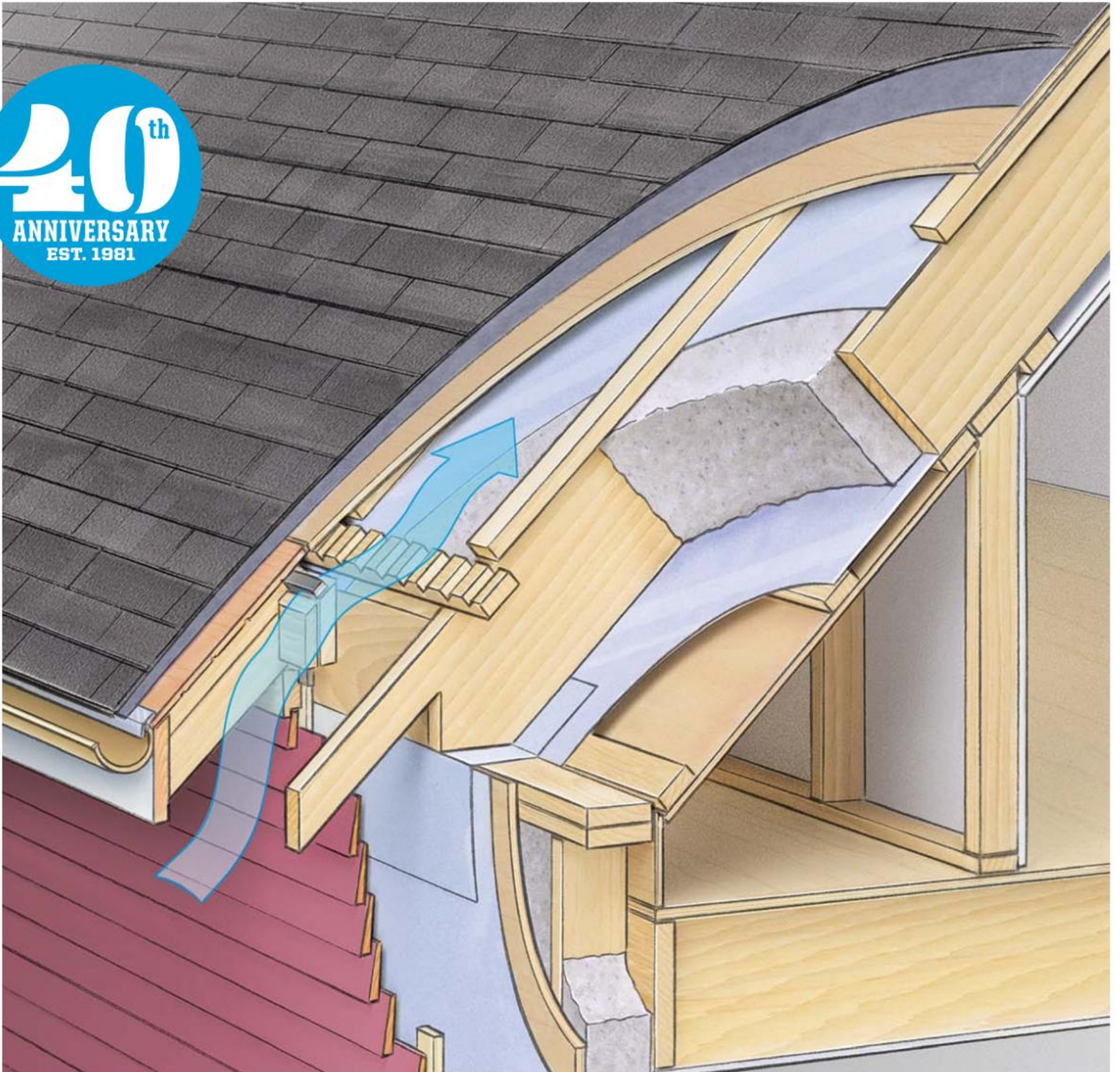


Fine Homebuilding

ISSUE 299 // JUNE 2021

A NEW WAY TO INSULATE ROOFS

This vented and vapor-open approach is energy-smart and durable, and a good option for mixed and cold climates





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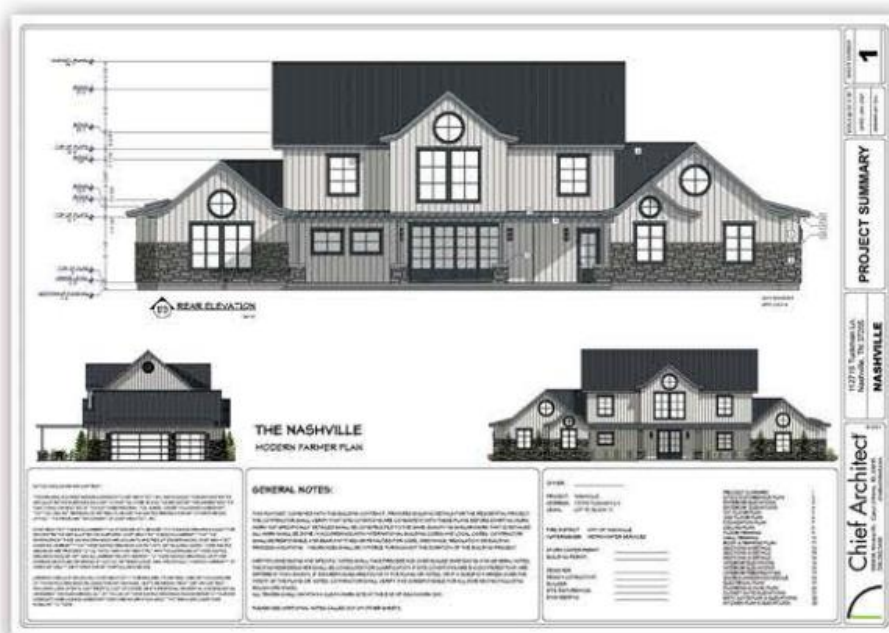
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Cover drawing by Dan Thornton



Private Residence, Chicago Installing contr.: Custom Installations Architect: Kipnis Architecture + Planning GC: Shardon Builders
Distributor: Sheet Metal Supply Photographer: A.J. Brown Profile: Snap-Clad metal roofing Color: Weathered Zinc



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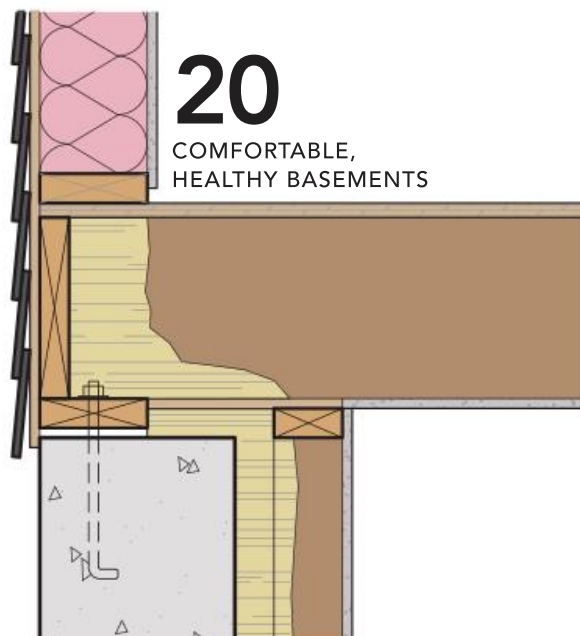
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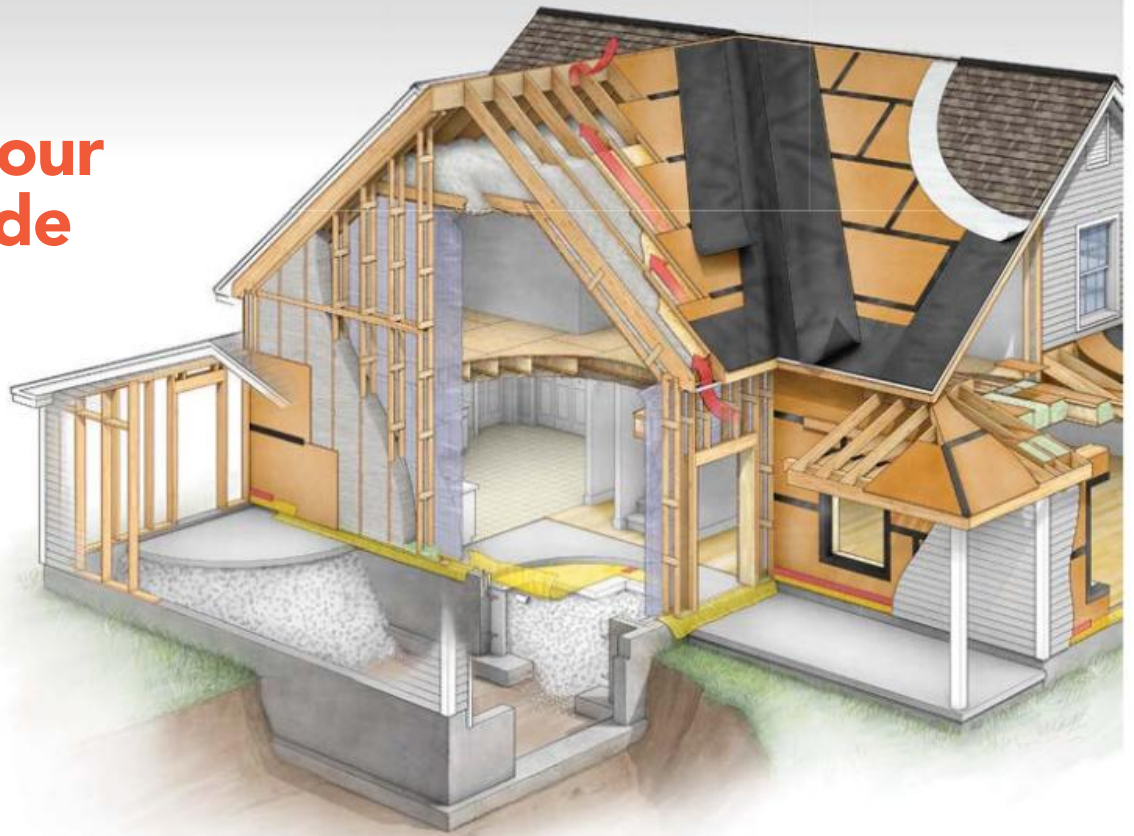
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Job-Site Diaries: Benefits of Building With ICFs

Builder Josh Salinger explains how an insulated-concrete-form (ICF) foundation boosts energy performance on this new home.



Episode 311: Getting off Gas

The editors discuss why some municipalities are trying to pressure homeowners to go all-electric: FineHomebuilding.com/podcast.



Discussion forum: Siding for extreme wind and rain

A homeowner in coastal Alaska asks for advice for protecting or replacing weatherbeaten cement clapboard siding. See what others suggest, offer advice, or ask a question of your own at FineHomebuilding.com/forum



Drying in a Roof With ZIP System Sheathing

In this Shop Class video series, builder Tony Blue walks through the entire process of installing waterproof and airtight roof sheathing. Watch the seven-part miniseries at FineHomebuilding.com/blog/shop-class.

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THE VOICES OF EXPERIENCE



As one of those kids who took things apart and then reassembled them, **DAN THORNTON** was always interested in how things work. His illustrations have appeared in *Fine Homebuilding* magazine as far back as issue #90. Since then, Dan has illustrated everything from simple jigs to cutaway views of entire wall systems, constantly building his knowledge of how things are made. In this issue, his drawings are featured on the front cover and in "A New Take on Insulating a Roof" (p. 34), and in Ask the Experts (p. 82).

Assistant editor **LANA MELONAKOS-HARRISON** (Spec, pp. 79-81) has a background in communications in nonprofit and for-profit settings. A California native who has lived in urban, suburban, and rural areas, Lana enjoys investigating how the built environment impacts our experiences, and how integrating old traditions with new ideas can improve quality of life. She has put these ideas into practice coordinating public art and other placemaking projects and participating in advocacy efforts centered around housing.



In 2007, **JOSH SALINGER** ("A New Take on Insulating a Roof," pp. 32-37) founded Birdsmouth Design-Build in Portland, Ore., with the goal of designing and building beautiful, high-performing homes that improve the built environment. Josh has certifications from Earth Advantage's Sustainable Homes Professional course, is an early graduate of the Passive House Builders training program at PHIUS, and is an accredited EEBA Zero Energy Building Professional. He lives in the Mt. Tabor neighborhood of Portland.

write an article

Fine Homebuilding welcomes articles from our readers. We'll acknowledge all proposals and return any we can't use, and we'll pay for any articles we publish. For details, check our website at FineHomebuilding.com.

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Shared objectives

As the debate around climate change ramps up, so does awareness of the potential implications of global warming. This motivates many in the green-building industry to consider materials and methods with an eye toward the future health of the planet. For others, this “existential threat” doesn’t resonate. So, where does that leave us in terms of how we build? If we take the predicted risks seriously and adopt practices for designing and building homes that lower their environmental impact, and climate change turns out to be a nonissue, what’s the downside? We would have a new stock of homes with lower operating costs that are more durable, lower maintenance, more comfortable to live in, and healthier for their occupants than most homes built today.

Such are the ideas that drive the community behind Green Building Advisor (GBA), *Fine Homebuilding’s* sister website. Its members come from diverse disciplines and perspectives, but the collective goal is to build better. What started as a fringe movement (green building) has grown up and is based in modern building science, which is physics, not fluff. That’s why we are filling this issue with content from GBA—because green building has become best practice.

GBA covers topics such as environmentally sensitive design, cutting-edge materials, energy-efficient construction techniques, must-know building science, and relevant building codes—and that is what you will find in the following pages. Josh Salinger’s piece, “A New Take on Insulating a Roof” (pp. 32-37), demonstrates the ways in which green-minded builders constantly innovate around the details of complicated assemblies. He has developed methods for building low-energy homes with minimized greenhouse-gas emissions and low embodied carbon. He goes on to share his solution to insulating a vaulted ceiling without the use of plastic-foam insulation.

