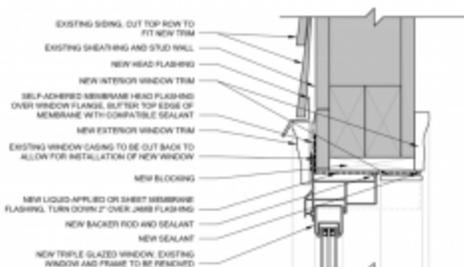


# Window Installation Guide



*Windows are big holes in walls that must be sealed against wind, water, and heat. This guide tells you what to think about, how to install them, and why doing it right matters.*

Window technology has come a long way toward energy conservation, comfort, maintenance, and ease of use. Pretty soon, windows will be a power source. In spite of the technological advances, installation is the most important aspect.



## DETAILS: WHAT TO THINK ABOUT

Innie vs. Outie Sill Details for Thick Foam

Sill, Head, and Jamb Details for New Windows in Old Holes

## VIDEOS: HOW TO DO IT

- Three Ways To Flash An Innie
- Installing European Windows
- Installing A Flanged Window To Replace An Old One



- The Least Invasive And Most Affordable Option For Window Replacement



## ARTICLES: WHY IT MATTERS

Window Retrofit—From the RO, Out

Window Replacement Options For Remodelers

The Pen Test For Air-, Water- And Thermal-Tightness

### <building code>

- 2012 IRC: N1102.3.6 (R402.3.6) Replacement fenestration
- 2012 IECC: R402.3 Fenestration (Prescriptive)

### </building code>

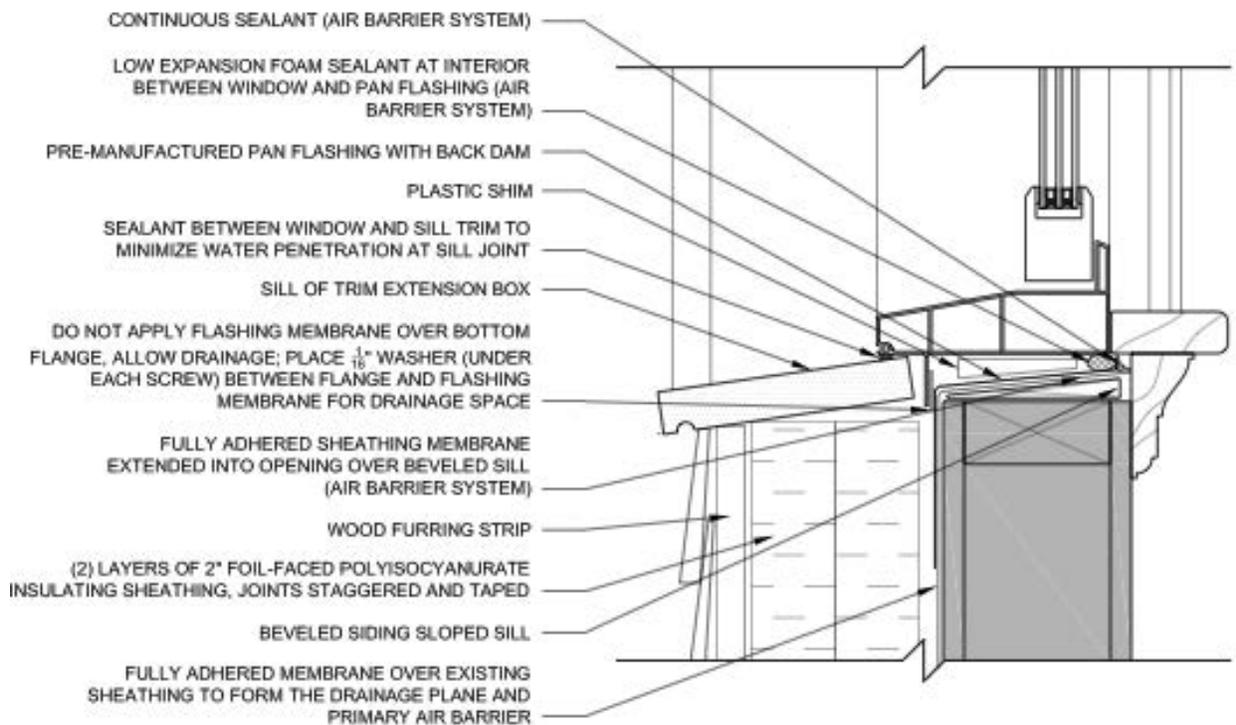
### More to explore:

1. Building America Solutions Center's [Complete Window Replacement Guide](#) (16 pages, public domain)
2. [ASTM's 2112 Standard Practice for Installing Windows, Doors, and Skylights](#) (87 pages, \$82)
3. [NREL's Measure Guideline on Wood Window Repair and Replacement](#) by Peter Baker at Building Science Corporation (94 pages, public domain).
4. [Moisture Control Guide](#) from EPA.gov/iaq/moisture

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DETAILS // WRB And Flashing, Windows, Doors, Skylights

# Innie vs. Outie Sill Details for Thick Foam



## The WRB is a BFD when choosing where to put the window

These architectural details are from *Measure Guideline: Wood Window Repair, Rehabilitation, and Replacement* by Peter Baker, PE.

They show how to integrate a new window into an old wall without introducing new water leaks or air leaks. In this case, four inches of foam was added to the outside; these details show how to set a window to the inside or the outside (innie or outie).

Either one is fine and each has its own charm.

- An innie is easier to incorporate into an existing drainage plane *behind* the exterior insulation
- An outie is easier to incorporate into a drainage plane *in front of* the exterior insulation.

So, the WRB is pretty much the decider.

### Other considerations:

- Innies set the windows into a recess, which protects windows from the weather.
- Outies add deep window sills—great for plant shelves, cat perches, and bowling trophies.

What all of these details have in common is that there is a continuous air barrier, a continuous water barrier, and a continuous thermal barrier for the wall.

Don't know what that is? **Take the Pen Test**

## Sources:

1. Building America Solutions Center's [Complete Window Replacement Guide](#) (16 pages, public domain)
2. NREL's [Measure Guideline on Wood Window Repair and Replacement](#) by Peter Baker at Building Science Corporation (94 pages, public domain).

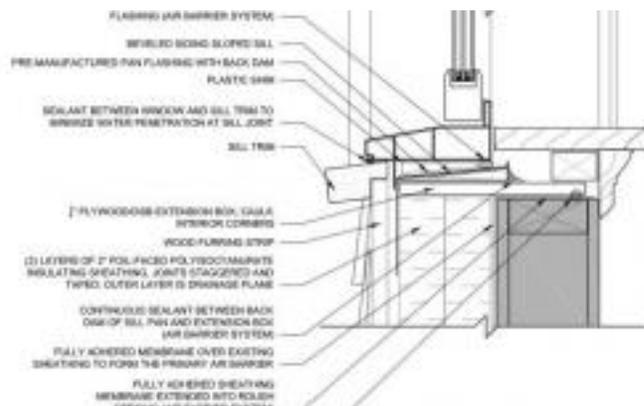
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2012 IRC: N1102.3.6 (R402.3.6) Replacement fenestration

