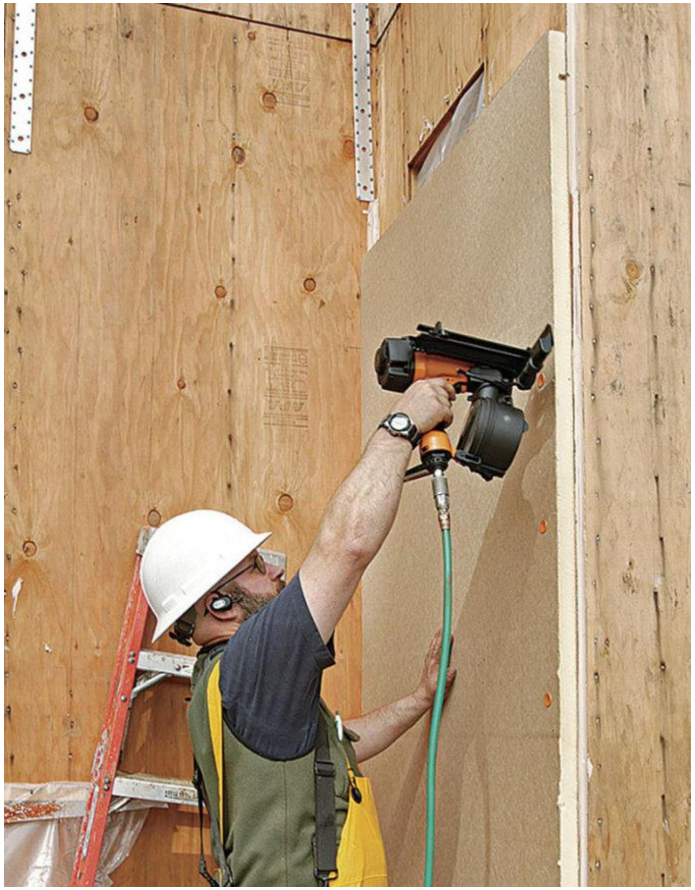
Rethinking the Rules on Minimum Foam Thickness



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Exterior rigid foam basics

Exterior rigid foam is great!

By now, most cold-climate builders understand the benefits of installing a continuous layer of rigid foam on the exterior side of wall sheathing.

Benefits of exterior foam

- The foam keeps the sheathing warm and dry all winter long, reducing the likelihood that the sheathing will get damp.
- The foam reduces air leakage.
- The foam reduces thermal bridging through the studs while improving the whole-wall R-value.

Ghosting is a sign of thermal bridging →

Pluses and minuses

Exterior rigid foam is good – it adds R-value, reduces thermal bridging, and improves airtightness.

But exterior rigid foam also does something “bad” – it reduces drying to the exterior.

If you want your wall to dry outward….

… install semi-rigid mineral wool instead of rigid foam on the exterior of your walls.

For dry sheathing, there are 2 approaches

- **The old-fashioned approach (no exterior foam)**: Make sure that the sheathing can dry outward in the spring and summer. Since most types of housewrap and siding are vapor-permeable, this approach is fairly easy to implement.
- **The newer approach (add exterior foam)**: Keep the sheathing warm and dry by protecting the exterior side of the wall with a thick layer of rigid foam. With this approach, you don't want interior polyethylene.

Either approach works.

Which approach is “best”?

Researchers who have measured the moisture content of wall sheathing have discovered that walls with adequately thick rigid foam stay dryer than walls without rigid foam.

Walls **without** exterior foam

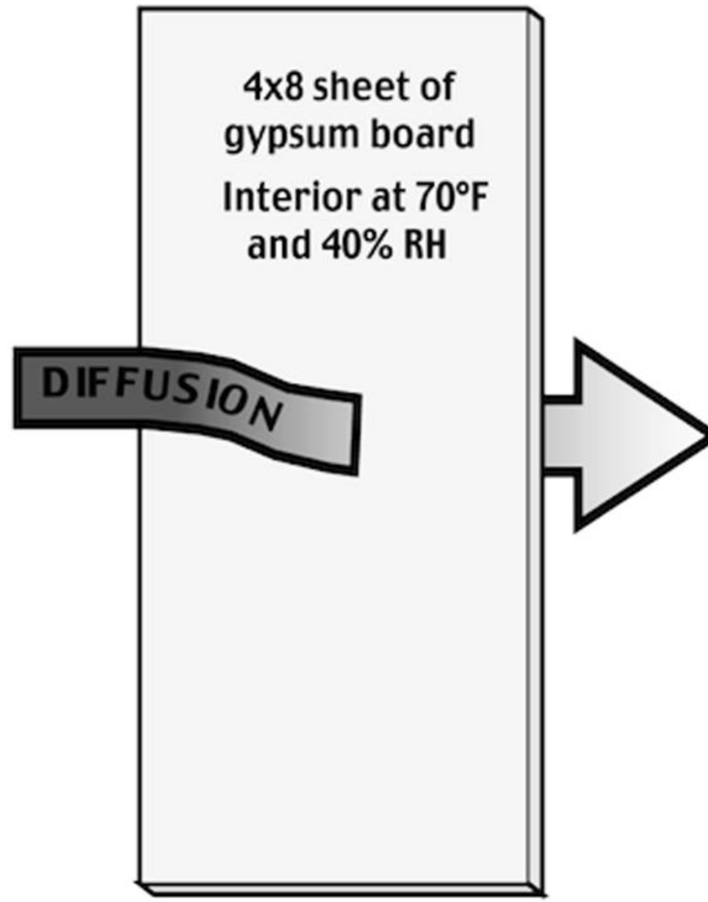
In a conventional framed wall without exterior foam, the sheathing gets wet in February.

In April and May, the damp sheathing dries to the exterior.