In “A Better Way to Demo” (pp. 66-71), Asa Christiana takes us to Portland, Ore., a city looking to do right when it comes to teardowns. It passed the country’s first deconstruction ordinance, an updated version of which mandates piece-by-piece dismantling of houses built before 1940, with the goal of protecting human and environmental health. We learn what the process entails and the payoffs it promises.

Determining the right mechanical systems for a house based on heating and cooling loads and ventilation requirements is a layered process in and of itself. Add energy conservation to the goals and you’ve got a bigger ball of wax. In “All About HVAC” (pp. 38-45), Scott Gibson gives us an abbreviated road map to making smart choices.

At heart, the authors who contributed to this issue comprise a group of people who want to build beyond code minimum, no matter the motivation. Here they provide a snapshot of some ways and means for doing that. I hope it proves a valuable stepping stone on the path to better building.

—KILEY JACQUES
senior editor, Green Building Advisor



Cedar-siding inspiration. Of all siding types, cedar shingles may have the most creative potential. This reader recreated a historical cedar-shake detail using modern cedar shingles.

Another cedar detail

I enjoyed “Sidewall Shingles With a Flare” in the February/March issue (FHB #297). We have an old family home in Oregon with another unique cedar-siding detail. The home was originally sided with 30-in. hand-split cedar shakes, each course 12 in. to the weather. The original shakes were hand-split from cedar driftwood at the job site. The house is right on the coast, and in the 1930s there were lots of logs transported in local rivers and excellent timber could be found washed up on the beach.

We wanted to preserve the original look as we made repairs over the years, but couldn’t find any shakes of comparable size. After consulting with the Cedar Shake & Shingle Bureau, mentioned in your article, we opted for the technique of “double coursing,” which uses 16-in. cedar shingles in double lay-



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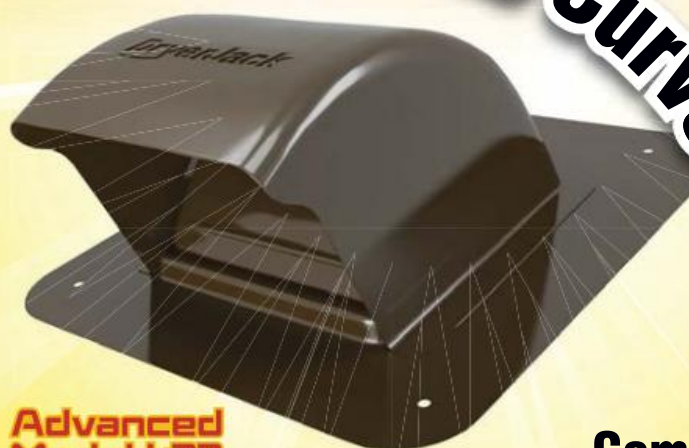
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—BRIAN PONTOLILLO
editorial director

ers, with 12-in. courses and thick butts that resemble the original shakes.

As suggested, we used #2 shingles on the inner course and more refined #1 shingles on the visible outer course. The inner course is fasted with 4d galvanized nails and the outer with barbed-shank stainless-steel nails, dyed brown since their heads show. Starter courses are two layers of #2 shingles with #1 shingles on top.

It really gives the feel of the original coarse shakes and the same deep shadowlines. We are quite pleased and after 20 years the building has almost been completely re-sided.

—DOUG THOM
via email

More porches, please

My husband and I read *Fine Homebuilding* magazine for years and found it very useful in planning our dream retirement home in Michigan. But we were always mystified by the popularity of decks, which are unusable in rainy or cold weather and expose the users to mosquitoes and other pesky insects. When we built our home, we made sure to have a covered screened-in porch as well as a small four-season sunroom so we can enjoy the out-

doors no matter the weather or the season. Although our house is finished, it would be nice to see more articles on screened-in porches and sunrooms.

—JANE MORSE
via email

Congratulations Chuck

As one of his tipsters, I wanted to send Chuck Miller a heartfelt congratulations on his 40th anniversary with *FHB*. What an achievement he has earned as a result of his dedication and hard work. I can't tell you how much I value what he does day in and day out. My career and craft benefit from it every issue. I get that your readers and participants are a big part of your work. That aside, what you do with their ideas—how you communicate it—makes all the difference. Having one central, reliable source makes it easy for us readers to feed you that data. I look forward to continuing working with you and *FHB* in the future. Keep up the good work, Chuck! Please stay for another forty.

—MIKE ALEXANDER
Monrovia, Md.

Doors should stay put

Regarding the tip "Temporary door control" (*FHB* #297)—beyond being something to trip over, why is it even necessary? If a door you've just hung swings open on its own, you've clearly botched the job. A properly installed, dead-plumb door should stay right where you put it—fully closed, fully open, or anywhere in between.

—ARNE WALDSTEIN
Housatonic, Mass.

Safety contradictions

I find it very disquieting that the cover of the March issue (*FHB* #297) features a picture

of carpenters setting roof trusses while not wearing hard hats or any fall-protection equipment in light of the cover-featured article in the September 2020 issue (*FHB* #293) about the proper use of fall-protection equipment. I also find this upsetting because every issue contains a warning of the inherent dangers of construction work and the necessity for safe working habits.

I fortunately escaped serious head injury when I fell from a roof when the extension ladder collapsed under me as I swung around to begin my descent. The general contractor on the job mandated that hard hats be worn at all times. I feel this saved me from serious head injury as the ladder tipped one way and I fell the other. I hit the ground on my side and head. Luckily, I received only minor cuts and much bruising to my face and neck.

I was partly at fault since I neglected to secure the top of the ladder when I climbed to the roof. I was only going to be up there for five or 10 minutes and it was a five-minute walk to the other side of the building to get a bungee strap. It was a very windy day with gusts up to 40 to 50 mph, and of course the ladder blew over while I was on the roof. Someone came along and reset the ladder for me but neglected to make sure the rung locks were engaged. Imagine my surprise when the ladder collapsed under me as I put my full weight on it. I developed much greater respect and attention to proper work habits after that. It's very easy to develop an attitude of "I know what I'm doing," and "That won't happen to me."

—PHIL WAGENER
via email

Reader says, ditch the decks. Seeing the weather and seasonal dependence of decks, this reader asks why more people aren't building more porches that can be used in any weather and even year-round.





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BY GLENN MATHEWSON

Energy codes as clear as glass

If not for local ordinances that would likely prohibit it, you could, in some half-baked pursuit of energy efficiency, build a house with no windows—the 2021 International Residential Code (IRC) won’t stand in your way (and people say the code is restrictive!). You couldn’t have done this in the 1800s, though. Before electric light was allowed as an exception, windows were required in order to provide natural light and reduce the use of candles and lanterns during daylight hours (largely to reduce fire risk). More recently, the need for windows to provide ventilation has been circumvented by the introduction of whole-house ventilation systems.

Whether windows are required or provided by choice, the code has long-addressed various safety concerns, from safety glazing in hazardous locations to emergency escape and rescue openings (EEROs). With the rising importance of energy conservation, it has added requirements to manage the energy penalties that can come with them.

Paths to code compliance

The energy crisis of the late ’70s brought energy-efficiency

considerations to many aspects of building, including window-code provisions. Though they have evolved, window-efficiency requirements today address the same two subjects originally targeted in the code: thermal transmission and air leakage. One requirement that was later added and then dropped is window-to-wall ratio. Just as you can build a windowless house, you can also build an all-window house. This makes sense on a couple levels. For one, windows have improved dramatically and can conceivably perform better than walls in some designs (for an example of this, see “Trombe Wall Solution,” pp. 50-55). More importantly, the code is designed to address the probable, not the possible. The free market will take care of outliers like all-glass houses.

Unlike other parts of the code that are largely aimed at protecting life and limb within the well-established goals, practices, and assemblies of architecture and construction, the energy-code provisions started out as outliers. They were located in optional “appendix” chapters and specialized books, and for acceptance, they needed to be flexible in their applica-

tion. It’s convenient that they are bound in scientific and mathematical principles, as this allows different methods of code compliance to be compared against each other in near equivalency. In short, energy codes are full of options. Values discussed in this article are for the “prescriptive” method, where you simply have to meet minimum requirements for each performance characteristic.

From those values, however, the performance of individual features can be traded to yield an overall equivalency, such as a higher R-value in the ceiling insulation coupled with lower-performing windows. Similarly, another method allows the estimated cost of energy consumption attributed to various subjects to be flexible, provided the sum of cost is less than a standardized estimate. This method could allow for lower-performing windows to be offset by a high-performance heating system, for example. Altogether, the energy code provides four (or more, depending on how you count) different paths to get to the code’s minimum-required efficiencies, and with the ability to mix and match assemblies and components, and even use

Check the label.
The ratings labels on factory-built windows provide the performance data needed to comply with the energy code’s prescriptive window requirements.



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Actual test sample .03 air leakage.	

different compliance paths for different assemblies within the same home, there are more ways to meet code for any one home than we could even begin to cover here. Here’s what you need to know to select windows using the prescriptive path.

Thermal transmission

Windows are evaluated not by R-value—the resistance to heat movement—but by U-factor, which measures heat transmission. This is a mathematical relationship, where U-factor is the reciprocal of R-value ($1 / R\text{-value} = U\text{-factor}$). A lower U-factor in a window is like a higher R-value in a wall. Just as the minimum R-value increases in colder climates, the maximum-allowed U-factor decreases in cold climates. Lumped together with doors under the word “fenestration,”

First we went above.



IRC Table N1102.1.2 provides maximum U-factors (minimum performance) between 0.50 and 0.30 for climate zones 1 (warm) through 8 (cold).

U-factor only measures the non-solar-heat movement through the window assembly. Essentially, it measures heat lost from indoor air to the outside when it's cold out, and heat gained from outdoor air when it's hot. Though cooling is not required by the code in the way heating is, warmer climate zones still have requirements to limit the heat gain via solar radiation through the window. The solar-heat-gain coefficient (SHGC) is like the U-factor in that the lower the value, the less solar radiation the window transmits inside. The same table referenced previously provides maximum SHGCs from 0.25 to 0.40 for climate zones 1 through 4. In colder climates, there is no SHGC requirement, as the warm sun is typically welcome in the heating season and can improve a home's overall energy efficiency.

As in nearly all code subjects, there are exceptions that address specific considerations. For example, one might want a fancy glass front door, or a window that incorporates Grandpa's stained glass from the old family homestead. Just as provisions for safety glazing have exceptions for decorative glazing (stained glass), so does the energy code. Not specific to decorative glazing, Section N1102.3.3 allows up to 15 sq. ft. of glazing to be exempt from all U-factor and SHGC requirements in each dwelling. Additionally, Section N1102.3.4 exempts a single opaque door, often used for a front door, from these requirements.

Air transmission

Heat can bypass all the units of measurement we've discussed thus far when traveling through a gap on a current of air. Factory-built windows must be laboratory tested to meet code minimums for air leakage. A window can have no greater air infiltration than 0.3 cfm per sq. ft. in accordance with the NFRC 400 standard from the National Fenestration Rating Council or with the AAMA/WDMA/CSA 101/I.S.2/A440 standard from the—what? Never mind.

For the majority of mainstream manufactured windows, the title of that standard won't

out testing, they're assigned default values based on the type of construction, given in Tables N1101.10.3(1) through N1101.10.3(3)]. For new construction, subject to maximum air-leakage rates verified by blower-door tests, leaky site-built windows will be revealed and will have to be offset by tighter construction elsewhere or repaired.

Window replacements

Though I often use automobile standards as a comparison to building-code standards, the analogy falls apart when discussing repairs and rebuilds. You can't rebuild a house to

facing windows could be lower performing to reduce costs, while being offset by higher-performing but basic bedroom windows. This design option can also be utilized in new construction using prescriptive methods without trading assemblies or evaluating energy costs. The intent is to provide maximum design and cost-analysis freedom.

Though not related to the energy code, emergency escape and rescue openings (EEROs) must be addressed when discussing window replacements. Replacement windows that fit inside existing frames often reduce the size of the clear opening below the minimum size typically required for an EERO. Inspectors have been known to derail window replacements on these grounds. However, the IRC has taken a larger look at this and allows replacements that may reduce the opening size, provided they are the largest standard size the manufacturer makes for the rough opening and either the same style or a style with a larger opening.

Though on paper this may appear to reduce safety, in reality, many older windows are very difficult to operate, have broken latches, or are sealed completely shut. In other words, old windows can have more problems than just energy loss. A new window with easy, smooth, and functional operation may yield a slightly smaller opening, but may ultimately offer more safety in addition to better energy efficiency.

Glenn Mathewson is a consultant and educator with BuildingCodeCollege.com.