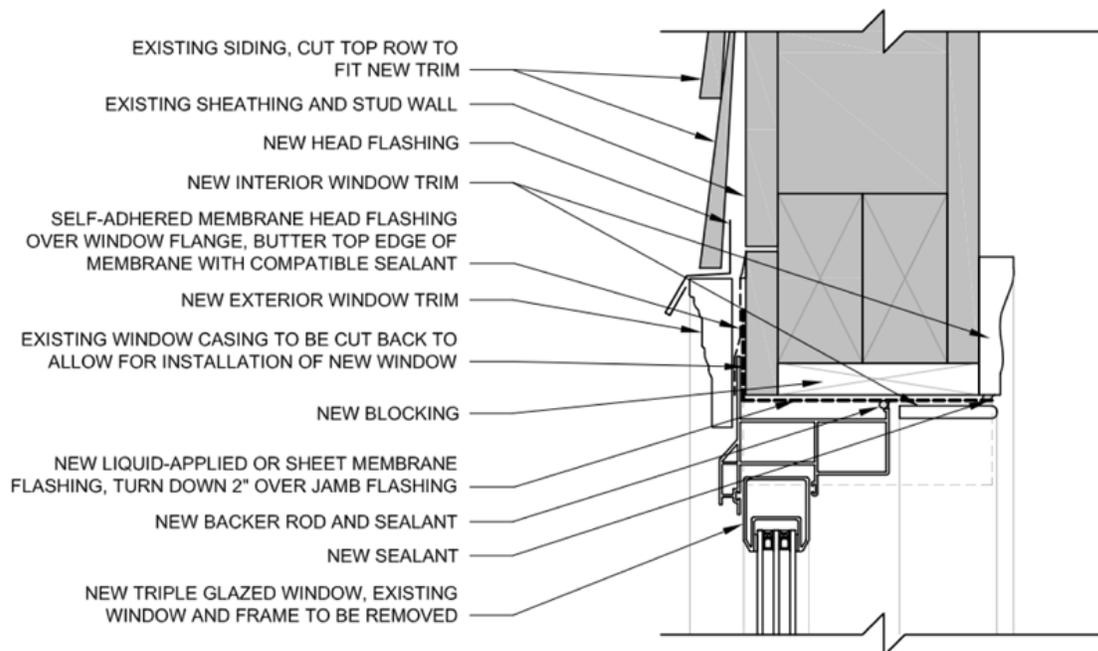
2012 IECC: R402.3 Fenestration (Prescriptive)

`</code>`

## Slideshow:



# Sill, Head, and Jamb Details for New Windows in Old Holes



**Integrating a new drainage plane into an existing one is not as easy as it looks on a phone, but you've got to start somewhere, right?**

These architectural details are from *Measure Guideline: Wood Window Repair, Rehabilitation, and Replacement* by Peter Baker, PE.

They illustrate one way to successfully integrate a new window into an old wall without introducing water or air leaks. These detail drawings are for a slightly smaller window, so there is 3/4 inch padding on the sides and top and beveled padding on the bottom.

## How to do it:

- Caulk the window flanges to the wall on the sides and top, but not on the bottom.
- After the window is fastened into place, cover the side flanges with flashing tape.

- At the top, lift the building paper and tape the top flange, then lay the building paper back over the taped top flange.
- Leave the bottom untaped so that water can escape.
- Air seal the inside with low-expansion canned foam.

If new siding is within the scope of work, then reframe the opening as needed and install windows as you would in a new house—basically the same as explained earlier, but without padding the opening or tying into buried building paper.

If exterior foam is part of the package, you'll need to fashion some sort of jamb extension, either inside or out, to accommodate the thicker wall. That means **you have to pick between innies and outies**: Either one is fine and each has its own charm.

### Other considerations:

- Innies set the windows into a recess, which protects windows from the weather.
- Outies add deep window sills—great for plant shelves, cat perches, and bowling trophies.

What all of these details have in common is that there is a continuous air barrier, a continuous water barrier, and a continuous thermal barrier for the wall.

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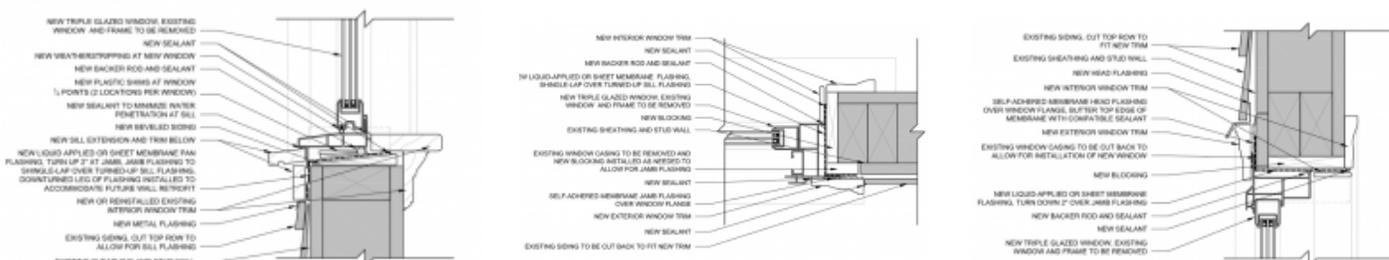
<code>

2012 IRC: N1102.3.6 (R402.3.6) Replacement fenestration

2012 IECC: R402.3 Fenestration (Prescriptive)

</code>

### Slideshow:



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**VIDEO** // WRB And Flashing, Windows, Doors, Skylights

# Three Ways to Flash an Innie

**Flashing a window opening in a "thick" wall—deeper than 6 inches—is a critical step in preventing bulk water intrusion. You can do it using either stretchable or non-stretch flashing tape.**

As part of the renovation to a 1970's raised ranch, the energy performance is being significantly improved. Triple-glazed windows are being installed and four inches of rigid foam insulation will blanket the walls and roof.

In thick walls like this, windows can be installed to the inside or outside, called "innies" and "outies," respectively.

These three videos are about innies.

## 1/ How to Flash an Innie with Non-Stretch Tape



## TRANSCRIPT:

The first steps in the process involve prepping the rough opening. The carpenters have to fill in the extra pieces above the window to flush things out.

Dave: "We like to install windows over a sloped sill, so we use beveled siding. I'll put a couple of nails in there to hold it in place because we will be shimming the window on this and putting a peel-and-stick membrane on it."

Some tapes can stretch around corners, but Dave's going to demonstrate with a standard, non-flexible flashing tape.

Dave: "You see there's a little piece of plastic inside, like a fishing line."

First, he splits the release sheet.

Dave: "Pull that out."

He works from the center out to either side, keeping the flashing tape along the inside edge of the window.

Dave: "Later on we're going to put 4 inches of foam on this house. So we'll put another piece [of flashing] on; we want to be able to go out over the 4 inches of foam and turn down."

Now we can cut the tape—not quite all the way, which leaves a little bit to stretch.

Dave: "I'm putting 2 inches to the outside and the rest is going inside."

[INSTANT REPLAY]

Dave wraps the corner, putting only as much peel-and-stick inside the rough opening as the depth of the window. He cuts the bottom, but again not tight to the corner so he can bend the tape around.

Dave: "The corner is the weakest point—and we've crossed it twice. Then we can put another little piece on that will go over it again. Even though this would be kind of like a reverse-flash, it is already flashed. It's not really a reverse-flash."

We're giving the corner, the weakest point, triple coverage.

## 2/ How to Install Pan Flashing With Stretchable Tape



David: We like to install windows over a sloped sill ...

Dan: ... and then they use some sort of flashing tape to protect the sill plate. In this video, we're going to focus on using a stretchable tape. John starts at one end—folding it up the jack studs about 2 inches—and works his way to the other end ... making sure to wedge it tightly into the corners.

David: "On this, we have a pan flashing, but we also need another flashing that will go out over our foam afterward."

Dan: Because the stretchable tape doesn't have a split release paper, they stick another section of flashing tape to the exposed sticky edge so that it will span the exterior foam.

### 3/ A Hybrid approach to pan flashing: Stretchable and Non-Stretch Tapes



This is a hybrid approach to pan flashing from Dave Joyce and John Albert of Synergy Construction. It uses both standard non-stretch flashing tape and a stretchable tape.

It begins, as always, with a sloped sill.

Then John applies square pieces of stretchable tape to the corners.