Two mechanisms for outward moisture migration

Moisture can migrate from the warm interior to cold sheathing two ways:

1. Exfiltration
2. Outward vapor diffusion

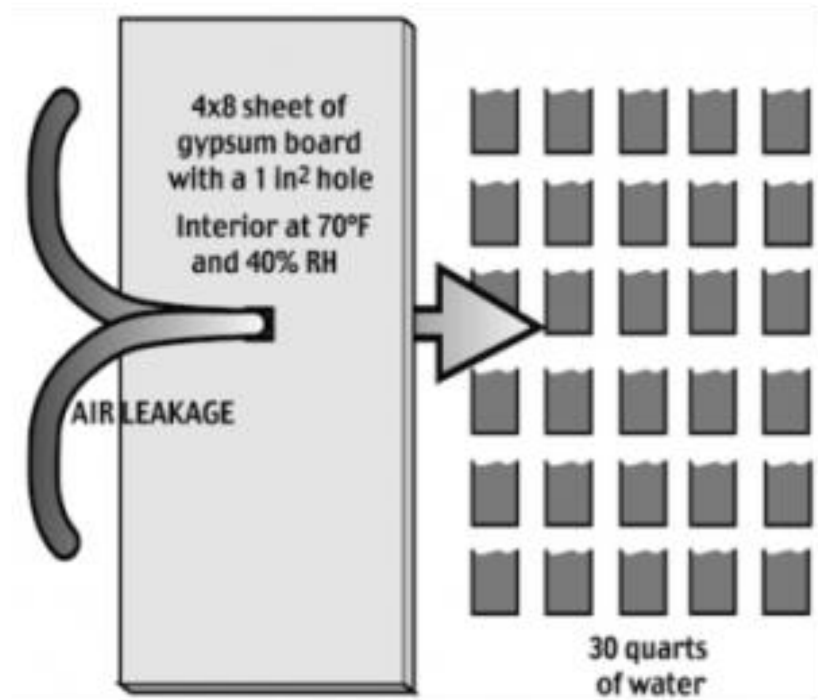


[Image credit: Building Science Corp.]

Which mechanism matters most?

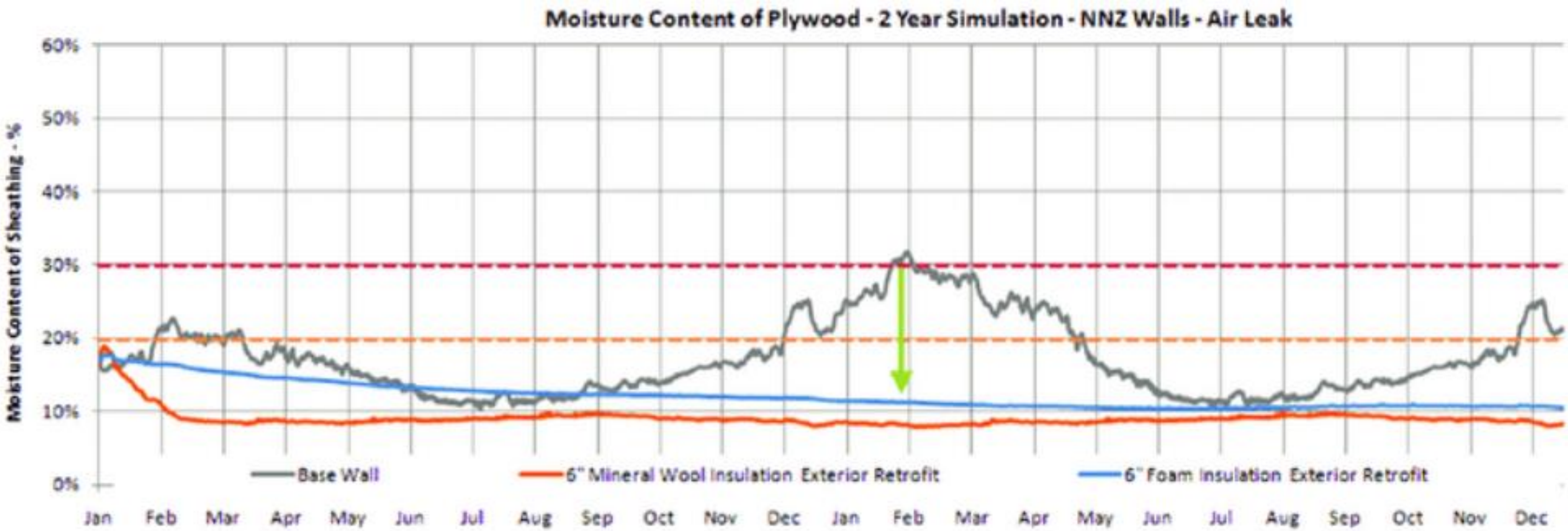
In most homes, exfiltration moves much more moisture than diffusion.

But in a very tight home, it's possible for diffusion to be the dominant moisture transport mechanism.



[Image credit: Building Science Corp.]

Moisture content of sheathing



↑

February

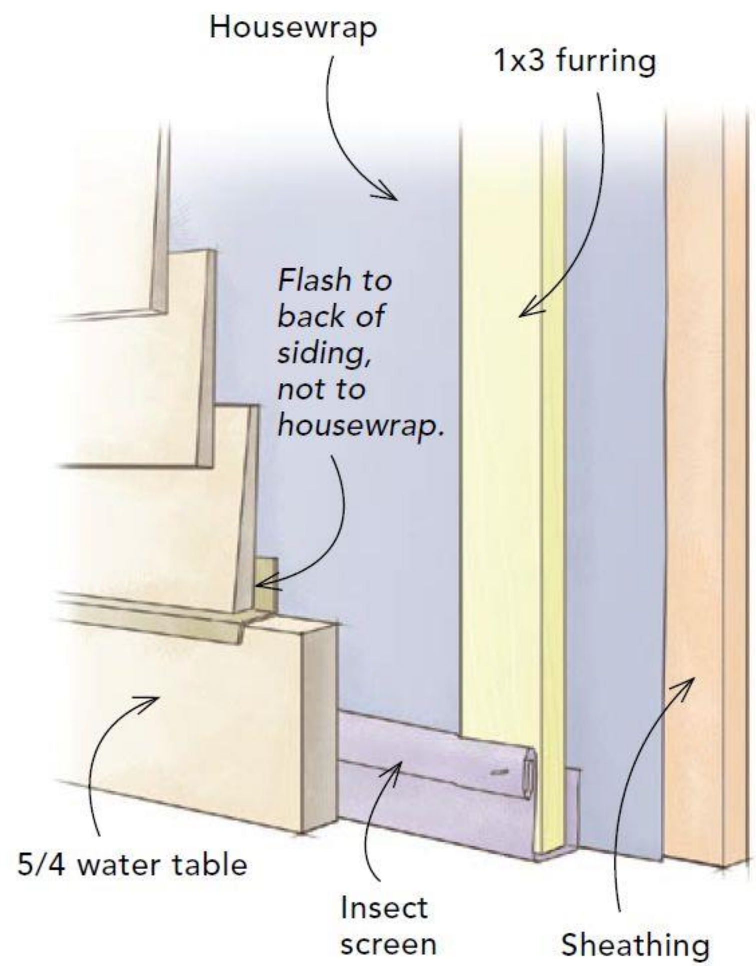
Does this type of moisture cycling cause problems?