"Large and ornate main-level, street-facing windows could be lower performing to reduce costs, while being offset by higher-performing but basic bedroom windows."

matter. The various values and test listings of energy-code compliance are provided on the label adhered to each window, typically an NFRC label. It's a good idea to leave those labels on the windows until after you get a final inspection. You won't need labels, though, for site-built windows such as the stained glass you moved from the farmhouse. Site-built windows are excepted from air-leakage requirements [though not from U-factor and SHGC requirements—with-

old standards like you can a car. Full window replacements (not simply reglazing a broken pane), must meet the same standards as new construction for U-factor, SHGC, and air leakage—but as always, there are options. When more than one window is replaced, an area-weighted average of all the windows can be taken for both U-factor and SHGC. This allows for higher-performing windows to offset lower-performing windows. Large and ornate main-level, street-

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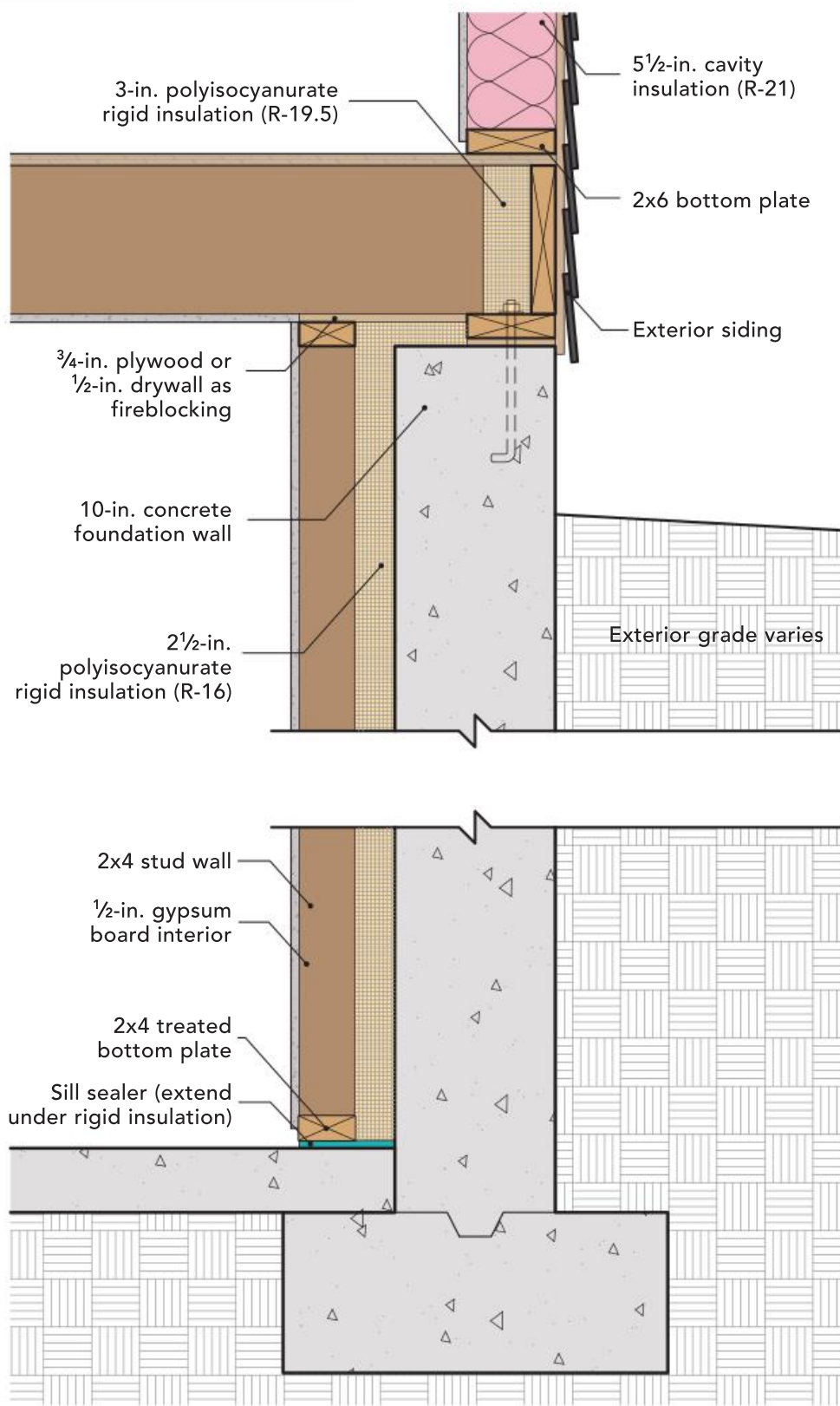


Three ways to insulate basement walls

BY MARTIN HOLLADAY

Basement-wall insulation can be placed on the exterior side of the wall, on the interior side of the wall, or on both sides of the wall. When the basement wall is insulated from the interior, there are a few different ways to achieve minimum R-values. This article illustrates the three most common options: continuous rigid insulation, a combination of continuous rigid insulation and insulation batts, or closed-cell spray foam. Regardless of the insulation method you choose, here are some things to keep in mind.

The first step is to make sure your basement is dry. Before installing any interior-wall insulation, verify that your basement doesn't have a water-entry problem. Next, consider your climate zone and code-minimum R-values. Basement insulation required by the 2012, 2015, and 2018 International Residential Code (IRC) is as follows: at least R-5 in climate zone 3, R-10 in zone 4 (except marine zone 4), and



A CONTINUOUS LAYER OF INTERIOR RIGID FOAM

One simple way to insulate the interior of a basement wall is with a continuous layer of rigid foam that is thick enough to meet the minimum R-value for your climate zone. If you can't reach your R-value target with one layer of rigid foam, it's perfectly acceptable to install two layers of rigid foam. (If you are installing two layers, make sure to stagger the foam seams.) Rigid foam can be adhered to concrete with foam-compatible adhesive or can be attached with special fasteners like Hilti IDP or Rodenhouse Plasti-Grip PMF anchors. Once the rigid foam is installed, you can install a 2x4 stud wall on the interior side of the rigid foam, or you can install 1x4 strapping, 16 in. on center, to facilitate installation of the drywall. If you frame a 2x4 wall, don't forget to install fireblocking at the top of the wall.

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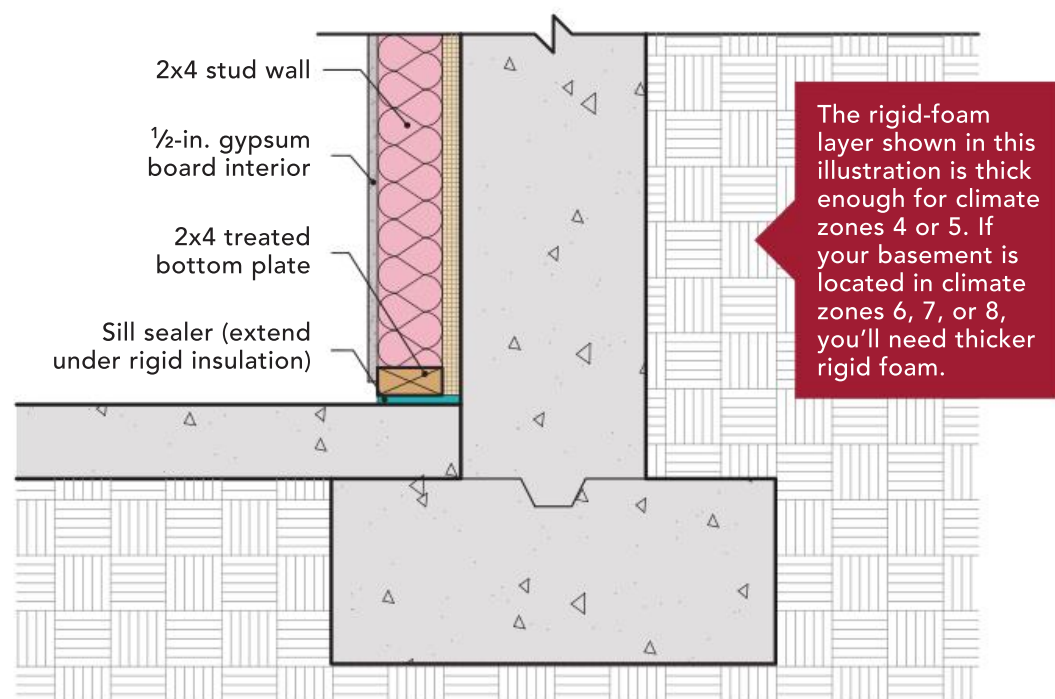
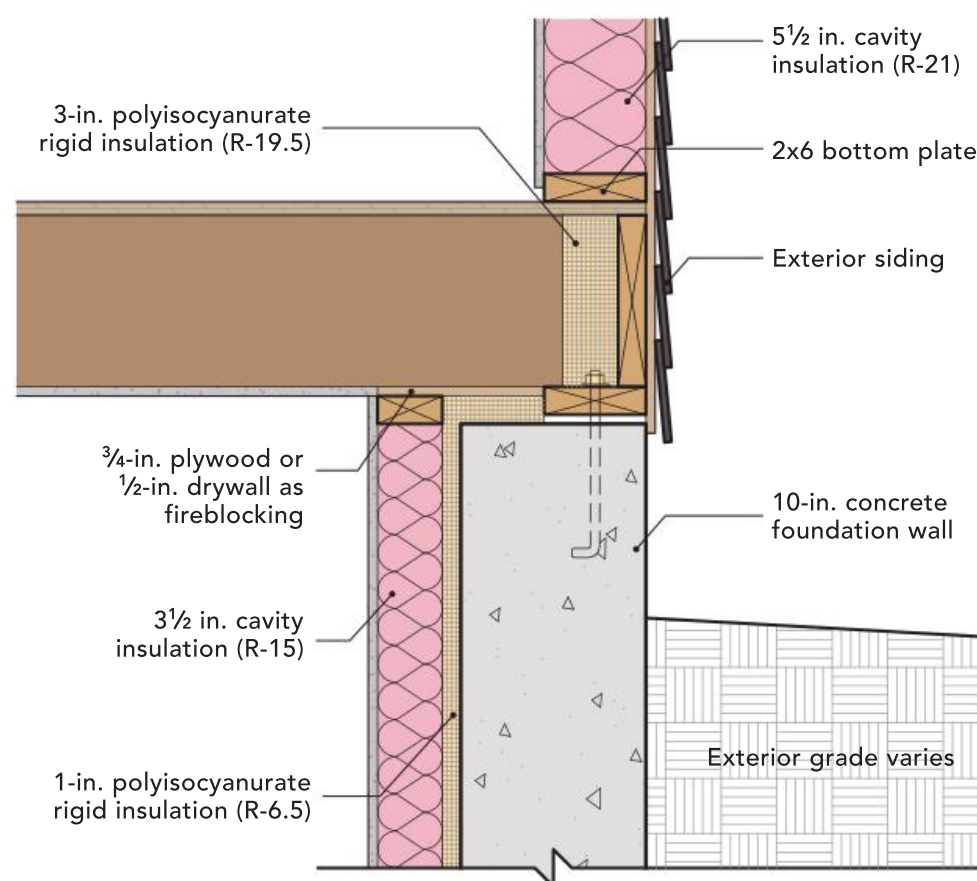
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CONTINUOUS INTERIOR RIGID FOAM WITH ADJACENT STUD WALL FILLED WITH FIBERGLASS OR MINERAL-WOOL BATTS

Many builders prefer to leave the stud bays uninsulated, as shown in the previous assembly (p. 20), because it's common for basements to experience occasional flooding, and fibrous insulation becomes a soggy mess if it ever gets wet. On the other hand, you may prefer to boost the assembly's R-value by insulating between the studs. If so, keep two principles in mind. First, your rigid foam layer needs to be thick enough to prevent condensation problems. A conservative approach calls for at least R-2.5 of rigid foam in climate zone 3, at least R-5 of rigid foam in zones 4 or 5, at least R-7.5 of rigid foam in zone 6, and at least R-10 of rigid foam in zones 7 or 8. Second, mineral-wool batts generally perform better in damp environments than fiberglass batts.



R-15 in zones 5, 6, 7, and 8 and marine zone 4. That said, local codes may differ from these general guidelines, so it's worth asking your local building department about minimum R-value requirements in your community.

Note that the IRC lists two different R-value requirements for basement walls: a lower number (for example, R-15 in zone 5) for continuous foam, and a higher number (for example, R-19 in zone 5) for "cavity insulation"—usually interpreted as fluffy insulation like fiberglass installed between studs. Since it is inadvisable to insulate a basement wall with fluffy insulation like fiberglass unless the wall has first been insulated with a layer of continuous rigid foam or spray foam, it's generally best to focus on an approach that uses continuous insulation, and to ignore the "cavity insulation" approach.

On the interior side of a basement wall, all three common types of rigid-foam insulation—polyisocyanurate, expanded polystyrene (EPS), or extruded polystyrene (XPS)—perform well. That said, green builders usually avoid the use of XPS, since most brands are manufactured with a blowing agent that has a high global-warming potential. Problematic blowing agents are also used in most brands of closed-cell spray foam, so if you plan to use closed-cell spray foam, seek out a brand of insulation that uses one of the new, more environmentally friendly blowing agents—for example, Heatlok HFO spray foam from Huntsman Building Solutions.

Basement-wall systems should never include polyethylene sheeting—neither between the concrete and the foam insulation, nor between the gypsum drywall and the insulation. In these locations, polyethylene can trap moisture, leading to mold or rot.

If you live in an area where termites are a problem, your local building code may require that you leave a 3-in.-high termite-inspection strip of bare concrete near the top of your basement wall. These requirements vary widely from jurisdiction to jurisdiction, so it's wise to seek local advice on this issue.