Next, he cuts the flashing tape top length and removes one side of the release paper.

Working from his left to right, John applies the flashing tape to the sill, turning up the edges a couple of inches at each end.

Because the corner is already flashed, you can just cut straight up, allowing the bottom flap to be applied to the exterior foam when that is added later.

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# Installing European Windows



## OFFICIAL TRANSCRIPT:

The first step to installing any window is to prep the rough opening.

This includes patching the sheathing, double-checking the measurements, and making sure that water can drain out.

**David Joyce:** "We like to install windows over a sloped sill, so we use beveled siding."

After the opening is flashed for protection against water leaks, prep the window.

These are European triple-glazed vinyl windows. They use brackets to secure the window to the framing.

They also have optional flashing flanges which help align the windows in the opening.

*[Editor's note: the flanges are not nailing flanges. They are an option for North American builders because we are used to flashing windows to the nailing flange. If anyone has video of flashing a European window without flanges, please share.]*

With the brackets in and the flanges on, it's time to put the window in the hole.

Triple glazed units are heavy; for large windows, it makes sense to remove the sash before installing. The bottom of the window is slipped into the opening ... and the top is angled in. In the case of this large bank of windows, it is important that the windows are in line with adjacent windows.

So the crew makes sure the numbers are consistent.

But alignment is also important for windows that are spaced farther apart. Siding and trim boards will have to line up with the sills and heads, so its worth getting them aligned correctly now. And to double-check with a laser.

When the windows are plumb, level, square, and perfectly aligned with other elements, they are fastened in the opening.

The flashing flanges do a good job of helping to hold the window in place ... while the brackets are fastened.

Dave shims between the bracket and the framing to keep the bracket at a right angle to the window. The shims also allow for a little bit of adjustment if one of the brackets is installed too snug. Now it's time to install the hardware.

**David:** *"The handle is really simple. A little piece of plastic covers the screws, turn it to the side and the screws are there. Slide it right in, feel where they start. You could do it with an impact driver or a drill, but then, you might end up stripping a screw or breaking a little plastic clip because you don't feel the snugness of it. Whenever you're installing a door handle or a window handle, it should probably be done by hand."*

*The opening mechanism has a pin in here, you just push it over, and it opens up the rest of the way."*

*—Thanks to David Joyce and Synergy Construction for letting us shoot video on their jobsite.*

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VIDEO // Windows, Doors, Skylights

# Installing a Flanged Window to Replace an Old One



If you need to replace windows that are old, inefficient, leaky, or painted shut, maybe even rotted, this video's for you

The start to finish steps to replace an entire window in your house (OFFICIAL TRANSCRIPT)

## **Remove the trim gently**

The first step in removing those old windows is to score the trim on the inside and the out and use a small prybar to gently remove that. We want to try to use that trim later.

## **Remove the window with a Sawzall**

The window itself is going to come out pretty easily, you're going to use a sawmill to cut down the jambs of that window, you're going to cut those nails and the window will pop right off. If you have a

flanged window, again, use that Sawzall, maybe even with a metal-cutting blade, and the window will come right out.

## Install pan flashing

We're going to protect the sill of this window with one of my favorite products, DuPont FlexWrap.

Before we do this, though, we always want to slope the sill to get some positive drainage to the outside. Then when the FlexWrap goes in, we're making a bathtub for that window to sit in.

We're going to capture any water that might get in from that window and make sure it goes to the outside of the building and not inside where it could rot or mold on the inside of the framing.

This 1950s house when it was built didn't have any insulation, and when the windows leaked into the wall cavity they could dry. But with today's energy codes and the insulation and the air tightness we are doing on our houses, we have very little capacity for our homes to leak and not have mold or rot problems in the future.

## Put the window in the hole

Now that we're got that sill in place on this opening, we're going to pop in the new window. We're using a flanged window in this case, which is similar to a new-construction window. If we didn't have the room—let's say if we were in a brick situation on the outside—we could fold those flanges in and screw through the jamb.

- It is very important to pay attention to plumb and level, and square on these new windows. Make sure you check the operation as you're installing them—very important,
- On the outside of the window, we're using a three-sided bead of caulk—basically an upside-down U—we're not caulking the bottom side of this window so that if any water were to get in, it can find its way out.
- After the window is in place and nailed off, we're going to go over that with another Tyvek product, called DuPont StraightFlash. If I didn't have a one-story house like this, I'd make sure to add a metal head flashing.

As you can see, it is really not a difficult process, but you really need to be a good craftsman and make sure that you're thinking about the waterproofing details.

## One last thing:

In my 20 years of building and remodeling, 99 percent of the window leak issues I've seen are totally install errors. Pay attention to the waterproofing details that we talked about.

—Matt Risinger is a custom builder, remodeler, and YouTuber in Austin Texas

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VIDEO // Windows, Doors, Skylights

# The Least Invasive and Most Affordable Option for Window Replacement



Sash and jamb liners can make a house better for a reasonable cost

The window replacement world boils down to four main options:

- Go down to the studs and replace everything
- Slide a new window into the old frame
- Replace the sash using airtight(ish) jamb liners
- Historic restoration

This video is about replacing sash using energy efficient jamb liners: the least invasive, most affordable, and probably the least effective method from an energy standpoint. But energy performance is not always the driving factor. Sometimes you just need to make an OK house better.

Replacement sash may make sense if the existing window frame is level, square, and in very good shape, showing no signs of water damage. If the window frame is integrated into the wall well so that no water leaks in, why mess with it?

If the house is in San Francisco, it sort of reduces the whole energy performance thing. Because perfect weather.

### **Here's how to do it:**

- Remove the existing sash and stops.
- Remove the pulleys and weights from the old double-hung windows.
- Fill the weight pocket with low-expansion spray foam to insulate and air seal the cavity.
- Snap new jamb liners into metal brackets mounted to the old jambs.
- Snap new sash into the jamb liners and tilt into place.

### **Source:**

BlueHouseEnergy.com via Building America Solutions Center

– [Building America Solution Center](#) is an online tool that collects best practice recommendations from the country's top building science and home building experts to help builders and remodelers get to net zero ENERGY READY homes.

# Window Retrofit—From the RO, Out



Goin' down to the studs ...

When replacing windows in an older house, you have many options: sash replacement, tilt-in replacement window pack, full-window replacement, interior or exterior storm windows, and historic restoration.

That is too many things to talk about in one article.

**This article is about full-window replacement:** removing the old window, along with the interior- and exterior-trim down to the rough framing. This often includes changing the size of the rough opening—either to change window types, frame a view, or just to let in more light.

Sometimes the opening gets bigger, sometimes it shrinks.

## What's the best way to do it?

The Building America program has been great for producing reams of publications on topics in home building that relate to energy efficiency and durability.

There are also virtual piles of information in other parts of the government: Energy Star (US EPA), NREL, PNNL, LBNL, ORNL and other National labs (DOE) as well as some nonprofits and media companies.

**We're going to save you the trouble of sifting through all of it** and boil down a few key publications into a quick guide for full-window replacement. Today we're synthesizing:

1. Building America Solutions Center's [Complete Window Replacement Guide](#) (16 pages, public domain)
2. [ASTM's 2112 Standard Practice for Installing Windows, Doors, and Skylights](#) (87 pages, \$82)
3. [NREL's Measure Guideline on Wood Window Repair and Replacement](#) by Peter Baker at [Building Science Corporation](#) (94 pages, public domain).

*(BTW, thank you to all of the people who figure this stuff out and make it available.)*

## Once per generation opportunity

If the window retrofit is part of a siding replacement, it is wise to add a layer of exterior insulation to cut down on air leaks and to provide continuous thermal coverage. Insulation is a relatively cheap upgrade to an expensive siding project that happens only once every 50 years. And it makes a big difference in a home's energy performance.