Not usually. But we'll know more in 50 years.

Walls without rigid foam: best practices

Walls without rigid foam are more robust:

1. If they have plywood sheathing instead of OSB sheathing.
2. If they have a vented rainscreen gap between the siding and the housewrap.



Walls with rigid foam: best practices

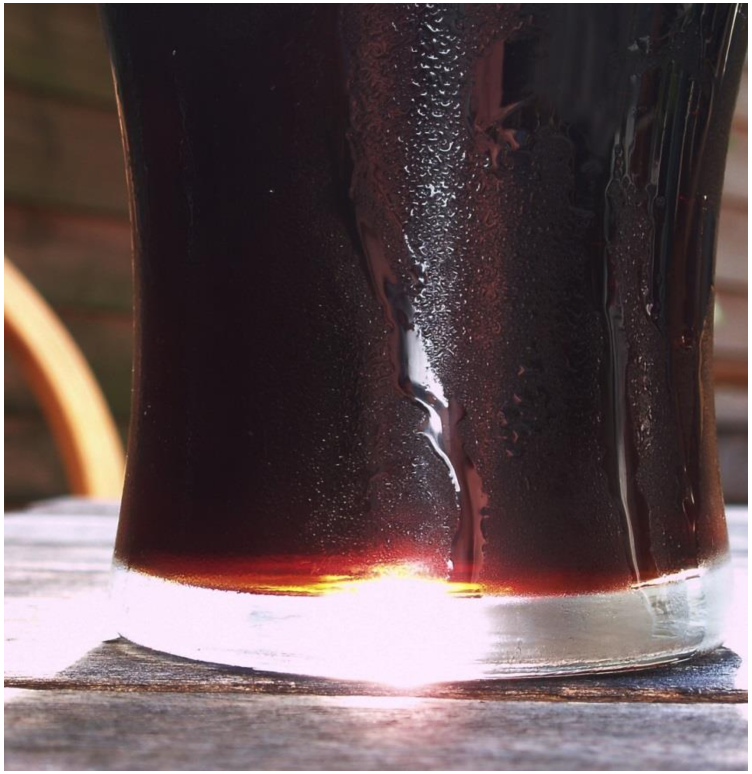
The foam needs to be thick enough:

- Thick foam keeps the sheathing warm all winter long – so it won't get damp. (Condensation or sorption happens on cold surfaces, not warm surfaces.)
- If the rigid foam is too thin, the sheathing gets cold – and therefore damp. Since rigid foam stops drying to the exterior, that's risky.

The difference between condensation and sorption

Condensation happens on hard, impervious surfaces like glass or metal.

If a material is porous (like wood), what happens is **sorption**.

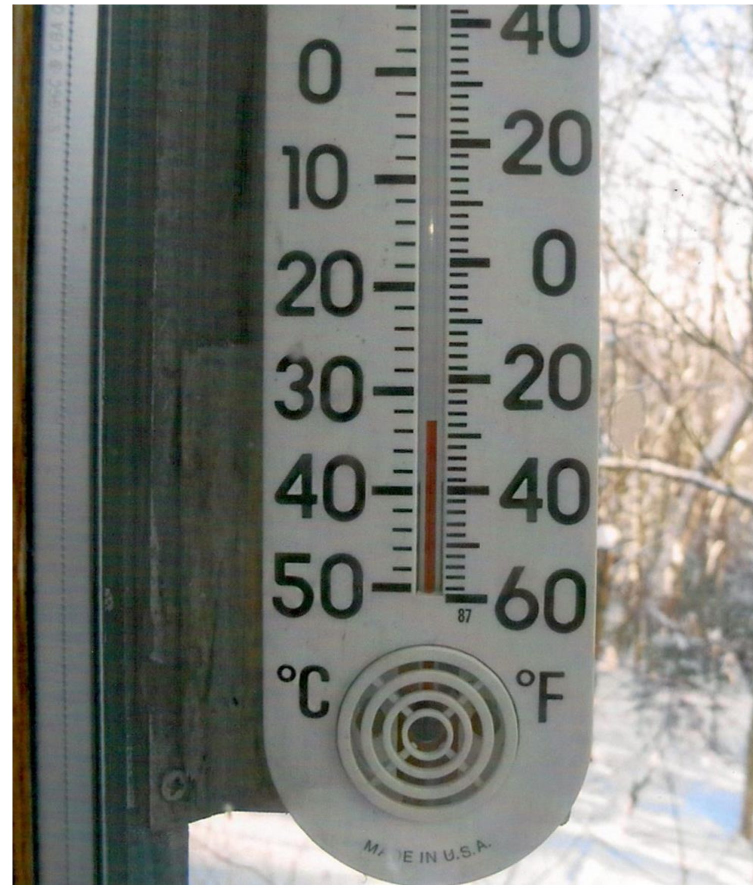


Rules have been established

Climate Zone	Minimum R-Value of Foam Sheathing
Marine Zone 4	R-2.5 for 2×4 walls; R-3.75 for 2×6 walls
Zone 5	R-5 for 2×4 walls; R-7.5 for 2×6 walls
Zone 6	R-7.5 for 2×4 walls; R-11.25 for 2×6 walls
Zones 7 and 8	R-10 for 2×4 walls; R-15 for 2×6 walls

These rules work

The rules allow for a very limited amount of sorption (usually on the coldest day in December or January, for a few hours a day), working on the assumption that there are lots of opportunities for drying and moisture redistribution.