Don't forget about airtightness as well. During the winter, indoor air tends to be



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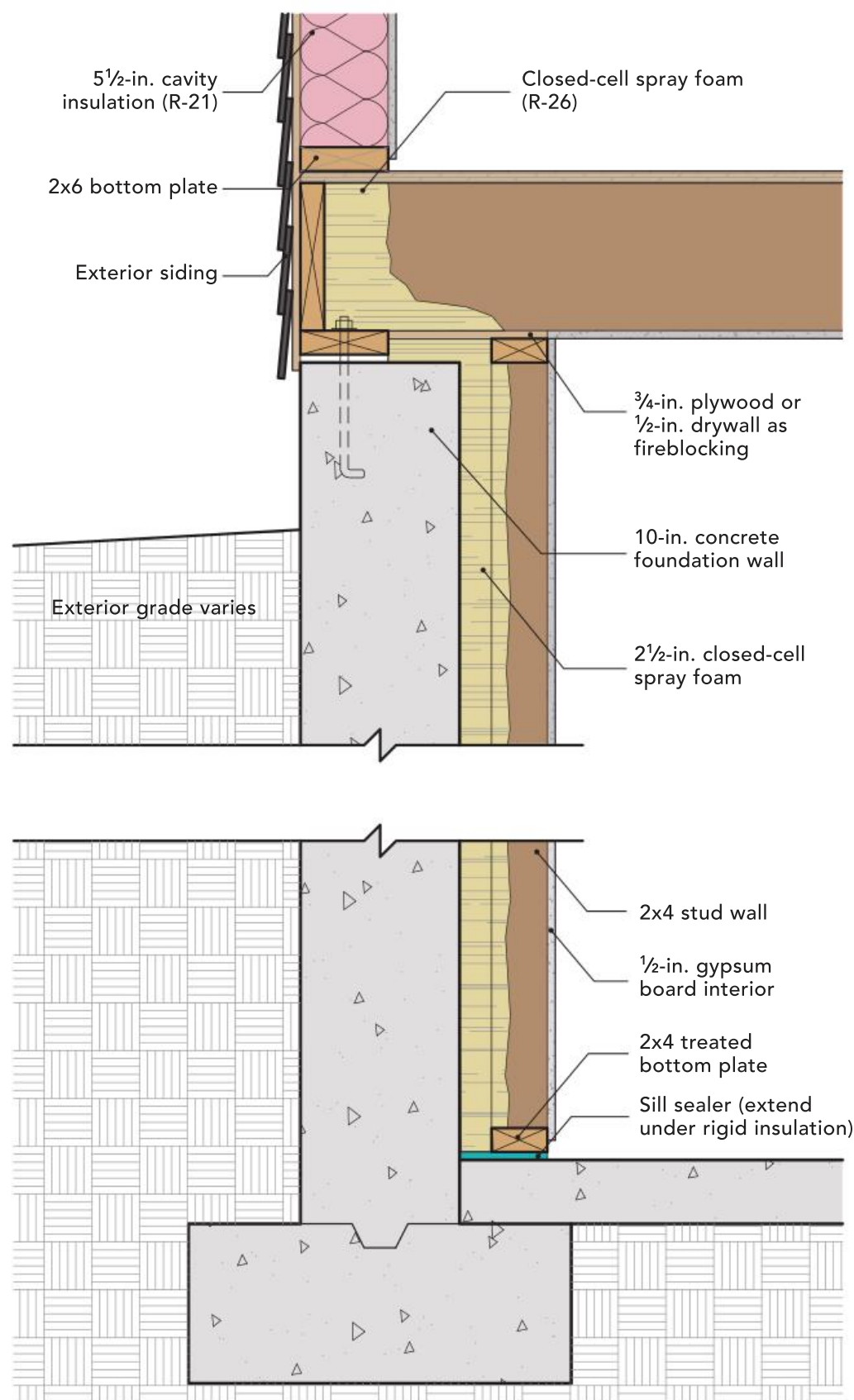
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INTERIOR CLOSED-CELL SPRAY FOAM

If you plan to insulate your basement walls with spray foam, you'll want to frame your 2x4 walls before the foam is sprayed, leaving a gap of 1½ in. to 2 in. between the back of the studs and the concrete wall. The gap will be filled later with closed-cell spray foam. (Note that open-cell spray foam is too vapor-permeable to be suitable for basement walls.)

If your basement has stone-and-mortar walls, you can't insulate them with rigid foam—the only type of insulation that makes sense for stone-and-mortar walls is closed-cell spray foam. Although it's possible to buy do-it-yourself two-component spray-foam kits for this type of job, it's generally less expensive to hire a spray-foam contractor for large jobs like basement walls.



warm and humid, while concrete foundation walls tend to be cold, setting up ideal conditions for potential condensation. You can limit the chance of condensation or mold by preventing any interior air from contacting cold concrete. If you are installing interior rigid foam, all of the foam seams need to be sealed with caulk, high-quality tape, or canned spray foam. If you are hiring a spray-foam contractor to insulate your wall, make sure that there are no gaps or shrinkage cracks in the foam that could allow indoor air to contact the concrete.

When rigid foam or spray foam is installed on the interior side of a basement wall, the foam must be separated from living spaces by a so-called thermal barrier—that is, a layer of ½-in. drywall or a material that has been approved as equivalent in fire resistance to ½-in. drywall. If you don't want to install any drywall, you can use Thermax, a brand of rigid-foam insulation that can be left exposed (because it has passed tests for thermal resistance), or you can use mineral-wool insulation as a thermal barrier.

And remember—if you're installing interior basement-wall insulation, don't forget to insulate the rim joists.

In most U.S. locations, basement-wall insulation is required by code. Properly installed, basement insulation will save energy, improve comfort, and reduce the likelihood that your walls will be damp. With a lower chance of dampness, there will be fewer opportunities for mold growth—so your insulated basement will probably smell better than it used to.

Martin Holladay is a retired editor living in Vermont. Drawings by Alexandra Baczek.

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DIAGNOSTIC THERMOSTATS

I knew high-end thermostats and HVAC equipment were getting smarter, but one of the first systems we installed hardly seemed like a success when it turned itself off on cold days. However, it was kind of cool to walk up to the thermostat and read a plain-language explanation that the problem was static pressure. Apparently, the old, undersized ductwork couldn't handle the airflow when the blower ramped up, so the smart machines turned themselves off for self-preservation.

Smart thermostats also learn how long systems run on very cold or hot days, which tells us the real heating or cooling load, how much a system is oversized, and what size will work better. Some thermostats also make setting up zone damper systems much more reliable. In my experience with these complicated setups, it's easy to make mistakes like accidentally connecting the zone three damper to the zone two thermostat.

Smart modern thermostats that connect to the internet allow for quicker, more accurate diagnostics. I can log in from my home office and see what's happening on a system 50 miles away. I can see if it's something the homeowner can fix—clogged filter or wrong thermostat setting—or if I need to call a pro. We can even set it up so we get emails or texts when the system shuts off because of a problem. Just remember to turn notifications off when you're on vacation, or you might find yourself in a dark hotel room with five systems texting you about power-line instability.

Doug Horgan, vice president of best practices for BOWA in McLean, Va.

ECOBEE

Ecobee smart thermostats work with most typical HVAC systems with standard thermostat wiring. The diagnostics aren't as sophisticated as HVAC-equipment-brand thermostats that tie directly into a system's main board, like the thermostats shown below, but they do record run times so you can tell how oversized your system is. They can also add other smart features to an existing system, like automatic setback and remote monitoring and control.



WATERFURNACE

Some WaterFurnace thermostats record the state of each zone thermostat, zone damper, and the main machine's status every fifteen seconds. Wi-Fi accessories upload dozens of sensor readings to the internet multiple times per minute, which is helpful for diagnosing strange behavior. But keep data recording to a few weeks—I once created a million-line spreadsheet that made my computer cry.

CARRIER

The latest Carrier thermostats can quickly verify that zones are set up correctly and test their airflow to set fan speeds. The technology seems to be a work in progress, though—it's supposed to detect dampers wired backward, but I found a system where it couldn't find this problem. Still, its useful features allow us to provide better comfort for our clients and fix problems faster and easier.





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Powerful manometers

The digital manometer is the backbone of an energy rater's tool kit, used dozens of times a day. There are two at the top of the field: The Energy Conservatory (TEC) DG-1000 and Retrotec's DM32. These manometers can measure air pressure in two places at once and are used for home-performance testing, duct-tightness testing, and building diagnostics. They're touch-screen controlled and have built-in Wi-Fi and rechargeable batteries.

The basic functions of the two manometers are similar. Both show pressure and/or flow on the screen, as well as the selected setup and flow ring. Both create a Wi-Fi signal for connection to a phone for remote control of the gauge, which is very useful for testing multifamily buildings and producing app-based reports. Both have automatic fan-speed controls for reaching target pressure and graphics that show the correct tubing setups for common test scenarios.

An ability to update the software and firmware makes these instruments relatively futureproof and a solid long-term investment. While both devices perform as advertised, the Retrotec is superior. Our company recently replaced nine TEC DG-700s, TEC's previous manometer, with DM32s, because the DM32 starts faster, has better features, and is more-rugged than the DG-1000.

Ross MacPherson, operations manager for New England Air Barrier in Sagamore Beach, Mass. Jacob Bodah of Home Energy Raters LLC also contributed to this article.



Retrotec DM32

Recommended recalibration 5 years (\$165 plus two-way shipping)

Start-up time 10 seconds

Software update method USB to PC with Retrotec software

Equipment compatibility All Retrotec equipment and TEC blower doors, duct blasters, True Flow, and exhaust fan flow hood

Multipoint blower door Capable with Wi-Fi and companion phone app

Battery life Up to 11 hours

Screen size 3.2 in. vertical

Price \$1600



TEC DG-1000

Recommended recalibration 2 years (\$135 plus one-way shipping)

Start-up time 1 min. 26 seconds (45 seconds to main screen, 41 seconds to gauge ready)

Software update method Wi-Fi connection

Equipment compatibility All TEC equipment (user-friendly digital assistant walks through various setup options on screen)

Multipoint blower door Capable with PC and TEC software

Battery life Up to 15 hours

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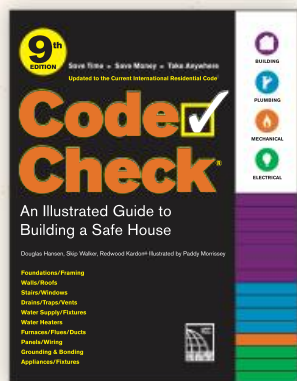


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A New Take on Insulating a Roof

For vaulted ceilings, this vented and vapor-open approach is durable and energy-smart, and a good option for mixed and cold climates

BY JOSH SALINGER

As the building industry turns its focus to the creation of low-energy homes and building practices that minimize greenhouse gasses, we've made what used to be a difficult and complex process—creating airtight, super-insulated houses—building as usual. The new materials and methods we have adopted are now baked into our muscle memory, and it's no longer especially challenging to build to meet the Passive House standard, for example, or to achieve net-zero energy.

At our small design-build firm in Portland, Ore., we are now looking beyond the energy consumption of the homes we build to the impact of the materials we build with on both people and the environment throughout the lifespan of the home, including its inevitable

end. In 2020, we made a commitment to stop using plastic-foam insulation above grade. (It's possible to avoid plastic-foam insulation below grade too, but we have yet to develop feasible, cost-effective ways to do so.) One of the toughest places to avoid plastic foams is in the insulated roof assemblies of homes with vaulted ceilings, but we have recently landed on a solid solution.

The versatile approach shown here has continuous venting, even on roofs with hips, valleys, and dormers. It manages vapor, with drying potential in all directions. The interior air barrier is easy to connect to the air barrier at the walls for continuity. And the rafter bays can be completely filled with insulation—we go with dense-pack cellulose, but other types will work just fine. Best of all,

it's buildable and cost-effective. All without the use of plastic foams.

The vaulted-ceiling problem

Increasingly common in today's home designs, vaulted ceilings follow the roofline, adding a sense of spaciousness in single-story homes or additional living space to some multistory homes. But insulated roof assemblies are a bit trickier to detail than walls.

In climate zones 1 through 3, you may be able to meet code-required insulation levels with fibrous insulation in a common vented roof assembly. You can also fill the rafter bays completely with fluffy insulation in an unvented assembly and open a vapor-diffusion port at the ridge in these climate zones. By stopping the sheathing short of



the ridge and covering the gap with a vapor-permeable membrane, vapor can diffuse out of the assembly to prevent condensation problems. It's an interesting solution described thoroughly in Joseph Lstiburek's excellent 2015 article "BSI-088: Venting Vapor," available at [buildingscience.com](https://www.buildingscience.com).

In climate zones 4 and up, however, condensation risks are much higher, and for a few reasons, vented assemblies are not an easy solution. These roof assemblies commonly have baffles—often Durovent or an Owens Corning product—on the bottom of the sheathing, which connect air-intake vents in the soffits and exhaust vents at the ridge to vent the roof assembly via the stack effect.

This approach allows batt insulation and avoids plastic foam, but only works if the

roof is a simple gable style, which often is not the case. Hips, valleys, and dormers can make this type of venting impossible. Plus, the thin plastic baffles are so flimsy that they often get crushed when rafter bays are filled with insulation. In other cases, where the rafter bays are larger or smaller than the typical 16 in. or 24 in. on center, inattentive subcontractors often jam and crush baffles into place. Another downside of baffles is the space they steal from insulation, which may make it impossible to meet code-required R-values, save energy, and improve comfort.

Mixed- and cold-climate builders tend to turn to spray foam or rigid foam to create durable insulated roof assemblies without venting. Unvented (hot) roofs are generally created in two ways. One is by applying

Why we're avoiding plastic-foam insulation

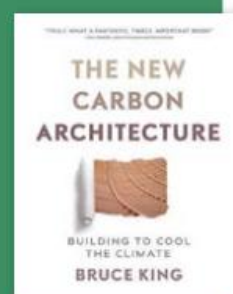
Plastic-foam insulation includes EPS, XPS, and polyisocyanurate rigid foam insulation, and open- and closed-cell spray polyurethane foam. While popular and effective, these products present problems that are increasingly difficult to ignore.

Despite how some manufacturers have reduced the high global-warming potential (GWP) of blowing agents in plastic foam, it is still significant, adding to the impact of the fossil fuels used to make the plastic in the first place. It is also difficult to recycle and reuse, contributing to global pollution by microplastics.

As a building material, plastic foam has additional drawbacks. Compared to fiberglass and fire-rated cellulose, plastic foam can be more flammable. Some products are prone to diminished R-value over time. It is not a reliable air barrier because it is difficult to seal to wood in a way that can withstand seasonal movement of the building. Plastic-foam insulation also may limit the drying potential of a building assembly to just one direction, which can present design challenges, and its hydrophobic nature is not always a benefit.