Adding a layer of foam complicates the window install, however, because it adds thickness to the wall and covers the nailing base to which you would ordinarily fasten the window. For details on how to install a window over exterior foam, see the illustrations below.

## Cut into the wall carefully

If you're not replacing the siding and the rough opening is changing, it is likely that the siding will need to be trimmed back. In doing so, be very careful not to damage the building paper, house wrap, or whatever weather resistive barrier (WRB) is in place.

That thin strip of building paper (or house wrap or other WRB) is your lifeline to integrating a new hole in an old wall's existing drainage plane (*which is buried under the siding*) that has worked perfectly for the life of the building.

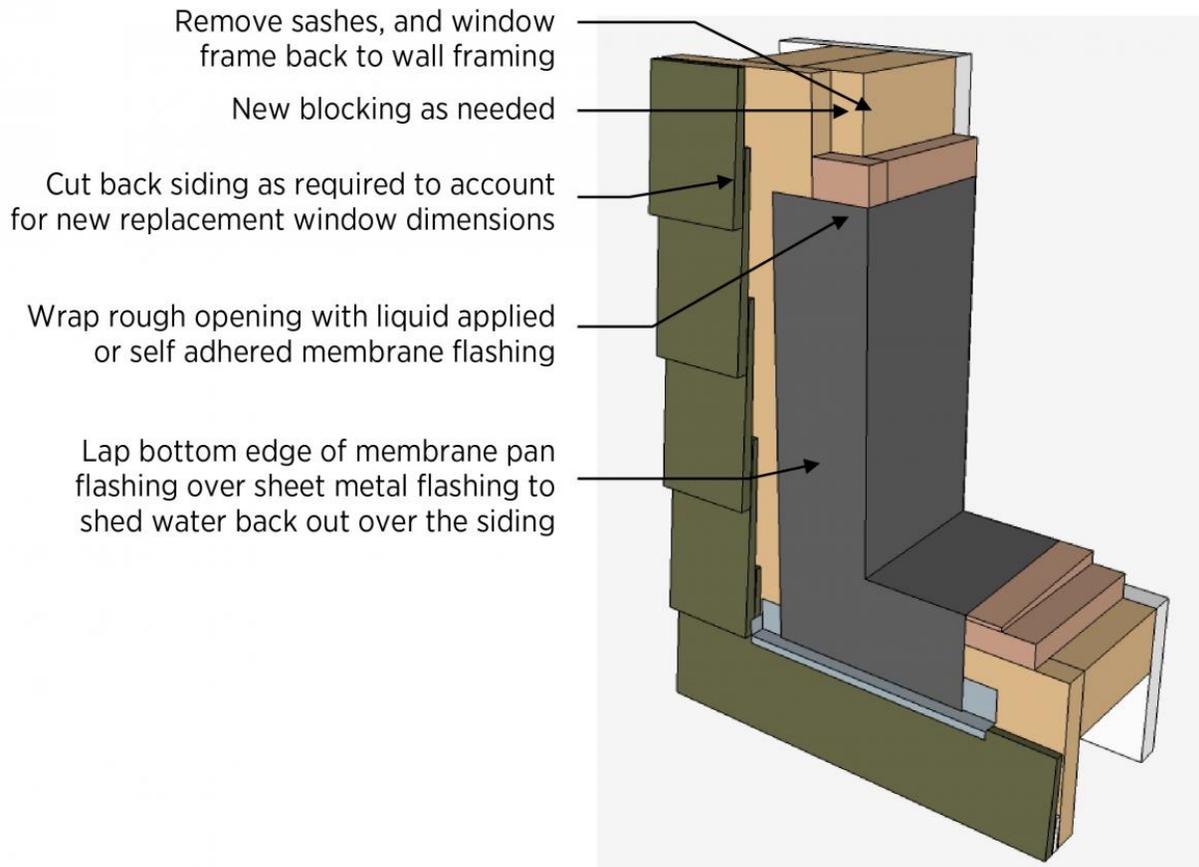
No pressure.

A couple of ways to protect the underlying paper come to mind. Most promising is to wedge a chunk of beveled siding or cedar shims under the edge of the siding but on top of the paper, then set your saw to a precise depth to cut the siding—and possibly to nick the shims—but preserve the paper. To do this you might want to tack a thin board to the house to support the saw bed and to keep it from changing depth dimension as it travels along lapped siding.

For working behind brick, the challenge is mortar droppings. If they bond to the paper, you may rip the paper when removing small pieces of mortar, so work carefully. Stucco may have two layers of building paper: one as a bond break and the other as a drainage plane. Tie into the drainage plane (the innermost layer).

## How to detail the rough opening

Here's how Peter Baker draws the sill plate once the rough opening is cleaned up (he illustrates padding the opening to fit a slightly smaller window):



*(drawing by Peter Baker, BSC, via BASC)*



# Window Replacement Options for Remodelers



## How to frame the conversation with customers to clarify which information is most relevant to the window choice.

Windows are an expensive part of any major remodel and they play a major role in a home's performance. It can be hard enough to keep all of the choices straight in your own head, let alone explaining it to customers. Hopefully, we can help by boiling it down to a couple of questions that can guide the conversation.

Begin by so determining where you are on the *invasive* scale. Next, talk to your customers about materials, performance, and durability. Finally, choose the window types: double hung, casement, awning, fixed, etc.

## **Question 1: How comfortable are you with me tearing into your walls?**

There are a lot of ways to replace a window—from handcrafted restoration to rip-out and replacement. Each option solves a slightly different problem and falls somewhere different on the invasive scale.

If disrupting the living space is a concern, a sash replacement or tilt-in replacement windows can get you out of a jamb fast (sorry).

## **Question 2: Why do the windows need to be replaced in the first place?**

It seems like a pretty obvious question and it's pretty simple to assume that in a large scale remodel, all of the windows will be replaced as a matter of course. Even if that's the case, look closely at why: the reason may point to the best replacement option.

Four common reasons:

- Water damage
- Too old
- Uncomfortable to be around/energy waster
- Hate to paint/hate to glaze/hate to maintain

### **Water Damage**

If water has leaked in to the framing from rain, then you need to do major surgery: Removing the existing window down to the rough opening and replacing with a 'new construction' window (such as a flanged window).

- You must be able to integrate the window into the existing building paper/WRB above and around the window, so flashing it right matters.
- You may also need to replace some rotted framing.
- This job is high on the invasiveness scale, it will include framing, drywall, interior trim, exterior trim, and siding work.

### **Old Age**

For windows with too many layers of paint, cheap construction, or just too many years or wear and tear, you have a few options:

- Restoration. Best for historic homes under preservation guidelines and homes in very mild climates, where heat loss or heat gain are not major concerns. Also an option if

you're totally broke, have a big pile of wood, a shop full of tools, and are willing to also

make some storm sash. 😊

- Replacement sash and jamb liners. The least expensive option; good for windows that are installed perfectly square and whose frame is still in great shape. Replacing 20 year old Andersen or Marvin sash with new energy efficient ones is a good option.  
#Bang4theBuck
- Tilt-in replacement window. Fast, clean, and easy, but not cheap. Best for square window frames with zero water damage. Replacement windows cost about the same, or more, than standard new-construction windows. But they pop in quick, so they are worth a look.

## **Uncomfortable, energy waster**

Some windows give you the cold shoulder, some make you hot. Cold windows cause condensation on the inside leading to mildew and mush.

Hot houses may be great for tomatoes, but not for people. Unless you're really old. In hot climates heat gain through windows is one of the top energy wasters (because it makes the AC work harder).

If there is no exterior water damage, you can keep the existing frame and use one of these less-invasive options:

- Replacement sash and jamb liners
- Tilt-in replacement window

Next, study up on energy ratings and performance factors. U-factor and solar heat gain coefficient are the main knobs you can turn to dial in performance.