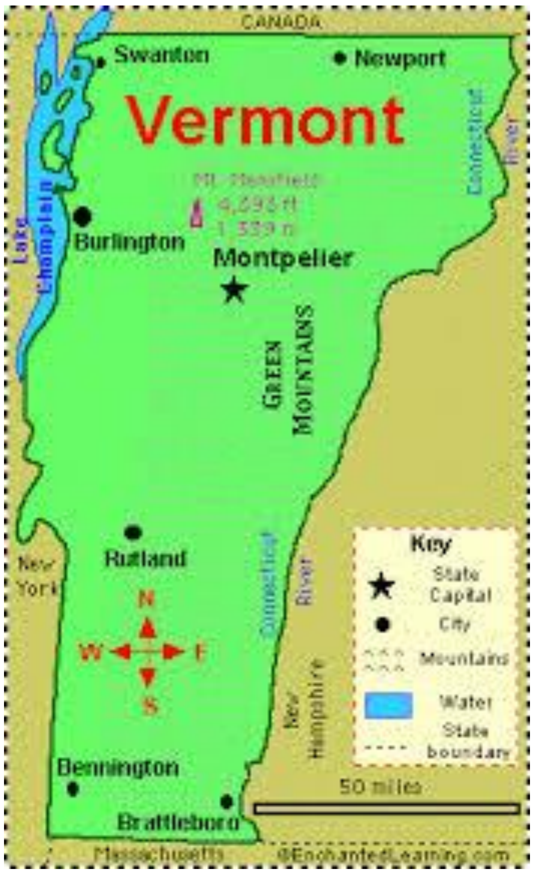


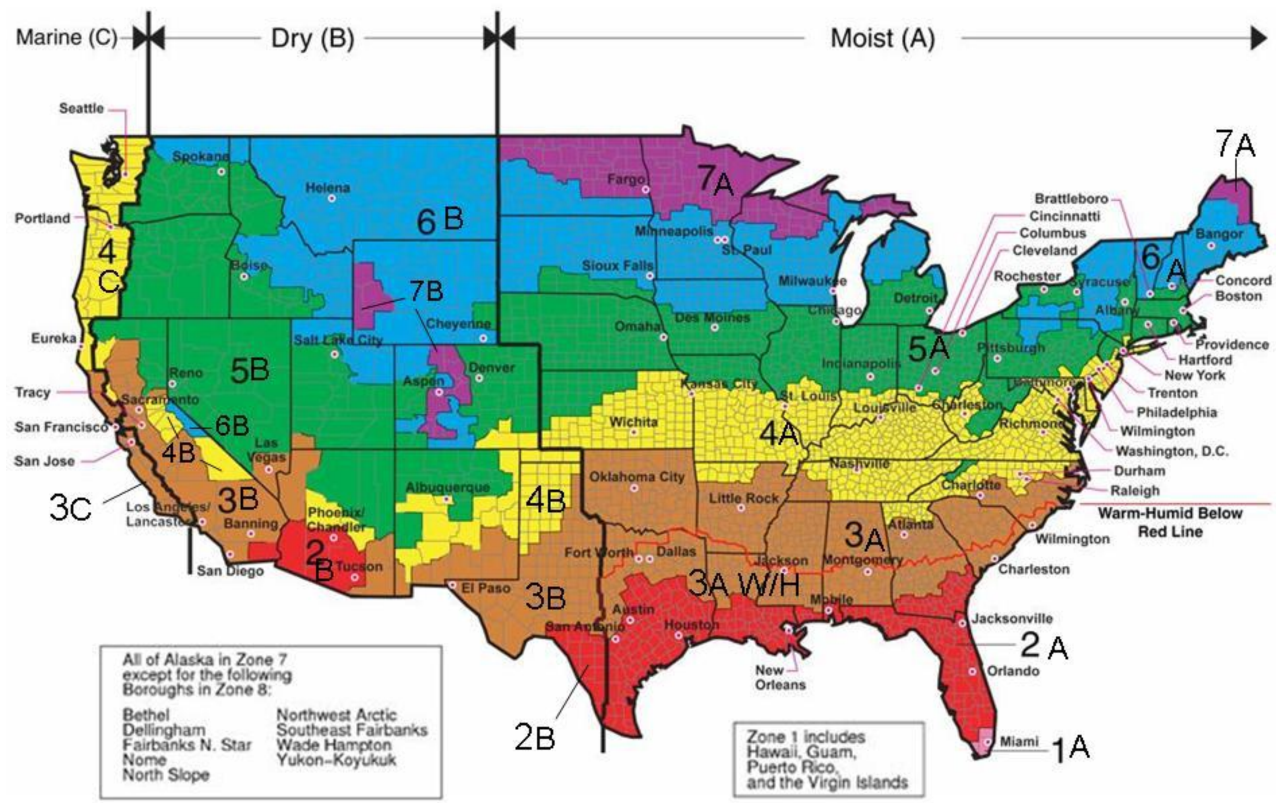
Summarizing:

- Exterior rigid foam improves a wall's performance – but it has to be thick enough to keep the sheathing above the dew point for most of the winter.
- Thick foam is always safer than thin foam.
- This type of wall dries to the interior – so don't install any interior polyethylene.

In Vermont…

All of Vermont is in Climate Zone 6.





Zone 6 rules

2x4 walls need rigid foam that is at least R-7.5

(2 inches of EPS or 1½ inch of polyiso).

2x6 walls need rigid foam that is at least R-11.25

(3 inches of EPS or 2 inches of polyiso).

Problem: The IRC (building code) allows R20+5 in Zone 6

The 2012 IRC introduced the so-called 20+5 problem.

(The Vermont code changed this option to "R-25.")

TABLE R402.1.1 INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

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

Joe Lstiburek’s 2013 advice: no interior polyethylene

Walls with exterior rigid foam:
“You want these walls to be able to dry in at least one direction. They can’t dry outboard due to the material properties of the insulation boards … So they need to be allowed to dry inward. No interior poly please.”

But then a 2016 article by Lstiburek ("Doubling Down") muddied the waters…

[Let's consider a] "2×6 wall with R-5 foam sheathing coupled with … fiberglass batt cavity insulation covered with … interior 6 mil poly … This wall is … still being built in Ontario. And **it works**. We know that it works because we have been building it for so long without problems."

What’s Lstiburek saying?

1. Yes, the foam on these Canadian walls is too thin.
2. Yes, these walls have interior poly, even though I recommend against it.
3. Paradoxically, the interior polyethylene is keeping these walls safe.

This raises a question…

If a 2×6 wall in Climate Zone 6 with R-5 exterior rigid foam works, why do most experts advise Zone 6 builders to install foam with a minimum R-value of R-11.25?

Thin foam? Really?

So, is thin foam OK?

Or is it still a no-no?