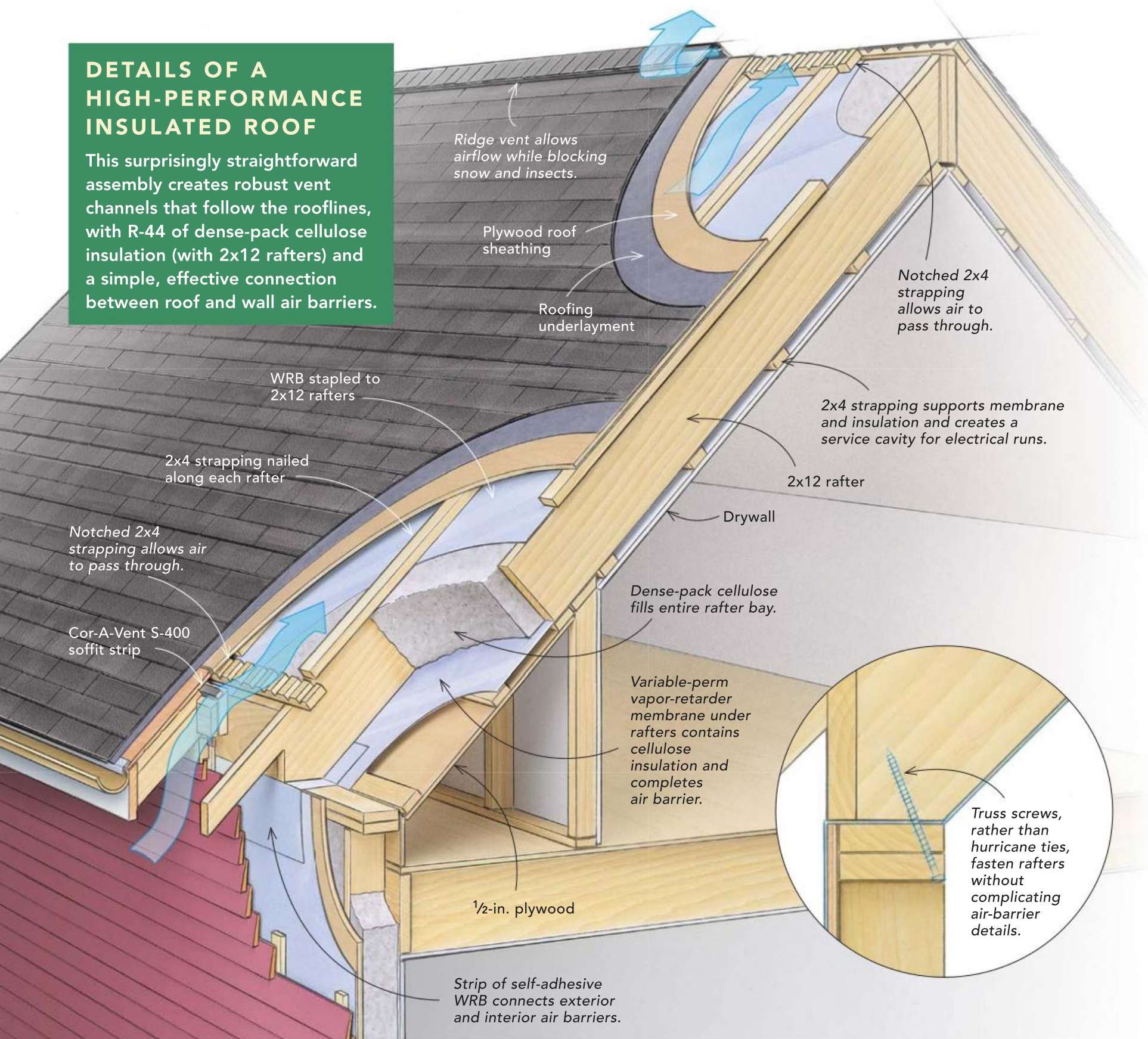
Spray foam has particular problems of its own. For one, it encapsulates wood in plastic, eliminating its potential to biodegrade or be reused. It also makes repairs and remodeling, even a basic upgrade like adding an electrical circuit, difficult. There are the adverse health effects for installers, the potential for improper installation and uncured foam, and the issues of heat created during curing.

For more information and alternatives to plastic foam, check out Bruce King's book, "The New Carbon Architecture" (2018, New Society Publishers).



DETAILS OF A HIGH-PERFORMANCE INSULATED ROOF

This surprisingly straightforward assembly creates robust vent channels that follow the rooflines, with R-44 of dense-pack cellulose insulation (with 2x12 rafters) and a simple, effective connection between roof and wall air barriers.



closed-cell spray foam to the bottom side of the roof sheathing to at least a minimum R-value that meets code and prevents condensation, and therefore the potential for mold and rot. Alternatively, rigid foam such as EPS, XPS, or foil-faced polyiso can be applied to the top of the sheathing, which prevents condensation on the underside by keeping the sheathing warm.

These unvented assemblies can certainly work, but they have limited drying potential and require plastic-foam insulation. Our

goal was to design a solution that had the durability of a vented assembly without the environmental cost of plastic foam.

A design-build solution

One of the benefits of working at a design-build firm are the frequent meetings between the architecture and build teams. They are where we find solutions that work on paper and in the field—like this foam-free assembly for vaulted roofs. Here's the basic anatomy.

After the roof is framed but before sheathing is installed, we staple a layer of a vapor-open water-resistive barrier (WRB), like the Tyvek Commercial Wrap used on this project, to the top of the roof rafters. Next, we nail flat 2x4 strapping along each rafter to act as spacers. To attach the sheathing at the eave and ridge, we install notched 2x4s perpendicular to the rafters, allowing air to pass through. On this project we used Cor-A-Vent soffit strips to keep insects out of the vent chambers, but we plan to move

STICK-FRAMED VENT CHANNELS

To create robust vent channels, first install a water-resistive barrier over the rafters, then 2x4 strapping and sheathing.



Roll out the WRB. A 10-ft.-wide roll of water-resistive barrier works perfectly with 24-in. rafter spacing. The team rolls it down or up, whichever is easier, and attaches it with staples.



Horizontals go on first. One row of horizontal 2x4 nailers—with a series of V-notches cut in them to allow air to pass through—is installed at the ridge, and another at the eave.



Verticals next. A 2x4 runs above each rafter, spaced slightly up from the lower horizontal strapping, to allow air to move from bay to bay.



Sheathing completes the channels. Roof sheathing is fastened as usual, creating a deck where roofers won't encounter any uncommon details.



Insect-proof soffit vents. Cor-A-Vent S-400 soffit strips block insects and debris. At the 2x4 strapping that continues along the rafter tails, Breckenridge plywood will finish off the open-soffit design.

the notched strapping lower and wrap it with screen in the future as an easier way to accomplish the same goal.

With these details, when the sheathing goes on, we end up with durable and effective vent cavities, connected to the exterior with vents at the soffit and ridge and connected to each other at hips and valleys. You might be wondering why we don't use 2x2s above the rafters—we tried that early on, but the narrow boards ended up being chewed up by nails and staples. Laid flat, 2x4s make a

much better nailer. The WRB not only acts as the insulation netting at the top of the roof rafters, but it keeps the vent chambers clear and allows the insulated rafter bays to dry to the exterior.

On the bottom, or interior, side of the rafters, we install a variable-perm vapor retarder—such as Siga Majrex or ProClima Intello—which manages moisture and acts as the primary air barrier. Below this membrane goes another set of flat 2x4s, nailed on perpendicular to the rafters. The reason

for this lower strapping is twofold. First, the manufacturer requires it to keep the vapor-retarder membrane attached to the rafters when it is used as netting for insulation. Second, the strapping creates a shallow service cavity behind the drywall, where we can install junction boxes and electric circuits without penetrating the air barrier. And because the membrane is used as the insulation netting at the bottom of the rafters, we make sure our insulation contractor deletes the netting and its install from their bid,

AIR BARRIER AND A SERVICE CAVITY

Below the rafters, the air barrier will contain the cellulose insulation, followed by strapping and drywall.



Vapor-permeable air barrier. The Siga Majrex is rolled out and cut on the floor, and then lifted up and installed perpendicular to the rafters.



Tape and strapping next. All of the seams are sealed with Siga Rissan tape designed for the Majrex membrane, including the flap at the bottom where the air barrier emerges from the top plate.



helping us recoup some of the extra labor and material costs.

Drying in both directions

Moisture tends to build up in roof assemblies. Inside the home, showers, cooking, breathing, house plants, seasonal changes, and air leakage all add humidity, not to mention the moisture released from new construction materials. Outside, seasons and conditions are in constant flux. Our vented roof assembly is vapor-open, meaning built-up moisture can dry to the inside or outside. This gives it the greatest potential for drying out and avoiding degradation, mold, and rot.

Starting at the top, the vent chambers manage condensation under the sheathing via airflow from the soffit to the ridge. Vapor will always move from areas of more concentration to less, so, should the interior of the home be more humid than the surrounding

environment, or if the assembly is wet, the built-up water vapor will drive toward the vent cavity, diffuse through the WRB, and escape via the roof vent.

The reason this assembly works for all types of roof architecture is because the venting chamber is above the rafters. This allows air movement over hips, through valleys, and around dormers. These details block the flow of air and make venting difficult in the more common scenario of having the vent channels within the rafter bays. To accomplish this where one roof area intersects another—such as the shed roof and gable roof on the project featured here—we simply leave space in the grid of 2x4 strapping to allow for air to pass from one set of vent chambers to the other. These small spaces help improve flow throughout the assembly. Roofing code includes a table that calculates the openings needed to properly vent cavities

of any given square footage. We used those to engineer this assembly, and we crunch the numbers for each specific roof.

On the bottom of the rafters, a variable-perm membrane is the assembly's vapor-control layer. The permeance of a variable-perm, or “smart,” vapor retarder modulates based on humidity. As opposed to a vapor retarder that maintains a consistent permeance throughout the seasons, a smart vapor retarder responds to them. During colder, dryer conditions, when condensation risk is high, this material allows less vapor to pass. During warmer, more humid conditions, when drying is the goal, the material allows more vapor to pass.

Another key piece of the assembly that manages moisture is the dense-pack cellulose insulation. As opposed to fiberglass, which is hydrophobic and sheds water, cellulose is hydrophilic, taking on and releasing



Ready for drywall.
The insulation subs cut small slits in the air barrier to fill the bays top to bottom, the team circles back to tape them off, and the drywall subs move in.

moisture over time, further mitigating the risk of large swings in humidity. Known as hygric buffering, this builds even more resilience into the system. That said, the assembly could still be effective with another form of blown-in insulation, including fiberglass.

Continuous air-sealing

Much more water is deposited in a building assembly through air movement than vapor diffusion—by a few orders of magnitude, in fact. For example, over the course of one year, a 1-in. hole in drywall can deposit as much as 30 quarts of water into the assembly through air leakage. Compare that to the 1/3 cup of water vapor that may diffuse through a 4x8 sheet of the same material in the same time frame.

To prevent air leaks from wreaking havoc on our roof structure and the home's overall energy performance, the vapor retarder used

in this assembly is taped at the seams and penetrations, and connected continuously to the air barrier where roof meets walls. We do this by placing a strip of WRB—in this case self-adhering Siga Majvest 500 SA—over the top plate prior to installation of the rafters, and then connecting that to both the vapor-permeable barrier under the rafters and the WRB on the exterior wall. It adds about an hour of labor to the build schedule for a typical home, but its impact on performance and comfort is well worth the effort.

With this air-sealing setup, you can't use the usual H2.5A hurricane ties from Simpson Strong-Tie for the wall-to-rafter connection without the air-sealing-origami nightmare we've learned to avoid. We use truss screws instead, driving them up through the top plate and into the rafters. We specify this to the structural engineer at the design phase of the project. The truss screws install faster

and easier than the hurricane ties anyway, so they're a net time-saver for our team, and the air-seal is much more effective. With this air-barrier strategy, we've had no trouble hitting our air-sealing targets, which are generally well below 1 ACH50.

To date, our team has done this install on three homes. While we have the main steps dialed in, we continue learn new tricks and add efficiency. Although the approach involves some extra materials, doing things in a slightly different order, and taking a little more time, it all feels relatively quick and easy now. The new vaulted-roof assembly helps us meet our high-performance standards without using foam, delivering a win for our firm, our clients, and our kids. □

Josh Salinger is founder and CEO of Birdsmouth, a design-build firm in Portland, Ore. Photos by Asa Christiana.

All Things HVAC

Choosing among heating, cooling, and ventilation systems is complicated. Knowing a few basics can lead to smarter selections.

BY SCOTT GIBSON

When it comes to heating and cooling equipment, which is more important: lower initial cost or lower operating costs? Should the equipment be all-electric, or is it OK in the era of climate change to buy appliances that burn fossil fuels? Is it safe to invest in new technology, or will that turn out to be an expensive mistake? There are many nuanced questions to answer when planning a new HVAC system or looking to upgrade existing components. Having a strong sense of your needs and the available products is a good place to start.

Energy and design consultants working with computer models can offer precise estimates of heating and cooling needs and the type of equipment—if not the manufacturer and model number—best suited to meet them. When the goal is to certify a new or renovated house under a rating program such as Passive House, that level of detail is a must. Energy consumption right down to the kilowatt-hour is a make-or-break question for certification.

Whether or not a computer-armed consultant is in the cards, having a grasp of heating and cooling basics is a good idea for anyone building a new house or renovating an old

one. Why bother? You won't be spending money unnecessarily. You'll at least know the right questions to ask the HVAC contractor. Plus, you'll be investing in equipment that makes sense for your climate and house—not some hypothetical average.

With that in mind, consider the fundamentals of HVAC design. These are the standard industry planning tools developed by the Air Conditioning Contractors of America (ACCA): Manual J, Manual S, and Manual D. These ACCA manuals are software programs available from a number of companies and used primarily by HVAC professionals. All of them are important and the foundation for good design.