## **Hate to paint, hate top glaze, hate to maintain**

If there is no exterior water damage, then there are a couple of less-invasive solutions than full window replacement:

- Replacement sash
- Tilt-in replacement window

Of course, that means keeping the existing frame, which you/your customers hate to paint. The invasive nature of fully replacing the windows may be worth it if your customers hate to paint THAT much.

Consider the sash and frame materials for durability, cost, and aesthetics—but remember: haters gonna hate, painters gonna paint.

## **Question 3: What are the next priorities?**

Now that you know what type of replacement system to get, zero in on materials and performance.

- Maintenance needs
- Energy, comfort, storm performance
- Longevity

Each situation has its own set of priorities. Historic accuracy may trump maintenance issues or energy performance, or vice-versa.

## **Maintenance:**

Customers may say that they will maintain the beautiful wood windows that they think they want, but people don't always do what they *hope* they'll do.

Young, gung-ho weekend warriors in a single-story home may actually be able to keep up the maintenance for the 15-20 years before their comb-overs take effect. This may be a good area for young couples with yoga pants to save a little cash.

Folks with a spare tire developing where their waistline used to be – and who live in a multi-story home, may indicate a low-maintenance solution. Another clue: is the car covered with last year's road salt, or is it sparkling clean?

**Vinyl or fiberglass** are very low maintenance and are a top choice of coastal builders. Vinyl has had a reputation for expanding and contracting, but according to the Efficient Windows Collaborative, that is less of a problem these days. Fiberglass is strong and dimensionally stable. Neither require maintenance.

**Composite** windows, made from a mixture of wood and polymers, require no maintenance, are dimensionally stable and durable.

**Aluminum frame** windows are strong, lightweight, and durable, but can be energy wasters if no thermal breaks are manufactured into the frame.

**Aluminum clad** windows come in many colors, are extremely durable, can have wood interiors, but they are the most expensive option.

**Plain wood** windows can last a long time if maintained well. They are less expensive than clad and fiberglass windows and comparable in cost to vinyl windows.

## Durability/longevity

When durability tops the priority list, cost slides down a slot. Choose name brand companies with solid warranties, and install them well.

For windows that do not need to last as long, you can get reasonably efficient windows that are low-maintenance and perhaps off-brand.

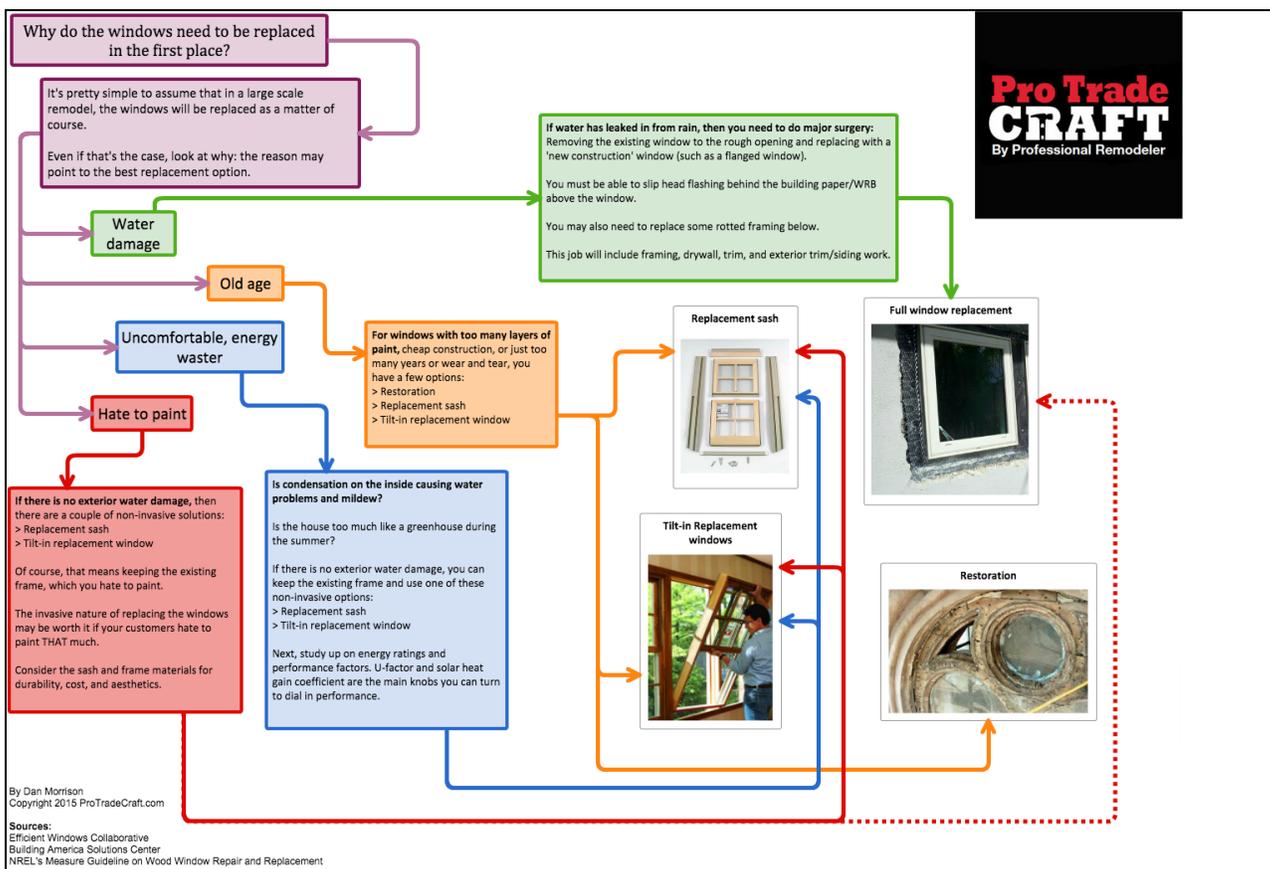
## Energy efficiency, comfort, storm performance