Two important points

- While Lstiburek has told builders who install exterior rigid foam to omit interior polyethylene, it turns out that including **interior polyethylene in this type of wall actually *reduces* risk** — at least in some circumstances and climates.
- **Simple rules favoring robust wall assemblies are easier to explain** than complicated rules that include exceptions — so even if Lstiburek is right (and he is), traditional rules might still make sense.

Walls that break the rules

How do we analyze walls like the one discussed by Lstiburek: namely, a 2×6 wall in Ontario with foam that is “too thin”?

This type of wall is at risk if the sheathing stays damp for a long time. Questions arise:

- How damp does the sheathing get?
- For how many weeks is it damp?
- Can it dry out quickly?

The answer to these questions:

"It depends."

Comparing the drying rate to the wetting rate

- All walls get wet.
- Sometimes the moisture comes from the exterior; sometimes it comes from the interior.
- Most walls also have so potential to dry out.
- Here's the key point: the wall will stay safe **as long as the rate of drying exceeds the rate of wetting** on an annual basis.

Is interior poly good or bad?

Paradoxically, the interior polyethylene that Lstiburek warned against in 2013 helps save the Ontario wall with too-thin foam.

But what about the fact that (in 2013) Lstiburek called interior polyethylene “quite frankly risky”? Shouldn’t that warning worry builders?

“Polyethylene is bad” because…

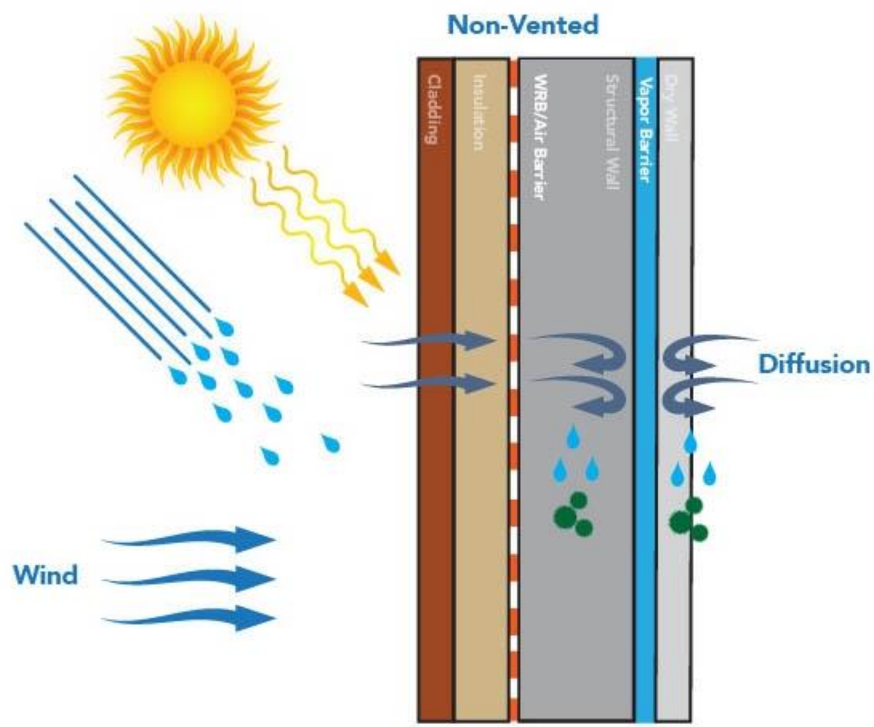
The anti-polyethylene bias that Joe Lstiburek began sharing in the 1990s had its origin in a cluster of memorable wall failures that he investigated in Florida.

Vinyl wallpaper

Lstiburek had been called in to inspect hotels in Florida with vinyl wallpaper. In some hotel rooms, the vinyl wallpaper was beginning to peel. Behind the vinyl wallpaper was a gruesome sight: damp drywall covered with mold.

The mechanism is obvious

In Florida, the direction of the vapor drive through these walls is usually inward — from the hot damp exterior to the cool dry interior. When the moisture hits the back side of the vinyl wallpaper, it condenses, soaking the drywall.



If you’ve got air conditioning, you don’t want interior polyethylene

Lstiburek warned in 2013 that polyethylene can be risky in any building with significant hours of air conditioning: “The interior polyethylene sheet has a big liability in buildings that are air-conditioned — it results in a vapor barrier on the wrong side of the wall.”

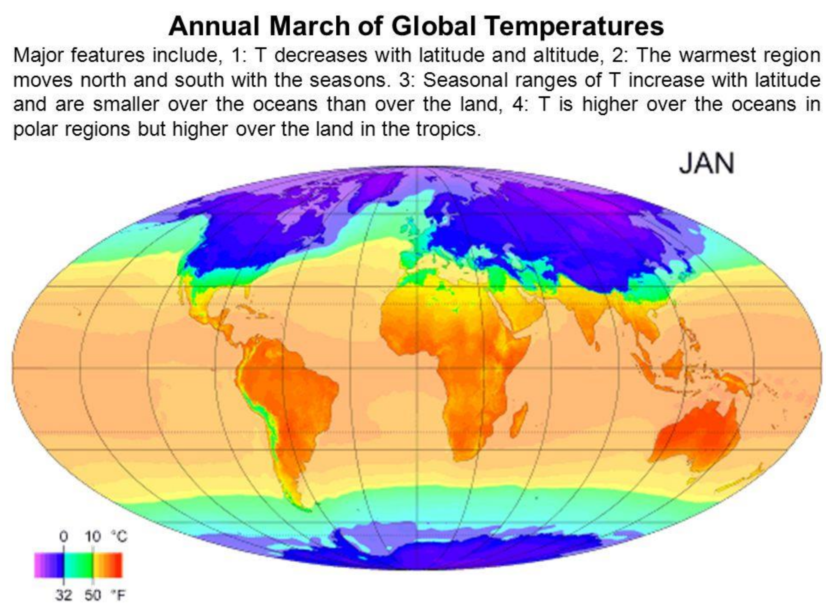
Where do we apply this rule? In Florida, clearly.

But what about Massachusetts? What about Vermont?

What’s changed since 2013?

Two things have changed:

- Lstiburek has softened his hard line against interior polyethylene, and
- Air conditioning has moved north, and can now be found in many parts of Ontario and Vermont.



Now builders are scratching their heads…

Remember, though:

The simple rules still work.

