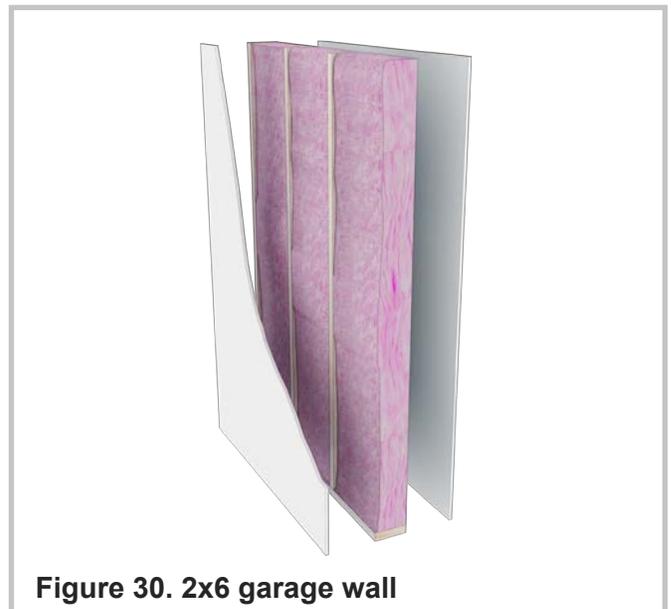


Figure 30. 2x6 garage wall

# TERMITE PROTECTION

The IRC requires the foundation wall be extended by 6 inches above the finished grade for all geographic locations and all wall types regardless of insulation method. The only exception to this rule is walls with masonry veneer, in which case the clearance can be reduced to 4 inches.

For above-grade walls with exterior foam sheathing insulation, the IRC includes an additional requirement for buildings located in the “very heavy” termite infestation probability zone (see Figure 31 for Termite Infestation Probability Map) to provide the minimum 6 inch clearance regardless of the cladding.

Note that Climate Zone 3 (see Figure 2)—the southern-most climate zone where R-13+ walls are required by the prescriptive path of the IRC—overlaps with the “very heavy” zone in multiple states including regions in California, Texas, Louisiana, Mississippi, Alabama, Georgia, and South Carolina. Masonry veneer is a common cladding of choice in these markets. Builders transitioning to this wall system should review their practices to ensure compliance with the minimum 6-inch clearance requirement (Figure 32).



Figure 31. Termite Infestation Probability Map

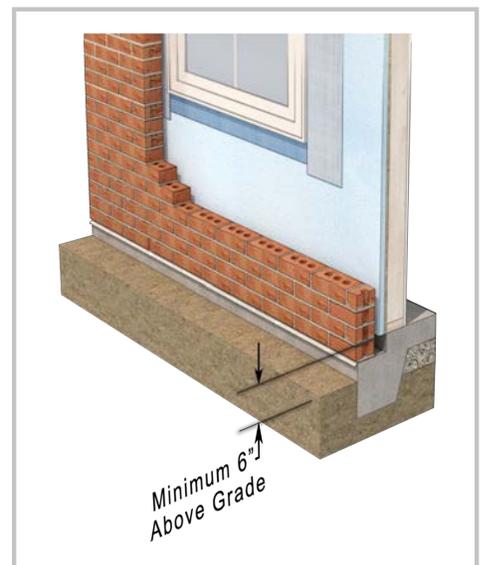


Figure 32. Minimum 6-inch clearance in the ‘very heavy’ termite zone.