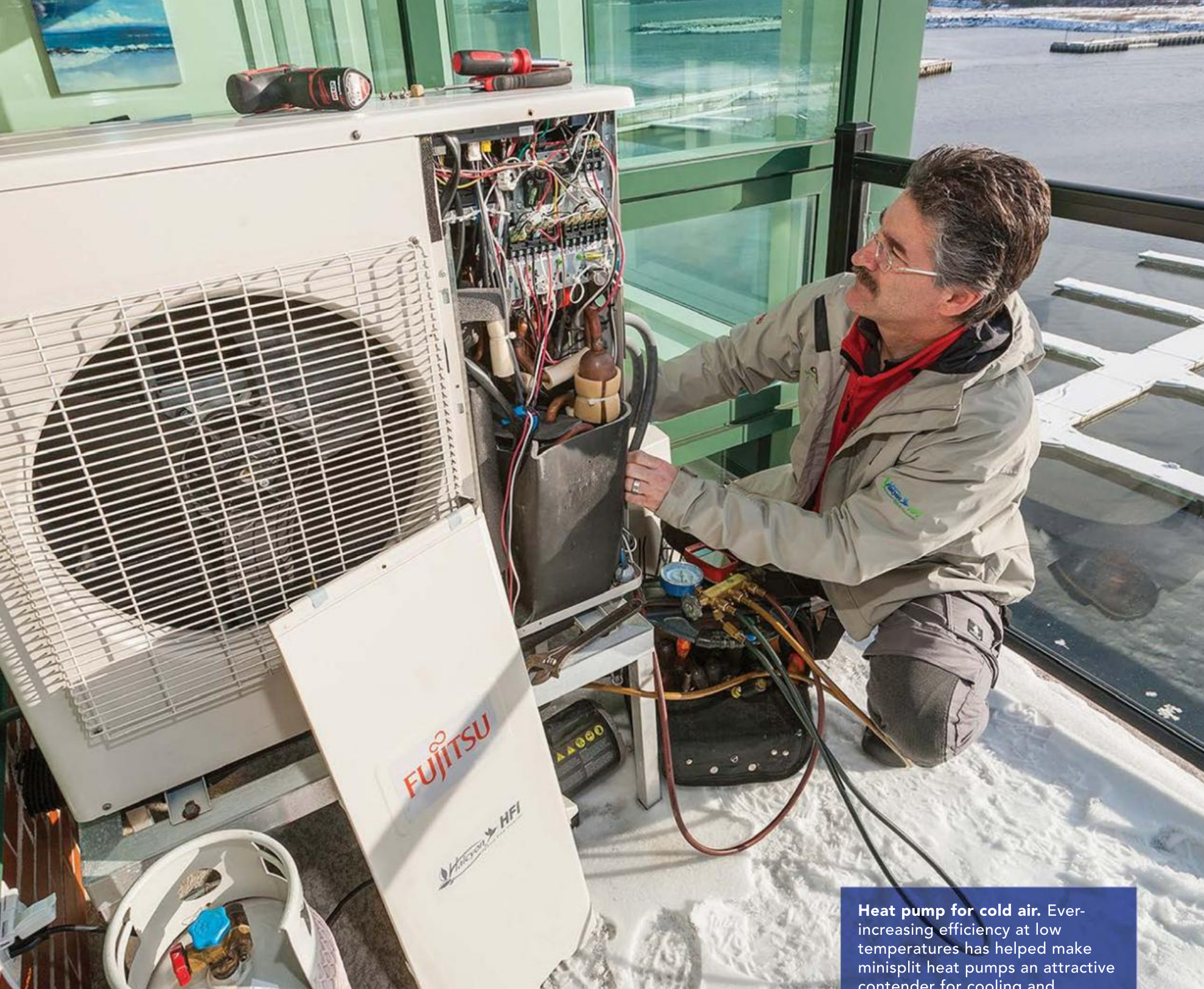
Start by calculating your needs

Manual J is the first step in planning a system. Its purpose is to calculate how much heat your house will lose on the coldest night of the year, and how much cooling you will need on the hottest day of the year. These are the heating and cooling loads, independent of what heating and cooling equipment a homeowner may choose. Loads are determined on a room-to-room basis so a contractor knows how much heating and cooling you'll need to stay comfortable. Some of the

most repeated advice from experts is that a Manual J calculation is essential to getting a heating and cooling system that works properly. Heating and cooling contractors develop their own rules of thumb over time. That's understandable. If you've installed 500 systems and they all seem to work well enough, you'd probably be just as confident in recommending one. The issue is that little extra a contractor may want to add to the capacity of a furnace or air-conditioning unit simply to guarantee they never get a call in the middle of the night from a homeowner complaining the house is too hot or too cold.

Manual J is designed to take the guesswork out of the process and make sure the equip-





ment that's installed is well-matched to the house and the locale. Here's how it works: After the technician plugs in various bits of information—how much insulation is in the walls, for instance; the specs for the windows you'll be using; and other variables—the program should produce a good estimate of heat loss or gain. The calculation will show how much heating and cooling you'll need to remain comfortable under the hottest or coldest conditions that might be expected in that area. These values help steer the contractor toward appropriately sized heating and cooling equipment.

In theory, a Manual J calculation should be straightforward. But judging from anecdotal

accounts, the opposite is true. Some heating contractors don't know how to do a Manual J calculation. Contractors may want to rely on rules of thumb they have picked up over the years instead, resulting in equipment that is oversized and more expensive than it needs to be. Information entered into the software template may be inaccurate because various assumptions about the house's construction are wrong, so the results are wrong, too. And the list goes on.

Look to reliable resources

In one of many articles on the topic at Green Building Advisor (GBA), Martin Holladay explains that the International Residential

Code (IRC), the dominant model building code in the U.S., requires a Manual J calculation, or other "approved heating and cooling calculations methodologies." Contractors are required to show local building officials that the calculations were completed. But code officials have been known to say that although they collect the data, they don't actually know what it means.

Asked whether HVAC contractors typically have a good grasp of ACCA planning tools, Michael Maines, a residential designer in Maine and a contributing editor at *Fine Homebuilding*, says no. "A few of the best ones do Manual Js in a thorough, honest way, but the vast majority just give their supply

house the floor area and they input standard, leaky-home values, leading to grossly oversized systems. Most systems I've seen do not look like they were properly engineered."

Because of these issues, Holladay believes that it's a mistake to trust the calculations that your HVAC contractor makes. "The bottom line is that any load calculation supplied by an HVAC contractor should be looked at with suspicion," he writes. He spoke with Allison Bailes III, an energy consultant in Atlanta, who adds: "Contractors are often engaged

in a race to the bottom. There just isn't any money in their budget for proper design."

These are broad brushstrokes that portray all heating and cooling contractors unfavorably. Many contractors no doubt know very well what a Manual J calculation is. Still, warnings like this may prompt homeowners to ask themselves: If my HVAC contractor shouldn't be doing this, what other options do I have?

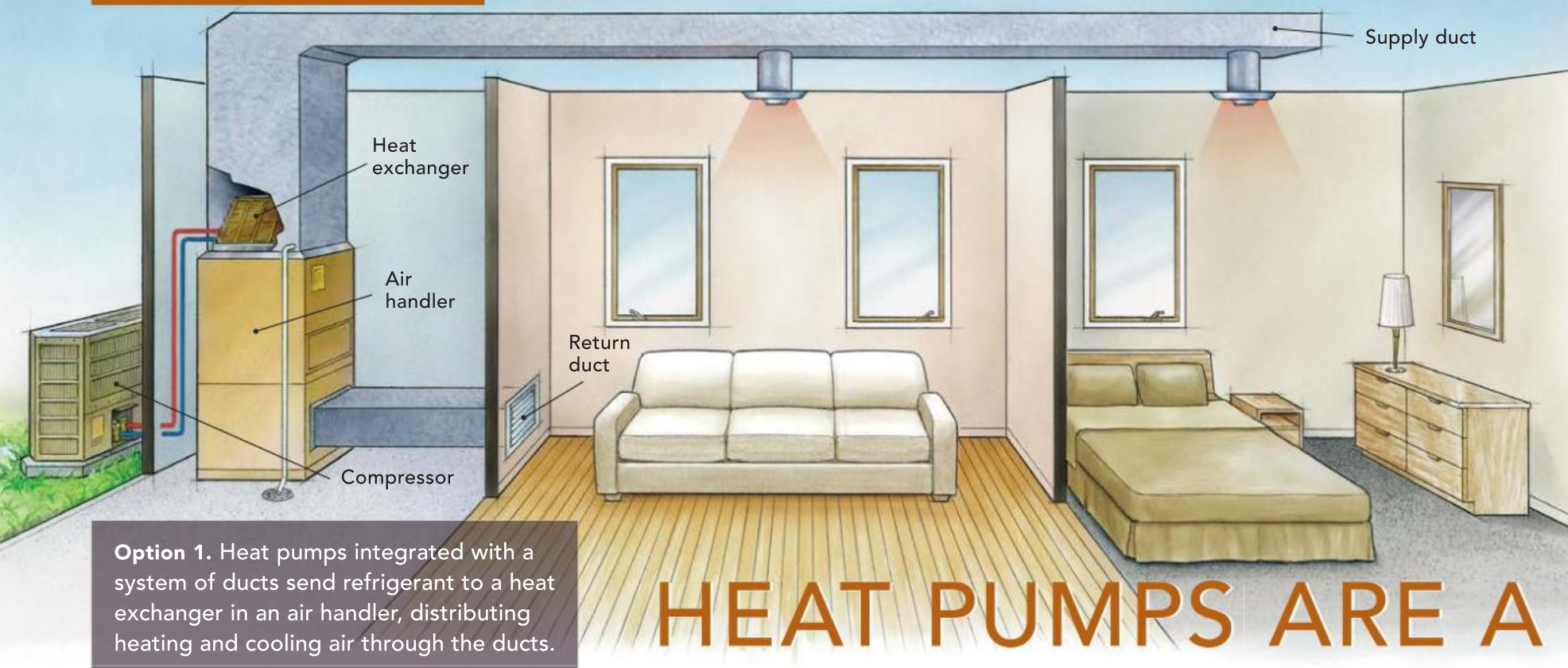
There are several, depending on how much money you have to play with and your com-

fort level with detailed technical topics—your willingness to wade into the weeds and figure things out. Here are some possibilities:

1. Do your own calculations. Take a look at articles that Green Building Advisor has published online in the past, including "How to Perform a Heat-Loss Calculation," and "Calculating Cooling Loads" by Martin Holladay.

2. Use a free online calculator. There are many to choose from, but the problem here is that you have no real assurance that the

CONVENTIONAL DUCTED SYSTEM



Option 1. Heat pumps integrated with a system of ducts send refrigerant to a heat exchanger in an air handler, distributing heating and cooling air through the ducts.

HEAT PUMPS ARE A

In simpler times, choosing heating and cooling equipment amounted to calling a contractor or two, getting what seemed like a good price, and letting the contractor do the rest. Now, faced with whole new categories of equipment that were virtually unknown a generation ago, homeowners have many more choices of what to buy. In the green-building sector, heat-pump systems are often a first choice.

Heat pumps were once mostly a fixture of the Southeast, where winter temperatures are mild and summers are hot and humid. At one time, air-source heat pumps needed auxiliary resistance coils when temperatures dropped much below 40°F. Led by such companies as Mitsubishi and Fujitsu, manufacturers went on to develop air-source heat pumps that could operate efficiently in below-zero temperatures. The vastly improved technology has helped make heat pumps, especially a kind of air-source heat pump known as a ductless minisplit, a big player in the space-heating market—even in cold regions like New England.

A heat pump extracts heat from the air or water and moves it somewhere else, without burning any fuel directly. A heat pump with a COP (coefficient of performance) of 4 gets 4kw worth of heat for every 1kw of electricity it consumes. That's four times as efficient as an electric baseboard heater. Efficiency falls off sharply in colder temperatures, but some heat pumps can still produce heat when temperatures are well below zero. Mitsubishi Electric Trane HVAC US, for example, says its Hyper-Heating Inverter (H2i) units provide up to 100% of their heating capacity at 5°F and up to 76% of their capacity at -13°F.

Heat pumps do double duty as both heating appliances and air conditioners. Running in reverse, a heat pump pulls heat out of the house and dumps it into the air (an air-source heat pump) or the ground (a ground-source heat pump) in the summer. Unlike a conventional furnace or boiler that burns a fossil fuel, a heat pump isn't a backdrafting risk and it doesn't contribute directly to carbon emissions.

results will be accurate. One free program that Bailes recommends is Cool Calc Manual J Software.