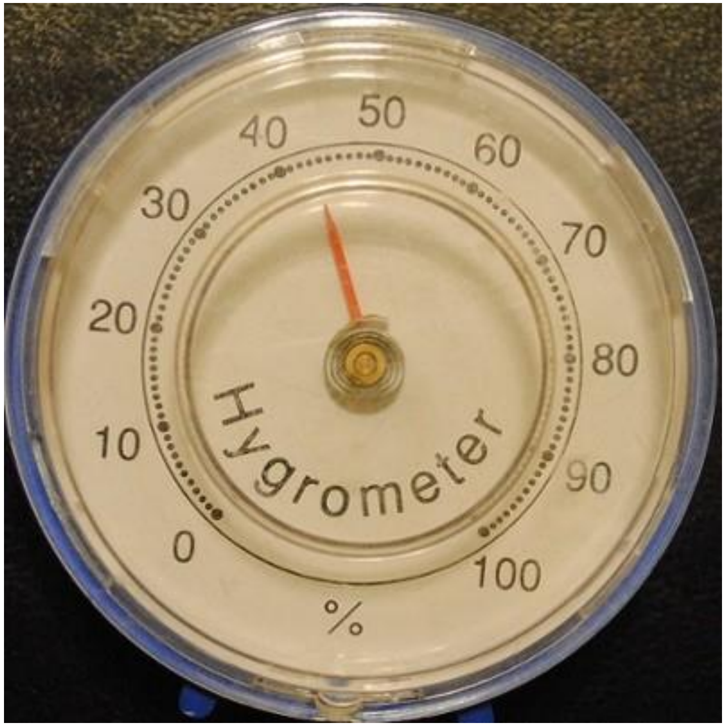
Lstiburek is right

Lstiburek is right when he reminds us that walls with exterior rigid foam that is thinner than it should be won’t necessarily fail.

If you break the rules, how can you reduce the risk?

If a wall has foam that is too thin:

- Include a good interior air barrier;
- Include some type of interior vapor retarder;
- Keep the indoor relative humidity in a reasonable (low) range during the winter (below 30%).

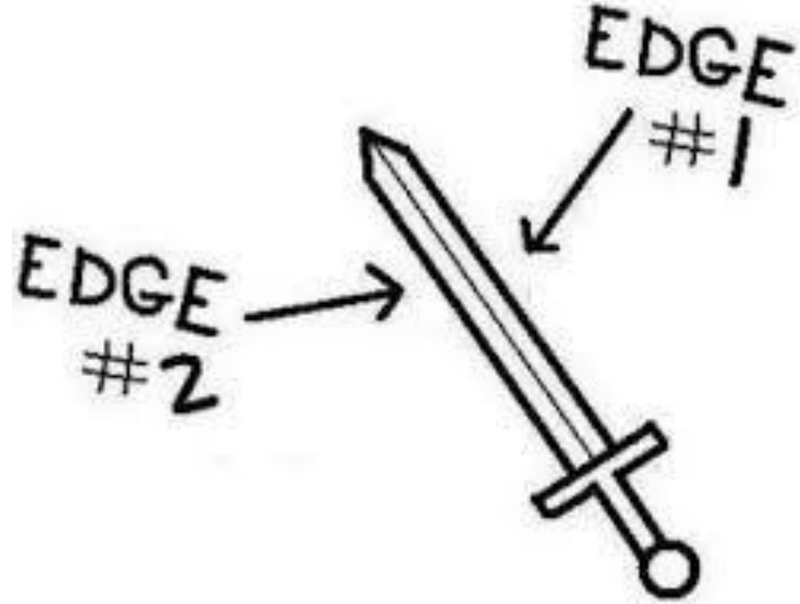


Will a ventilation fan save your walls?

- Builders have little control over how occupants will operate the home’s ventilation system or whether the occupants decide to install a humidifier.
- Buildings last a long time, and new owners may operate the building differently from the current owners.
- Robust assemblies help builders sleep at night.

Interior poly is a double-edged sword

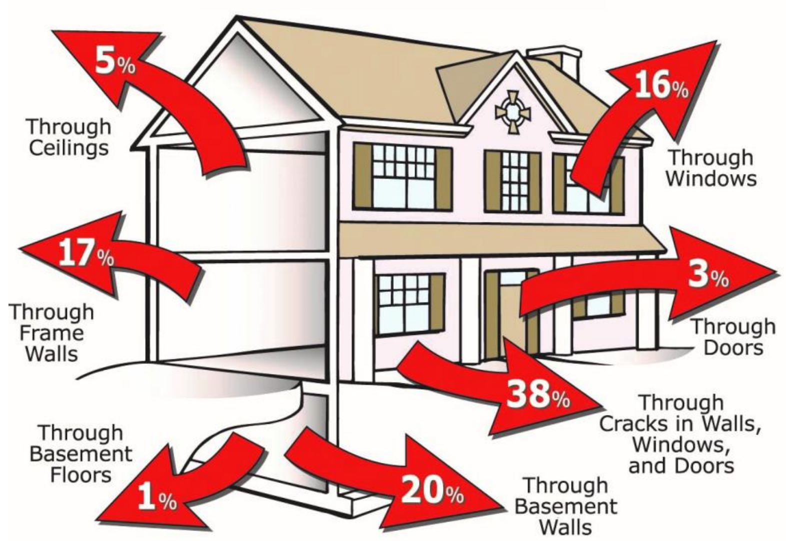
While interior polyethylene helps keep some types of wall dry during the winter (by limiting outward vapor diffusion), interior polyethylene may create problems during the summer, especially if the house is air conditioned.



How can I determine whether interior poly is good or bad?

The extent to which polyethylene is risky depends on many factors:

- The climate;
- The thickness of the exterior foam;
- The relative humidity of the interior air;
- The air leakage rate through the wall.