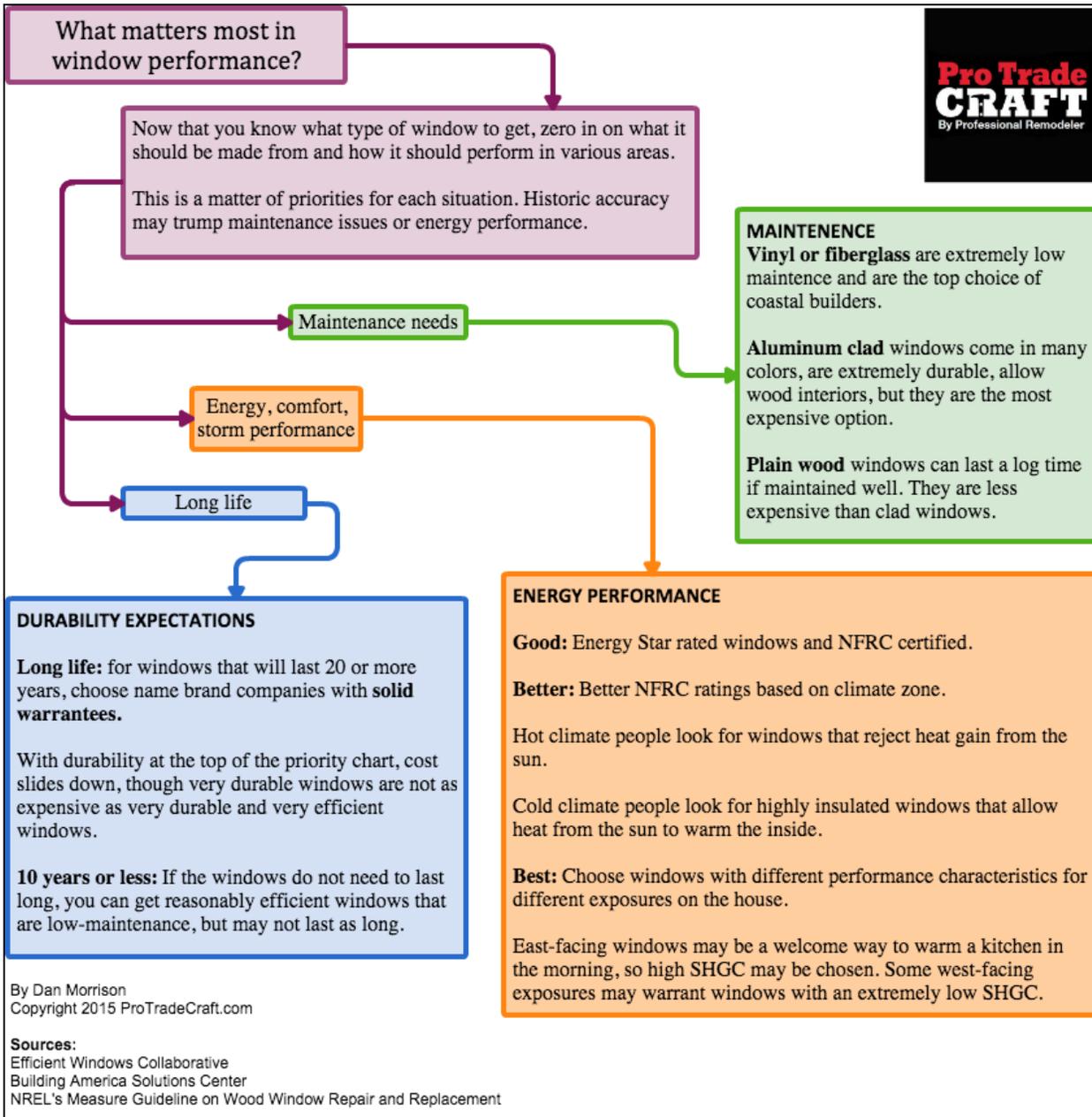
If energy and storm performance top the priority list, such as for a house on the coast of Maine or Miami, look at the stickers on the window.

- **Good:** Energy Star rated windows and NFRC certified.
- **Better:** Better NFRC ratings based on climate zone: hot climate people look for windows that reject heat gain from the sun; cold climate people look for highly insulated windows that allow heat from the sun to warm the inside.
- **Best:** Choose windows with different performance characteristics for different exposures on the house. East-facing windows may be a welcome way to warm a kitchen in the morning, so high SHGC may be chosen. Some west-facing exposures may warrant windows with an extremely low SHGC.

Like everything else in life, the right choice means weighing multiple factors and priorities.

## Here are a couple of simple flow charts to visualize the choices:

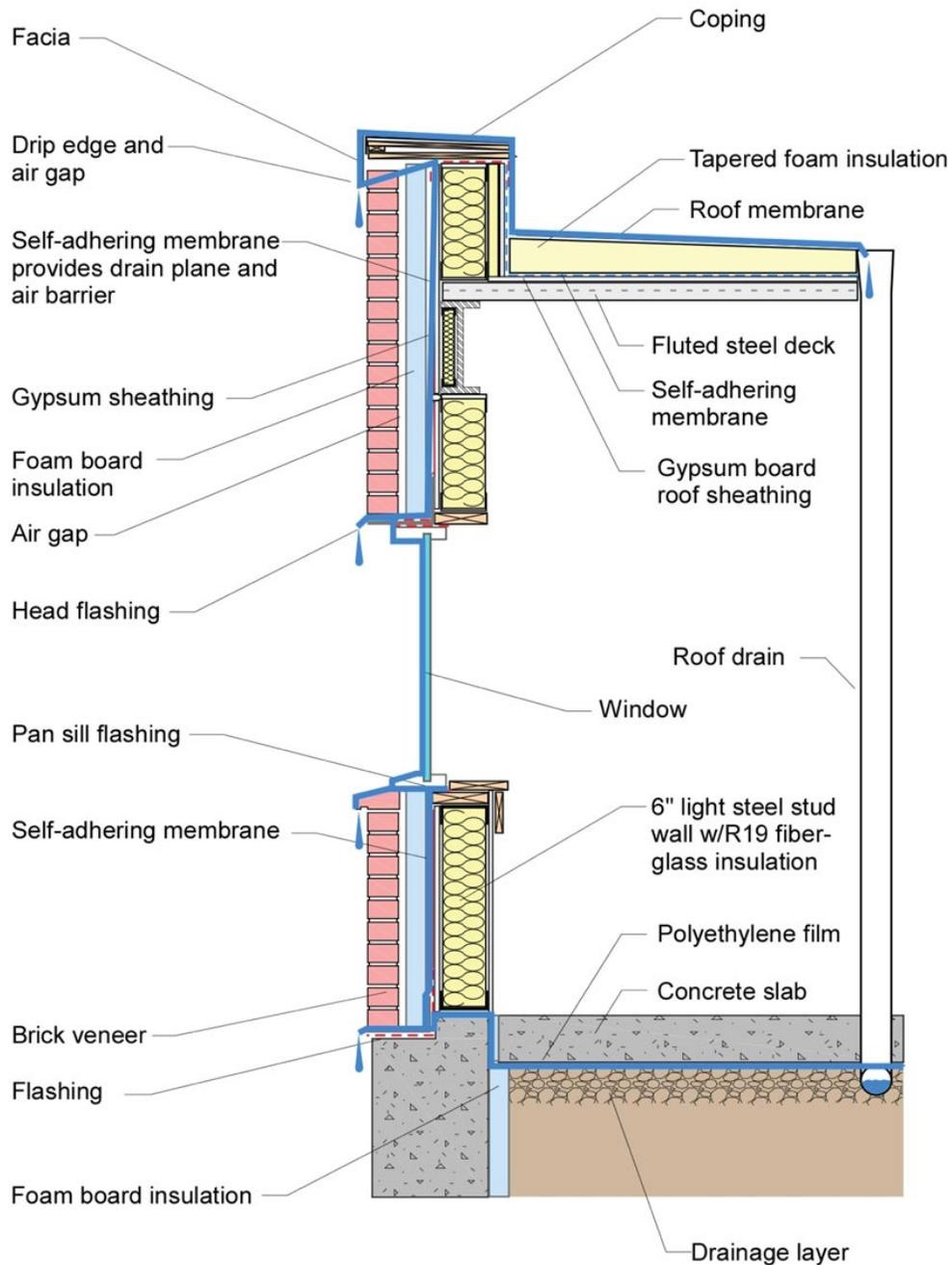




## Sources:

- Efficient Windows Collaborative
- Building America Solutions Center's Complete Window Replacement Guide
- NREL's Measure Guideline on Wood Window Repair and Replacement

# The Pen Test for Air-, Water- and Thermal-Tightness



Water and air leaks in a building shell are difficult enough to detail on simple buildings. Complex structures can cause migraines for builders, remodelers, and architects who don't pick up their pens and trace at the design stage. Photo: courtesy of EPA

## **The pen is mightier than the saw**

On the building physics red carpet, liquid water gets the most attention and is the darling of the media. Insulation gets some airplay, but invisible to most pundits is air, whose ability to carry moisture can be devastatingly deceptive.

Building durability and efficiency depend on controlling water, heat, and air flow. This article is about doing that with a pen and a piece of tracing paper.

## **Liquid is the most obvious damage function**

Liquid water damage can come in the form of wind-driven rain, flashing failures, roof leaks, or plumbing leaks. We're not going to talk about plumbing leaks here, but that doesn't mean they should be ignored. We'll talk about plumbing leaks later.