3. Hire a professional. Bailes says a number of companies do third-party HVAC design—including his, Energy Vanguard. “An internet search on that term, ‘load calculation,’ or ‘Manual J’ should turn up several companies that can help,” he adds. “People can also go to forums like the Q&A at GBA or Building Performance Institute (BPI) and ask for recommendations.” It could take

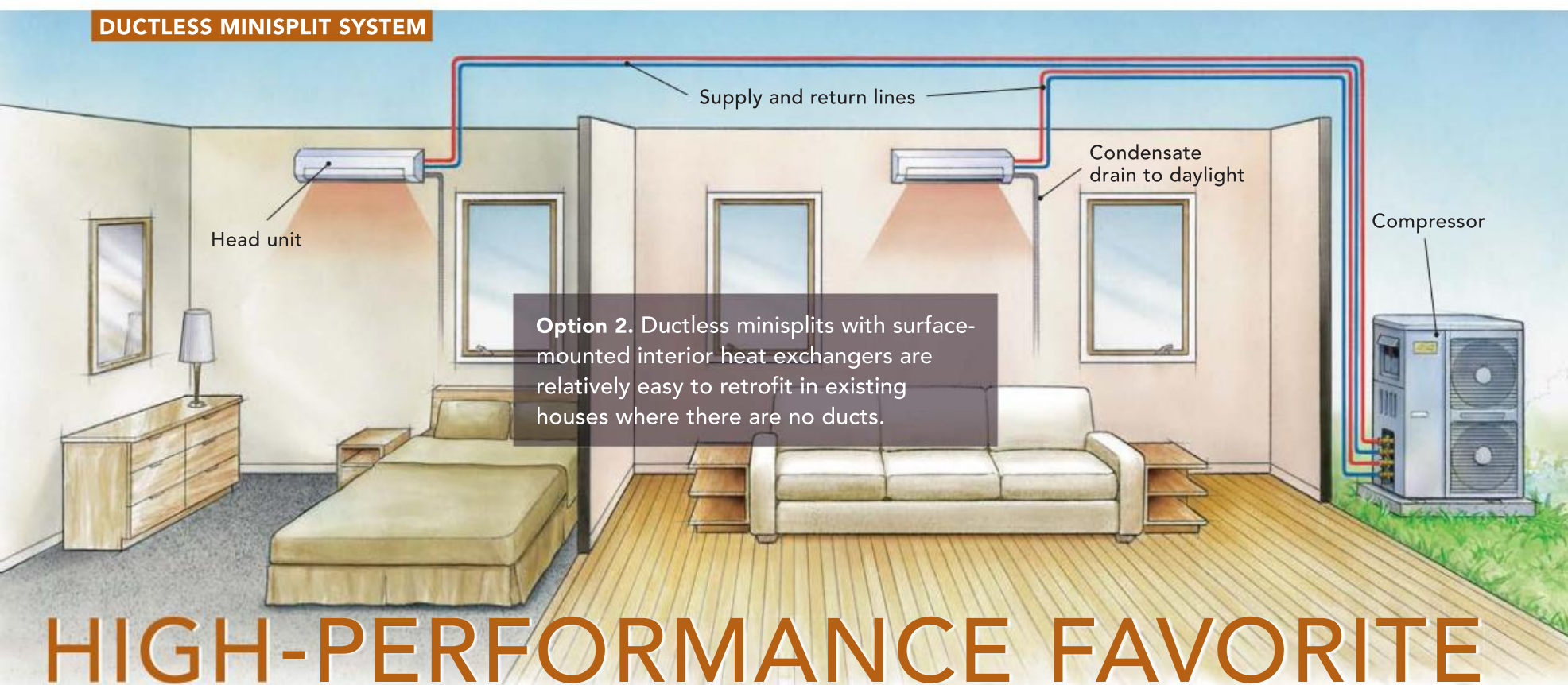
time to find someone who is both available and qualified, and it might cost more ultimately, but in the scheme of things it could be the best option.

Next, choose your equipment

Once the heating and cooling loads are known, the next step in the process of designing a system is selecting the appliances. This is where the ACCA’s Manual S comes in. Both the IRC and the International Energy Conservation Code (IECC) require

the use of Manual S to size equipment after load calculations are complete. Assuming your community has adopted the IRC, your contractor is required to use Manual S in this process (unless local officials have amended the code otherwise).

Equipment selection is key, no matter what type (or fuel) you choose. The capacity of the equipment—how many British thermal units (Btus) per hour the device will produce—should align with how much energy the house needs to stay comfort-



Air-source heat pumps come in several versions. They can be used with a conventional system of ducts that distribute conditioned air throughout the house, as a gas-fired furnace would do. They also come in smaller packages (ductless minisplits) that include an outdoor compressor and one or more indoor heads that send conditioned air directly into the room without the need for ducts. Ducted minisplits are a compromise. They provide conditioned air to a few adjoining spaces with a limited amount of ductwork.

Heat pumps also may feature what manufacturers call “inverter technology,” in which the outside compressor converts AC to DC and modulates the amount of power to meet heating demands more precisely than a fixed-speed compressor. According to Heather Buchicchio, director of product marketing for Mitsubishi Electric Trane, those one-speed systems are either on or off. “This can lead to unpleasant temperature swings as the system strains to maintain a constant temperature,” she says. “Inverter-driven

compressors, on the other hand, are always running in the background, adjusting speeds in real time.”

Designers like architect Chris Briley of Briburn in Portland, Maine, who specializes in well-insulated and air-sealed houses, appreciate the efficiency of ductless minisplits. When heating loads are low, a few indoor units can heat and cool an entire house, particularly when floor plans are open. This approach is cheaper than installing a conventional HVAC system with a fuel-burning furnace or boiler, a distribution system, and separate air-conditioning equipment.

Ductless systems work best when an outside compressor serves only one or two cassettes inside. “The more zones you have, the more cassettes you have,” says Briley. “And the more refrigerant lines you have, the more manifolds you may have. We all know that multizone systems are still suffering from some of those efficiency issues. So all of a sudden your simple and efficient heat-pump system has just gotten way more complex and expensive.”

THREE WAYS TO KEEP COOL

Cooling strategies run the gamut—from a whole-house fan in the attic that flushes out hot indoor air at night to a fully ducted mechanical system. In some parts of the country, AC is needed only a few days each year. In others, life is miserable without it. So, what are some of the options?

Whole-house cooling

Most central air-conditioning systems are split systems, which include a condensing unit that sits outside on a concrete pad, and an indoor coil connected to ducts that move cool air around the house. If you have a forced-air heating system, you already have the ducts for the air conditioning. Houses heated by some other means—a boiler, for example, or some other appliance that doesn't need ducts—will have to be ducted separately for the AC, or you'll have to choose a different type of air conditioning.

An air conditioner moves heat with the help of a refrigerant that alternates between a liquid and gaseous state. Inside the house, the refrigerant absorbs heat in a coil that cools indoor air. The refrigerant is then routed outside where the heat is ejected in an outside coil. This refrigeration cycle is the magic that pulls heat from inside the house and dumps it outside. The process involves the same mechanics as your refrigerator, which is just moving heat from inside an insulated box to your kitchen.

Air conditioners also dehumidify. Cold air holds less moisture than warm air. When the air handler inside blows warm (moist) indoor air over the evaporator coils, moisture in the air condenses on the coils. This water can be collected and sent down the drain and out of the house, so the air inside is drier and more comfortable. When the AC unit is too big, it cools down the air in the house very quickly and satisfies



the thermostat before the system has had a chance to remove all the moisture. This is why experts suggest the best scenario is when the air conditioner runs for longer periods of time; if the AC is running more or less constantly on the hottest afternoon of the year, it's been sized properly.

Space cooling

Window-mounted air conditioners are an excellent choice for people who don't want a whole-house



able. That concept seems like a no-brainer, but like many other HVAC issues, this also becomes complicated.

David Butler of Optimal Building Systems explains that there's a difference between the nameplate capacity of a device (what the manufacturer says it will do) and what it will actually do once it's installed. A number of variables can affect the performance of an air conditioner, Butler says, including indoor and outdoor temperatures and indoor humidity. If one of those variables changes, the air conditioner's capacity to change sensible capacity (the temperature) and latent

capacity (humidity) also change. That's why the same air-conditioning system operates differently in the arid Southwest than it will in the hot, muggy Southeast, no matter what the nameplate capacity might be.

His point is that contractors should stick to Manual S, not to the nameplate attached to the device. In Manual S, the procedure for choosing a furnace is simple, Butler says: The output should be between 100% and 140% of the design heat load. It gets more complicated for air-conditioning equipment because the contractor needs to know both the latent and sensible capacity of the equip-

ment when it's operating at design conditions, meaning the conditions specific to that location and not some hypothetical numbers that have nothing to do with where the house is.

For distribution, use Manual D

The "D" in Manual D is for ducts, the means by which a forced-air heating and cooling system moves conditioned air around the house. Not all houses have ducts. Instead, they may rely on hot water (hydronic heating systems, such as radiant-floor heating), radiation (such as a wood or pellet stove),

system and are content to cool just a room or two. They are less expensive to install and run than a central system, and for several reasons, they use less electricity for cooling. Smaller units will run on an 115v circuit. The downside is that they don't cool the entire house, so there will still be pockets of uncomfortably warm and humid air. Also, they are noisy.

Cooling capacity (measured in Btu per hour) should be based on the room size, with some adjustment for factors such as solar gain, occupancy, or location in a kitchen. Energy Star's recommended sizes start with a



EVAPORATIVE COOLERS



5000-Btu unit for rooms of up to 150 sq. ft. and go up from there. Remember, bigger isn't always better. AC units that are too big will bring down the temperature quickly and then power down even though the unit hasn't run long enough to bring humidity levels down to a point where the room is comfortable. Longer run times will make for a more comfortable environment.

A dry-climate option

Most of us equate air conditioning with devices that use sealed refrigerant loops, but that's not the only way of lowering indoor temperatures. One alternative is the evaporative cooler, also called a swamp cooler. These are often mounted on the roof and look like a louvered metal box, but window-mounted and portable units also are available. According to the Department of Energy, evaporative coolers can lower air temperature by as much as 40°F, although the air coming out of an evaporative cooler is typically not as cool as air blown from a window AC unit.

Inside the cooler is a thick pad moistened with water. Hot, dry air drawn through the pad by a fan evaporates water in the pad as it moves, lowering the temperature of the air. The fan pushes that cooler air into the house. Evaporative coolers are much simpler than a split mechanical system, so they cost less and are much less expensive to run because they use relatively little electricity. Some come with air filters that reduce airborne allergens, variable-speed fans, and remote controls.

The fact that an evaporative cooler does not need a chemical refrigerant is a big environmental plus because refrigerants typically have high global-warming potentials. But there is a catch: Evaporative coolers are best suited for dry climates. Where relative humidity is high, they are not as effective because when air is laden with moisture, evaporation slows down and with it the cooling effect.



WINDOW-MOUNTED AIR CONDITIONERS

or an air handler (with a ductless minisplit mounted on the wall or a direct-vent heater burning propane or kerosene). Even houses that don't have forced-air furnaces, however, may need ducts for central air conditioning, whole-house ventilation, or dehumidification. That's where Manual D comes in.

The physics of moving air around a house is more complex than it might seem. Unless you are interested in such topics as static pressure, effective duct length, and blower capacity, duct design will prove a difficult topic to understand. But there are general rules about ducts that should be helpful:

1. Ducts should not be located in an unconditioned attic or crawlspace. Ducts can be insulated, but a thin covering of insulation is no match for searing summertime temperatures or the deep cold of winter typical for an unconditioned attic. It doesn't make sense to spend a lot of money to heat or cool air only to squander the energy before it can do its work. So, put ducts in places where they don't get too hot or too cold—interior chases, conditioned attics, and conditioned crawlspaces.

2. Joist bays and stud bays don't make good ducts.

3. Rigid ducts are less likely to restrict airflow. Insulated flex duct works, but it doesn't work very well when an installer allows it to sag haphazardly. Flexible duct should be supported by straps, not wire, to avoid pinching off airflow.

4. Ducts should be sealed, ideally with mastic. Leaky ducts cause all sorts of problems, from wasted energy to pulling mold and other allergens into your distribution system. Duct tape isn't suitable for sealing ducts at seams between sections because it will eventually dry out and begin to leak. Mastic is messy but effective. Another approach is to

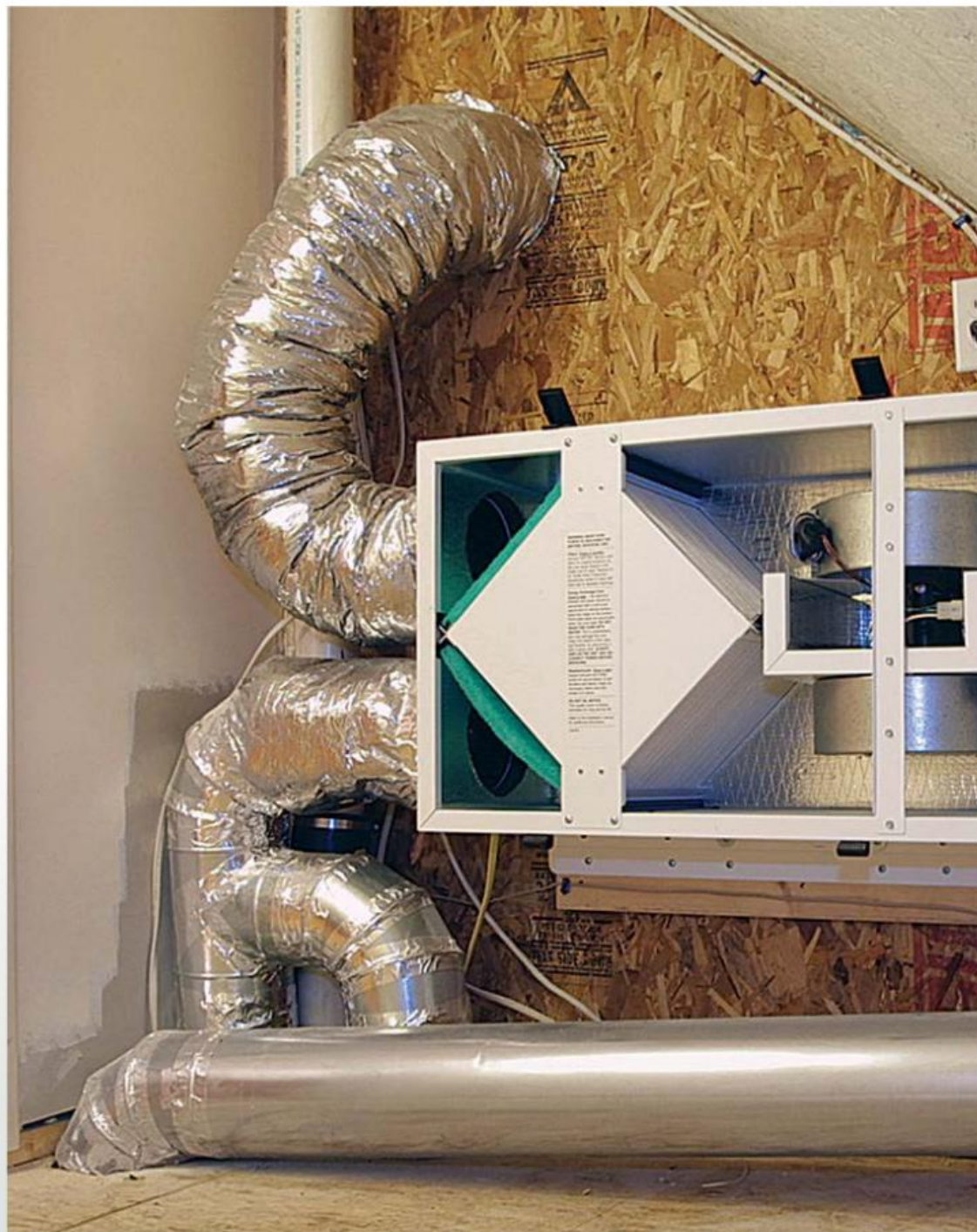
BUILD TIGHT, VENTILATE RIGHT

Houses with low rates of air leakage are better able to maintain indoor temperature, humidity, and overall comfort. But as houses get tighter, the need for mechanical ventilation to maintain indoor-air quality goes up. As with all HVAC systems, there are choices.