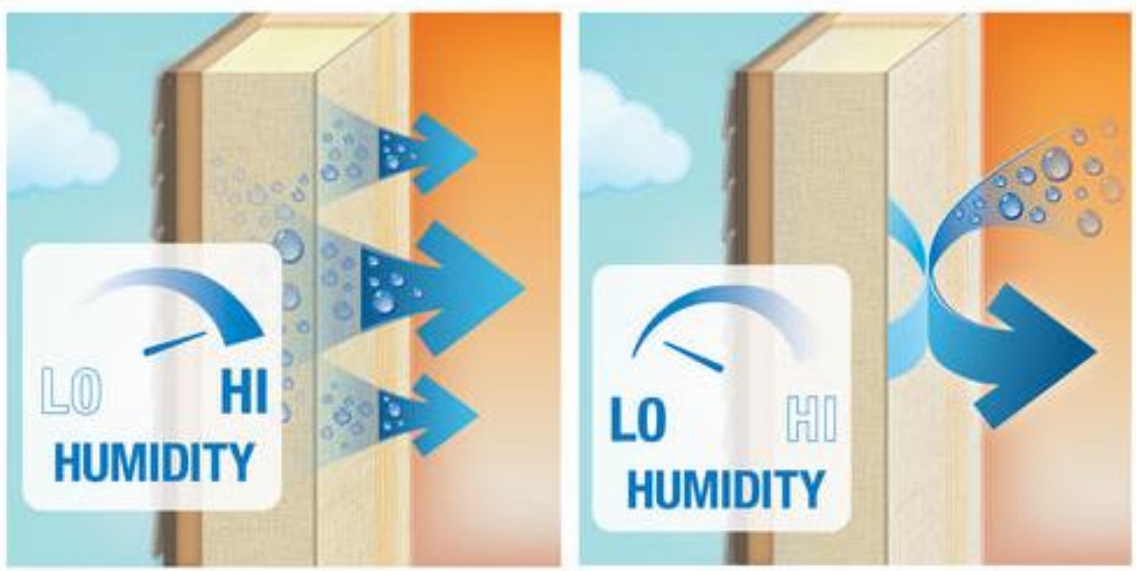
A “smart” vapor retarder reduces risk

In almost all climates, a so-called “smart” vapor retarder (a vapor retarder with variable vapor permeance, like MemBrain) is safer than interior polyethylene.

How do smart vapor retarders work?

When dry, smart vapor retarders inhibit the flow of water vapor.

But once the smart retarder gets damp, its permeance changes: it begins to allow water vapor to flow through it.

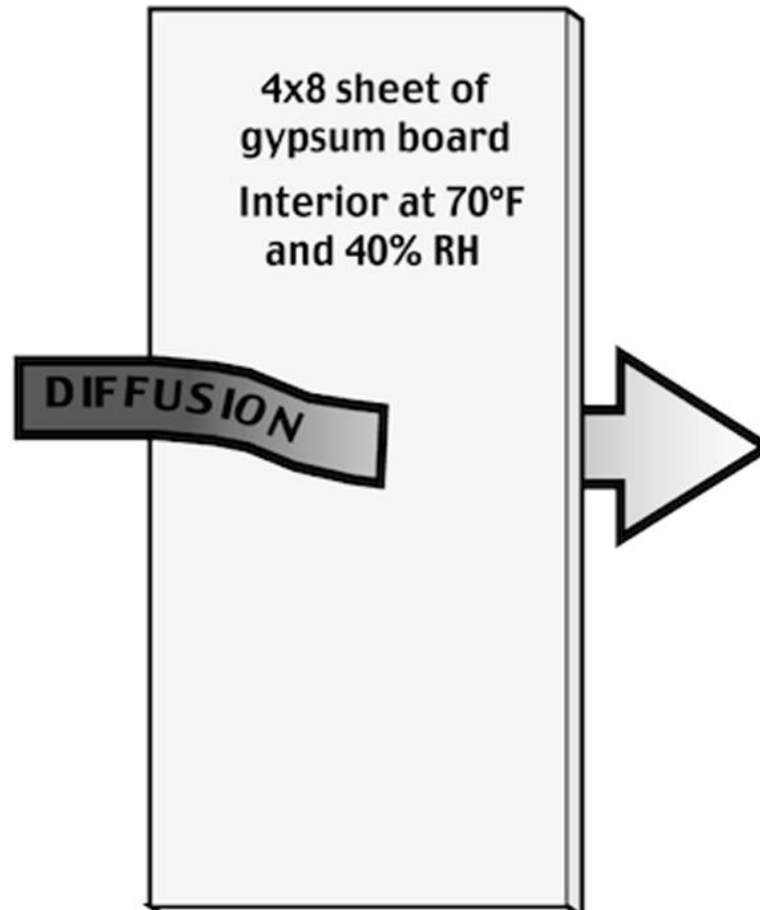


Smart vapor retarders affect diffusion, not exfiltration

In general, a smart vapor retarder doesn't affect air leakage rates.

A smart vapor retarder only affects the rate of vapor diffusion.

[Image credit: Building Science Corp.]



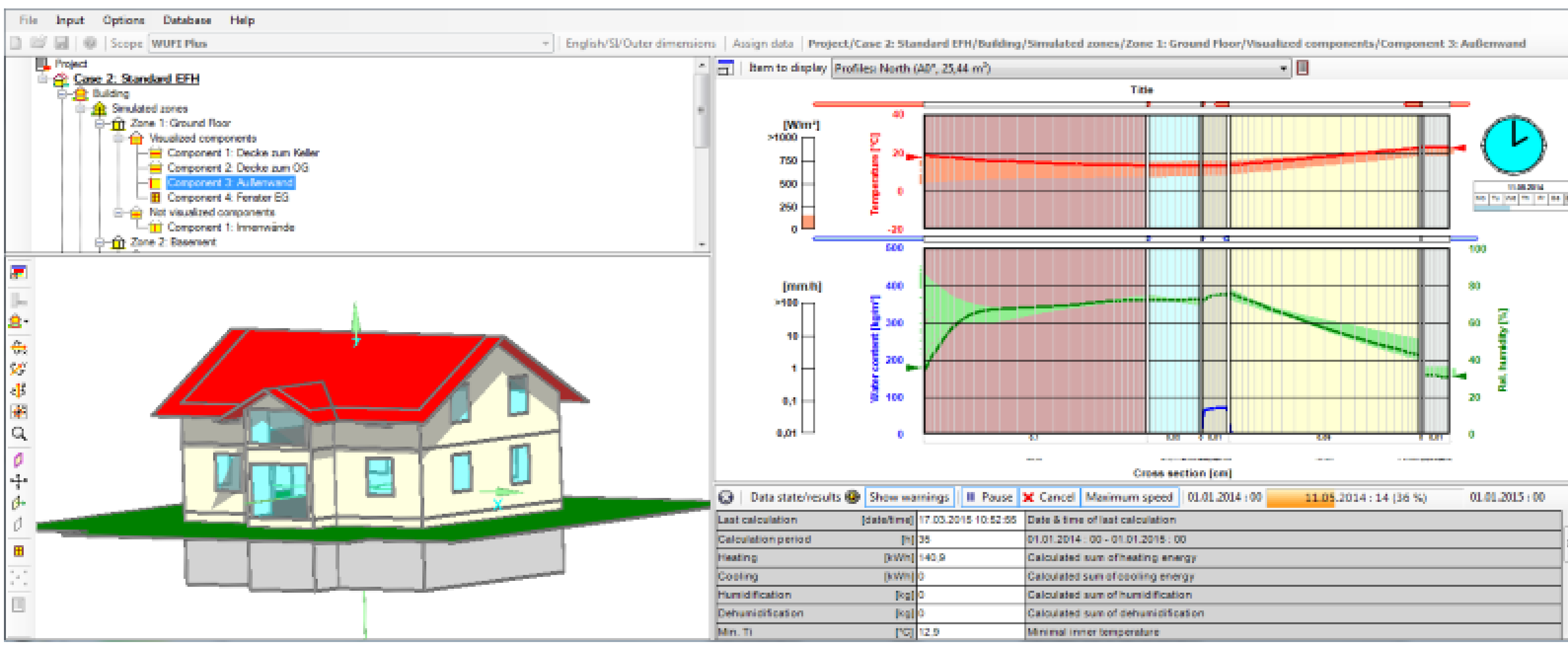
WUFI to the rescue?