Liquid water that comes from the sky is controlled with a (wait for it ...) *liquid control layer*.

(Worth the wait?)

It is composed of flashings, drainage planes, and capillary breaks all working together as a team.

## **Vapor drive changes with the seasons**

Moisture in the form of vapor usually leaks into assemblies on air currents, which can come from the inside or outside, depending on the season.

An air-conditioned house during a hot, humid summer tends to suck vapor into the walls from the outside. In winter, the reverse happens: Humid air from inside the house is driven into the walls through holes like electrical outlets, can lights, and unsealed interior soffits.

This is called *vapor drive*: movement of moisture in response to concentration differentials. Moisture moves from wet to dry, and from warm to cool.

As soon as warm moist air hits a cool surface (the plywood wall sheathing or the drywall, depending on the direction of drive), the vapor condenses into liquid and puddles in the cavity, out of sight from homeowners (and remodelers).

## **Heat flow can be predicted, too**

Physics has been smugly pointing out for years that heat moves from more to less, just like water. You can feel it moving out of you when you stand next to a single-pane window on a cold day, and you can feel it bombard you next to that same window on a sunny one.

(If physics weren't so smug, maybe more people would like physics. Just sayin'.)

## If you can't draw it, they can't build it

*The Pen Test* is widely talked about in building science circles, but it is not widely talked about in day-to-day home building and remodeling. The idea is that if you can draw a line on the building section showing where the air barrier, the drainage plane, and the thermal barrier are located—**and that line is continuous**—then the assembly can be built to work. But if you can't draw it, it isn't there. Many building scientists joke that they break in new architects and engineers by putting them through *The Pen Test* on various blueprints.

The EPA has an illustrated explanation of *The Pen Test* in their *Moisture Control Guidance for Building, Design, Construction, and Maintenance*.

*"... it's like a parachute: There's no law requiring you to use one, but it's a good idea."*

*—Lew Harriman, one of the principal contributors on using the guide.*

## Appendix A of that guide is reprinted with permission here

The images are typical of commercial construction and many urban residential buildings: brick cladding, parapet roof, gypsum sheathing, but don't let that scare you off.

Regardless of whether you're working on a Cape Cod in New England, a row house in San Francisco, an ultramodern dwelling in Seattle, or a farmhouse in Iowa, the principle holds: **If you can't draw the water control layer, the heat control layer, and the air control layer, then they won't get built.**

—The moisture control guide was written by Terry Brennan, Michael Clarkin, and Lew Harriman.

We would like to thank them for doing this work because it is important stuff and a lot of folks don't know the details.

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### PURPOSE

By tracing the continuity of all the materials for each control function, the “pen test” checks the completeness of:

- Rainwater protection
- The insulation layer
- The air barrier

To verify continuity, create sections in which each of these moisture-control elements is traced in a different color to show that the design specifically accounts for them. Contractors can then easily

check the sections against their experience with materials, trades, and sequencing. The sections will also provide maintenance workers in buildings and grounds with information useful in ordinary maintenance work or in the event of a problem during building use.

## PROCESS

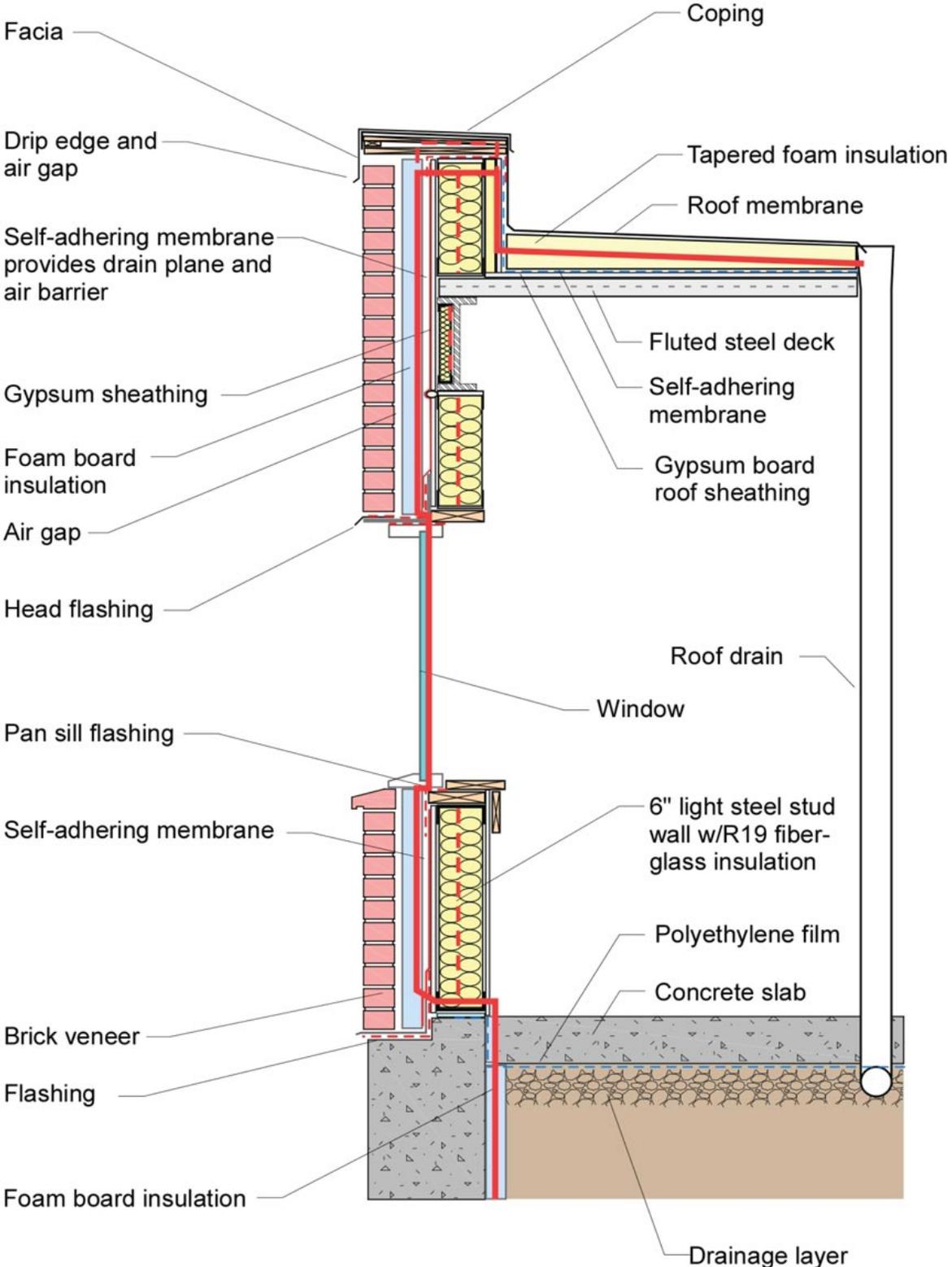
### Rainwater Layer Continuity

To demonstrate complete rainwater protection using the section drawing, place a pen on a material that forms a capillary break between the rain-control materials that get wet and the inner portion of the enclosure that must stay dry. Without lifting the pen off the paper, trace from the center of the roof around the walls, windows, and doors and along the foundation to the center of the foundation floor.