# INSULATING AND AIR SEALING RIM JOIST AREAS

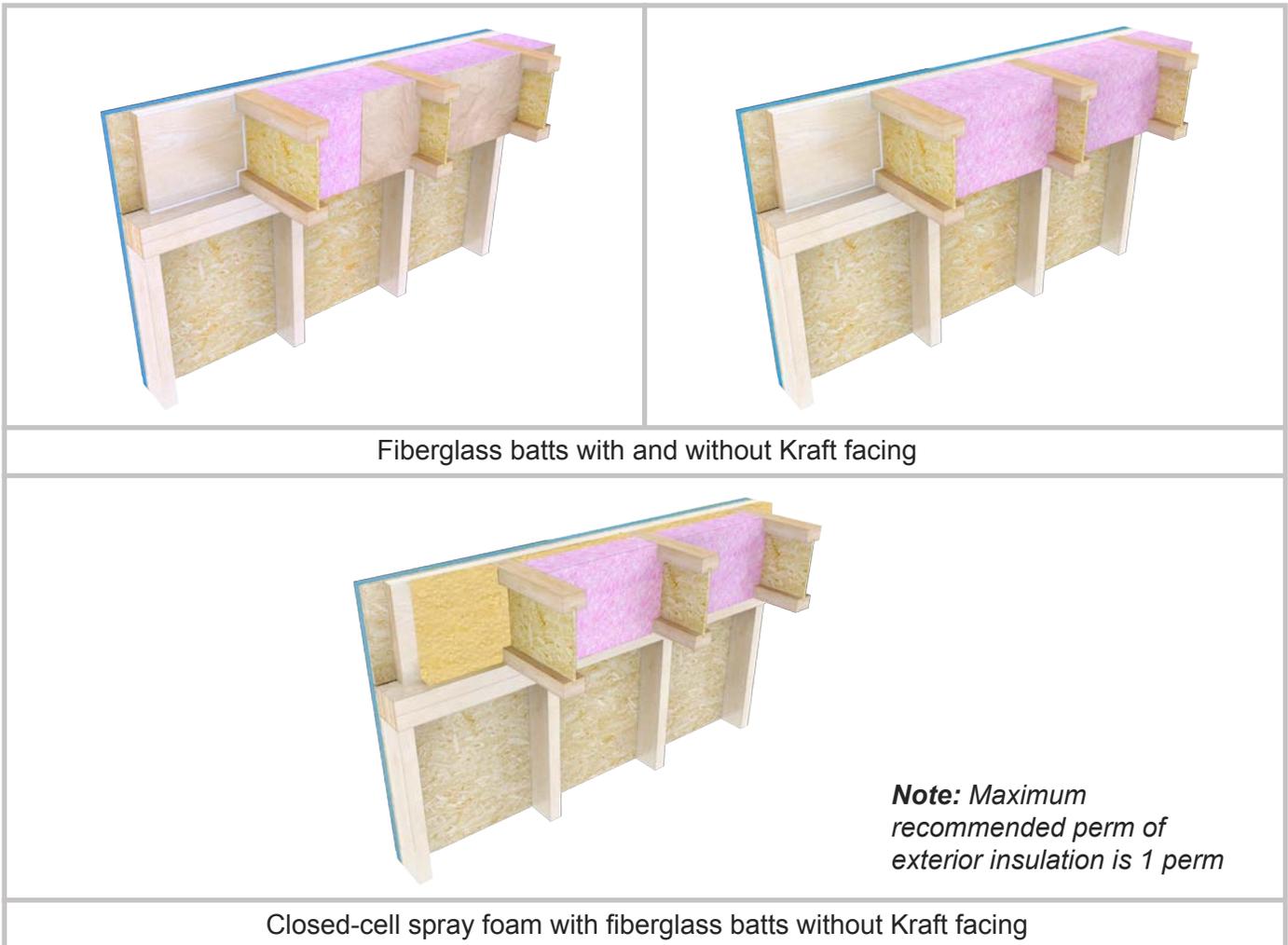
Rim board areas are required to be insulated to the same level as the wall – R-13+5 (or R-20) for Climate Zone 3-5. To achieve R-13 inboard of the rim, it is common practice to use fiberglass batt insulation with Kraft facing (or another vapor retarder facing) or fiberglass insulation without a facing (Figure 33). Mineral wool batt or board insulation can also be used at the rim.

Because exterior insulating foam sheathing outboard of the rim joist limits drying potential, it is not recommended to install interior insulation materials with low permeability so as to avoid a double vapor barrier condition. Where products such as closed-cell spray foam are used, it is recommended that the

coat thickness is limited such that the total permeance of the insulation coat meets Class III vapor retarder (~1 perm or greater). For example, closed-cell spray foam at less than 2 inches in thickness results in a permeance of more than 1 perm (generally 2 inches of ccSPF correspond to about 1 perm). (Permeance for the specific material/product should be requested from the product manufacturer.) In this application, the remaining balance of the R-value can be provided with unfaced batt insulation. As another option, if exterior foam sheathing with a moderate permeability is used (Class III) -- closed-cell spray foam on the interior of the rim joist can be used to provide the total required R-value. See the section on vapor barriers for additional discussion on this subject.

The IRC requires the rim joist to be part of the wall's air barrier. Minimizing air flow through the rim will help meet building air tightness requirements, improve performance of cavity batt insulation, and reduce potential for wall moisture problems. Air sealing the rim area can be achieved by one of the following strategies:

- Caulking horizontal and vertical joints at the interior face of the wall. The horizontal joints make up the larger leakage area. Sealing the vertical joints at the edges of the floor joists is a best practice to further reduce air flow at the rim.
- Relying on the taped and sealed exterior foam sheathing (see section on Air Barriers for more detail)
- Using a sprayed coat of air-impermeable material (e.g., spray ccSPF)
- A combination of the above measures.



**Figure 33. Insulating Rim Joists**