One way to analyze a wall with too-thin foam is with hygrothermal software like WUFI. In the right hands, a WUFI analysis answers the question of risk. In unskilled hands, however, WUFI can provide an answer that is wrong and therefore worthless.

That's why **I rarely advise builders to perform a WUFI analysis**.

What is WUFI?

WUFI tells the user whether the moisture content of any wall components (or other building components) rises over time.



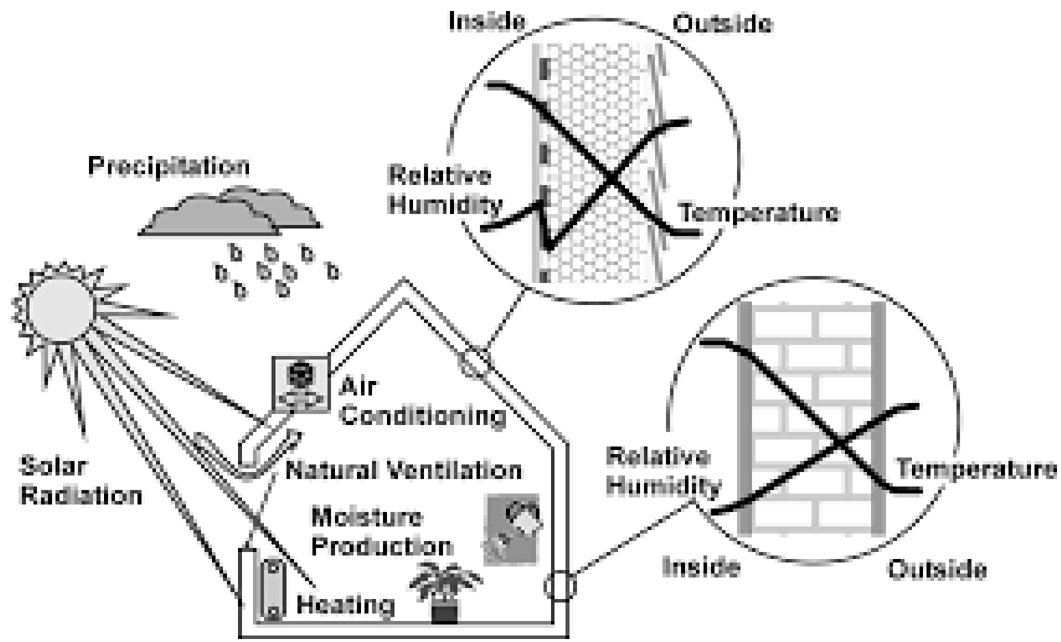
Who developed WUFI ?

WUFI was developed by Hartwig Künzel, a researcher from the Fraunhofer Institut Bauphysik in Holzkirchen, Germany.

The program was adapted for English-speaking users by Achilles Karagiozis, a building scientist who formerly worked at ORNL.

WUFI models moisture flows

The program includes complex algorithms governing heat transfer, adsorption, evaporation, condensation, air movement, and drying rates.



It’s a program for researchers

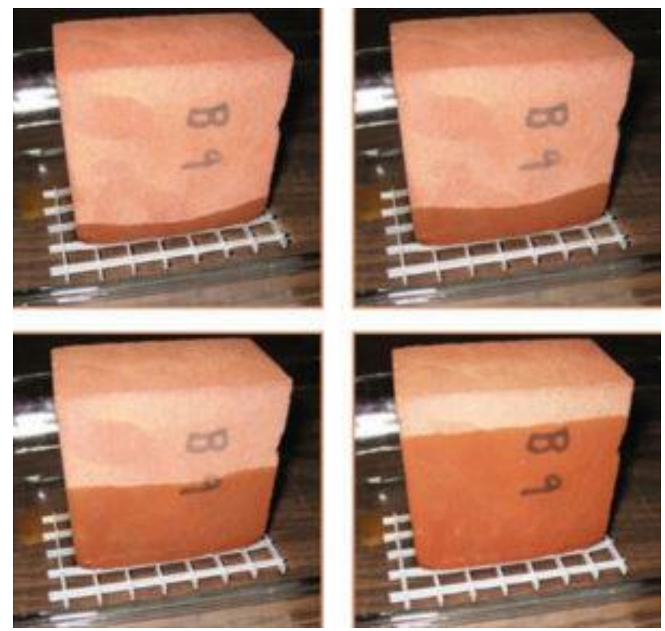
WUFI was developed for researchers, not architects, designers, or builders.

Problems with the WUFI approach

What inputs should I use?

Should I use defaults?

1. I don't know the materials characteristics of this particular brick or this brand of OSB.



2. I can't find my exact climate zone.

3. What interior conditions should I assume?

Lstiburek is also frustrated by WUFI

Lstiburek does not advise the use of WUFI by designers or architects.

Lstiburek said, “What you’re having to do is manipulate the properties of the model to force it into giving you the right answer.”

Stick with the rules!

Don’t install foam that is thinner than the standard recommendation.

In Vermont, that means that 2x6 walls need foam with a minimum R-value of R-11.25.

If you’ve already broken the rules…

Thanks!

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