Figure A-1 serves as documentation of rainwater protection continuity. The following describes the traceable capillary break in a sample section. Starting at the center of the roof:

- The roofing membrane is the first line of defense, protecting the water-sensitive inner materials from rain and snowmelt.
- Tracing the roofing membrane from the center of the roof to the edge of the roof, the roofing membrane rises up the parapet wall where it flashes beneath a metal coping, which also forms a metal fascia.
- The fascia forms a drip edge, channeling water away from the cladding.
- An air gap between the drip edge and the brick veneer forms a capillary break, protecting the materials beneath the coping from rainwater.
- Behind the brick veneer, air gap, and foam board, a self-adhering water resistant barrier (WRB) applied to the gypsum sheathing forms a capillary break between the damp brick and the inner wall assembly.
- The WRB laps over the vertical leg of a head flashing, protecting the window from rainwater with a drip edge and an air gap. Weep holes allow water to drain from behind the brick cladding.
- The window frame, sash, and glazing form a capillary break system that sits in a pan sill flashing at the bottom of the window.
- The pan sill flashing forms a capillary break protecting the wall beneath from seepage through the window system.
- The pan sill flashing shingles over the WRB in the wall beneath, which shingles over a flashing that protects the bottom of the wall system.
- The water-resistant barrier shingles over a flashing that protects the bottom of the wall system, where the foam sill seal makes a capillary break between the foundation and the bottom of the framed wall, connecting with:
  - One inch of extruded styrene foam insulation making a capillary break between the top of the foundation wall and the edge of the floor slab.
  - Polyethylene film immediately beneath the slab forms a capillary break between the bottom of the slab and the fill below. NOTE: If the bed of fill beneath the slab consists of pebbles greater than ¼ inch in diameter and contains no fines, then it forms a

capillary break between the soil and the slab. Apply the same procedure to the insulation layer and the air barrier.

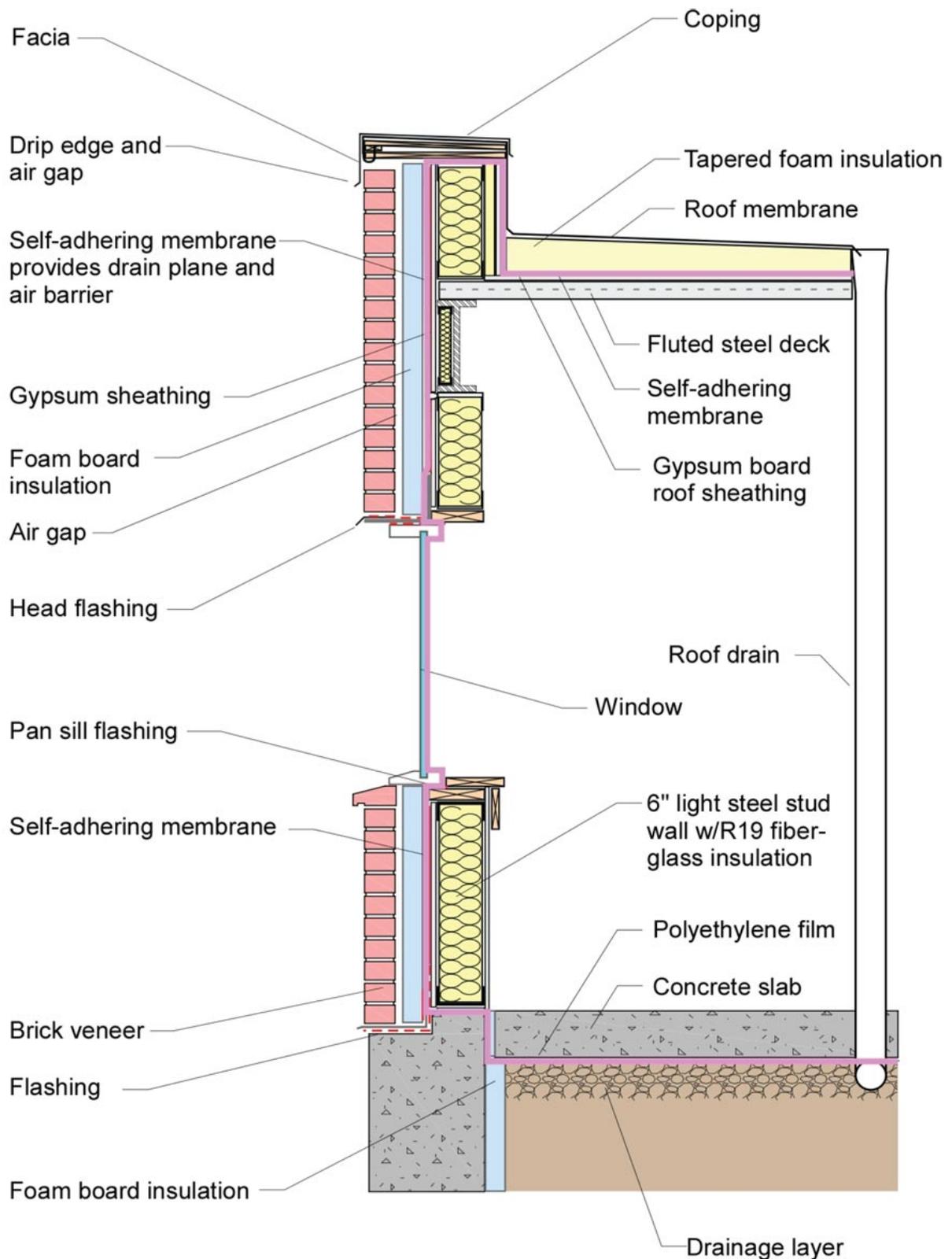


Insulation Layer Continuity

To demonstrate a continuous layer of insulating material around a section, place the pen tip on the insulating layer in the center of the roof and trace from one insulating material to the next around to either the bottom of the foundation wall or the center of the foundation floor.

Figure A-2 shows the continuity of thermal insulation in a sample section.

- Beginning at the center of the roof, trace through foam insulation to the edge of the roof.
- Up a layer of foam board insulation to the wooden blocking at the top of the parapet wall.
- The wooden blocking connects to the top of the exterior foam insulation board insulation and the top channel of the light gauge wall framing.
- The steel wall framing is filled with cavity insulation, and the thermal bridge through the steel is insulated by the exterior foam insulation.
- At the window head, the steel lintel is a thermal bridge through the insulation system, the rough opening around the window is sealed using backer rod and sealant.
- The window jamb, sash and glazing system provide insulation continuity to the pan sill flashing at the bottom of the window.
- The exterior insulating foam sheathing and cavity insulation carry the insulation layer to the foundation.
- Foam sill seal provides thermal insulation between the bottom of the wall and the concrete foundation, which carries thermal protection below grade to the bottom of the foundation wall.
- Vertical foam insulation applied to the interior of the foundation wall completes the insulation layer.



**Air Barrier Continuity**

Continuity of the air barrier is demonstrated using the same method used for rainwater control and the insulation layer. For this example air barrier materials and the sealants used to connect them are identified from the center of the roof to the center of the foundation floor. Self-adhering membranes are used as examples in this section, but note that wall air barriers may be formed using alternate air

barrier materials (e.g., fluid applied membranes, flexible sheets, rigid foam board insulation, and spray polyurethane foam).

- From the center of the roof trace the air along the self-adhering membrane on the gypsum roof sheathing to the edge of the roof.
- The self-adhering membrane continues up the gypsum board sheathing on the parapet wall where it connects to a transition membrane that spans the top of the parapet wall.
- From the transition membrane trace down the self-adhering membrane on the wall sheathing to an intersection with the window head flashing at the steel lintel.
- A transition membrane wraps from the bottom of the steel lintel into the rough opening where it connects to the window by sealant and backer rod.
- The window system forms the air barrier to the pan sill flashing where sealant makes the connection.
- The pan sill flashing carries the air barrier to the self-adhering membrane on the lower wall.
- A transition membrane connects to the concrete foundation.
- Polyethylene film or the concrete slab itself extend the air barrier to the center of the floor.

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**Go to the Source:**

**Moisture Control Guide** from [EPA.gov/iaq/moisture](https://www.epa.gov/iaq/moisture)

**##**

**END OF WINDOW INSTALLATION GUIDE**