Exhaust-only systems

Exhaust-only ventilation is relatively simple, often consisting of just one or more bathroom fans. The fans can be set to run continuously at a low volume, or they can be used as spot ventilation when someone is showering. A single-port fan (a self-contained, usually ceiling-mounted unit) has a single inlet and an exhaust duct that sucks moist air out of the house. A multiport exhaust fan can handle larger bathrooms with toilet and shower enclosures, or even multiple rooms. These units include an inline fan and two or more inlets. Because the fans can be placed some distance from the inlet grilles, these systems are pretty quiet, and they are available in a variety of sizes.

Bathroom fans and range hoods have one thing in common: They depressurize the house relative to the outdoors, meaning that with the fan running, there's a faint vacuum inside the building. The air that is pulled from the house must be replaced by air from the outside. Without any dedicated supply ducts, this replacement air will find its way through whatever cracks and voids there are in the building enclosure. In other words, you don't really know where the air is going to come from, just that it will inevitably get in.



use a proprietary product called Aeroseal, a method of sealing ducts from the inside with an adhesive aerosol that plugs leaks as wide as $\frac{5}{8}$ in., according to the manufacturer.

Questions not covered in ACCA manuals

The ACCA manuals can guide HVAC decisions on a quantitative basis: How big a furnace do I need to stay warm in winter? What output do I need from an air-conditioning system to stay comfortable in July? But there's other criteria that may have just as much relevance.

For example, if you're replacing an existing gas furnace but planning to move in two years, do you buy a top-of-the-line condensing gas model with a great efficiency rating when it costs twice as much as a less efficient but more affordable alternative? Even an economy furnace should last a decade, so the new owners of the house will be the ones who are stuck with lower efficiency and higher energy bills. Spending a lot of money on a piece of equipment you're about to leave behind may not make much sense when the simple payback on the purchase doesn't equal its added cost.

First, the importance of cost vs. higher efficiency is a question that even homeowners planning to stick around will want, or need, to ask. Money saved up front with a less expensive appliance is always attractive. But higher efficiency that reaps bigger rewards over time may be a better long-range investment.

"It depends on what their priorities are," Maines says of how he might advise clients on this question. "In most cases, I would say that higher efficiency is best, but if it comes at a huge premium, it may make financial sense to scale back on performance specs. An

Top of the line. An energy-recovery ventilator is among the more sophisticated options for ensuring an adequate amount of fresh air indoors. An ERV transfers heat and some moisture between incoming and outgoing air streams.



Supply-only ventilation

In a supply-only system, a fan brings fresh air into the house with exhaust air leaving the building through gaps in the building enclosure. The fan (or fans) can be installed in a mechanical room through an exterior wall with incoming air filtered or mixed with room air to lessen the temperature difference.

An existing air handler—what you'd have with a forced-air heating system or central AC—also can be used. Air from the outside is ducted into the return side of the furnace. To keep operating costs lower, the air handler can be run at a fraction of its usual speed as long as it provides enough fresh air to keep the house comfortable or meet the guidelines of ANSI/ASHRAE standard 62.2.

Supply-only systems pressurize the house. Some builders worry that this could cause problems during the winter by driving moisture into wall cavities. Energy expert Bruce Harley says not to worry about that. The upper part of a house already is under positive pressure in the winter from the stack effect, he says, and the relatively small airflow of the ventilation system won't have much of an impact.

Balanced systems—the preferred method

Balanced ventilation systems match outgoing air with incoming air to eliminate pressure imbalances. One problem with whole-house ventilation systems is that in removing conditioned (heated or cooled) air from inside the house and replacing it with outdoor air, the ventilation system runs up an energy tab. The incoming air is fresh, but it also must be heated or cooled to keep the indoor temperature comfortable.

Balanced systems have a way of dealing with this problem. Outgoing air and incoming air go through a heat exchanger, so much of the energy that would be lost is transferred to the opposite air stream. In winter, indoor air transfers its heat to incoming fresh air; in summer, the opposite occurs. This type of system is called a heat-recovery ventilator (HRV). The two airstreams have no direct contact with each other. Heat transfer can be remarkably high—greater than 90% with the most efficient models on the market.

A second type of system is the energy-recovery ventilator (ERV), which in addition to capturing some of the heat in the air stream also transfers some of the moisture. This is helpful in certain climates. In a hot, humid environment, for example, outgoing indoor air in summer has been cooled and dehumidified by an air conditioner. An ERV is designed to transfer some of the moisture in the incoming fresh air to the stale indoor air that's on its way out the door. With an ERV, there is some mixing of the two air streams. If you buy a top-of-the-line ERV system like the Zehnder ComfoAir, expect to pay \$7000 or more, depending on the number of ducts and other features. From a cost-savings point of view, spending that kind of money makes more sense in very cold climates than it does in moderate ones.

energy model should be helpful in making that decision.”

More pressing is the immediate need to lower carbon emissions in order to blunt climate change. Should homeowners limit their search to appliances that do not burn any fossil fuels because they may help reduce carbon emissions? Some municipalities around the country are already making that decision for home buyers by banning gas connections in new construction, and more restrictions are likely to follow.

For now, it's both an ethical and practical question homeowners have to answer

for themselves. If the source of electricity is renewable, an all-electric house is very appealing—as long as the grid stays up and running. But in some locales, power outages may be all too common, forcing homeowners to backstop their houses with both a gas-fueled generator and a fuel-powered auxiliary heater. “Whole-house batteries are getting close to being an effective alternative,” Maines adds, “but we aren't quite there yet on the financial front.”

Avoiding fuel-burning heating equipment also may be the logical choice when the plan is to add solar capacity to the house. Excess

production might be used to charge electric vehicles or offset the use of electricity by other appliances, such as a water heater or kitchen range. Decisions on heating and cooling equipment also can be guided by the interior design of the house. Ductless mini-splits would do well in a well-insulated house with few interior partitions; not so well in an older house with a number of small rooms and lots of doors.

In short, one size does not fit all. □

Scott Gibson is a contributing writer at *FHB* and Green Building Advisor.

Crawlspaces

To avoid moisture problems, either condition or isolate the space

That Work

BY JUSTIN FINK

Years ago I was working with a builder on a job in New England where a small crawlspace foundation was being poured for an addition to an old house. The builder had set metal foundation vent openings into the foundation formwork, but told me that as soon as the building official did his final inspection he planned to seal the vents from the inside using rigid foam. Warm outdoor air, he explained, holds more moisture than cooler crawlspace air. When that humid outdoor air enters through the crawlspace vents, it condenses on the cool surfaces and can lead to rot, mold, and poor air quality.

Yet, according to a report published by the U.S. Department of Energy, builders and designers often stick to this failure-prone “vented crawlspace” approach because they believe the code doesn’t allow them to build an unvented one. Therein lies the confusion.

First, vented crawlspaces can work, as long as they’re detailed correctly—most aren’t. Second, the building code typically does not allow “unvented” crawlspaces, but it does allow the construction of sealed, “conditioned” crawlspaces. A successful crawlspace, from a moisture perspective, must be either part of the conditioned envelope of the house, or completely separated from it. Anything in between is a recipe for disaster.

Unvented? Say “conditioned”

As building scientist Joseph Lstiburek warns, the term “unvented” has led to a lot of crawlspace problems over the years. “Unvented implies that you just don’t install vents. Wrong. Big time wrong,” he wrote in a Building Science Corporation article. “There

has to be a means of removing moisture from the crawlspace when the crawlspace is connected to the house. ...Houses are ‘conditioned’ and conditioning means controlling temperature and relative humidity.”

The way to control temperature and relative humidity is to exchange crawlspace air with the living space above the crawlspace in some way instead of relying on air flowing through from the exterior. But in order to perform as intended, the crawlspace needs to be protected against moisture, insulated, and air-sealed to isolate the space from the exterior.

This is relatively easy in new construction, but can be difficult in retrofits. Approaches vary, but perhaps the most popular is to insulate with spray polyurethane foam or rigid foam board applied to the walls of the foundation (on the inside or outside face) as well as the rim board of the floor framing. The floor of the crawlspace doesn’t need to be insulated, but it must be covered with a continuous layer of at least 6-mil polyethylene sheeting sealed at all transitions and seams.

Risk is tied to region

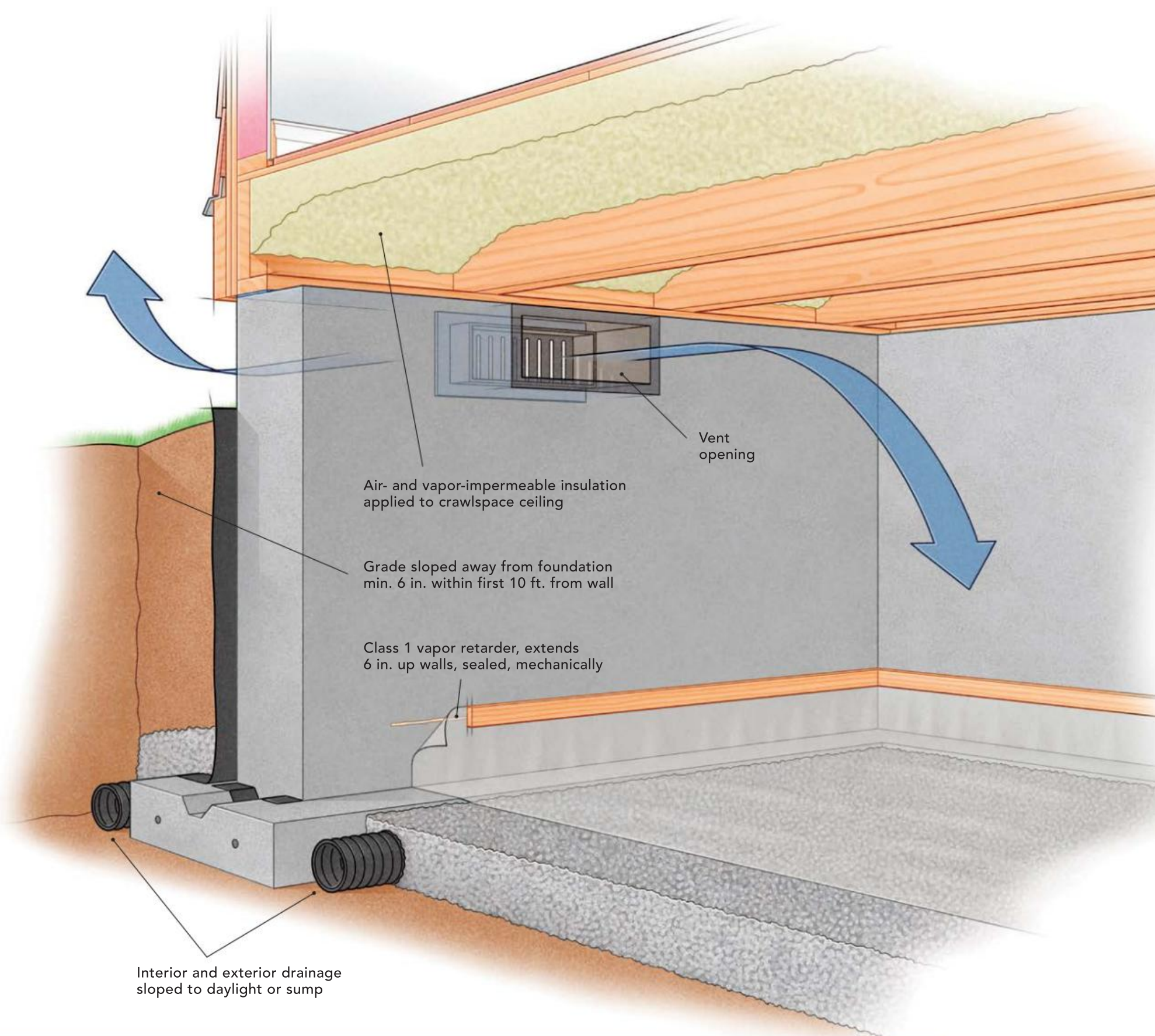
Declaring that all vented crawlspaces are dangerous is misleading. In fact, vented crawlspaces in arid climates tend to fare well all year long. This can also be true for regions where summers are hot and dry even if winters are cold and damp.

A study of crawlspace performance in marine and cold climates of the Pacific Northwest published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers in 2010 concluded, “The combination of relatively dry summers with low dew points (even in the marine climate) allows vented crawlspaces to perform adequately.” Over the 18 months they monitored the moisture content of framing facing the crawlspaces in their study, the authors found “moisture content was below 13% in all cases, well below the 20%+ level normally needed to induce mold or decay.” □

Justin Fink is builder-at-large. Drawings by Peter Wojcieszek.

A VENTED CRAWLSPACE CAN WORK IF DONE RIGHT

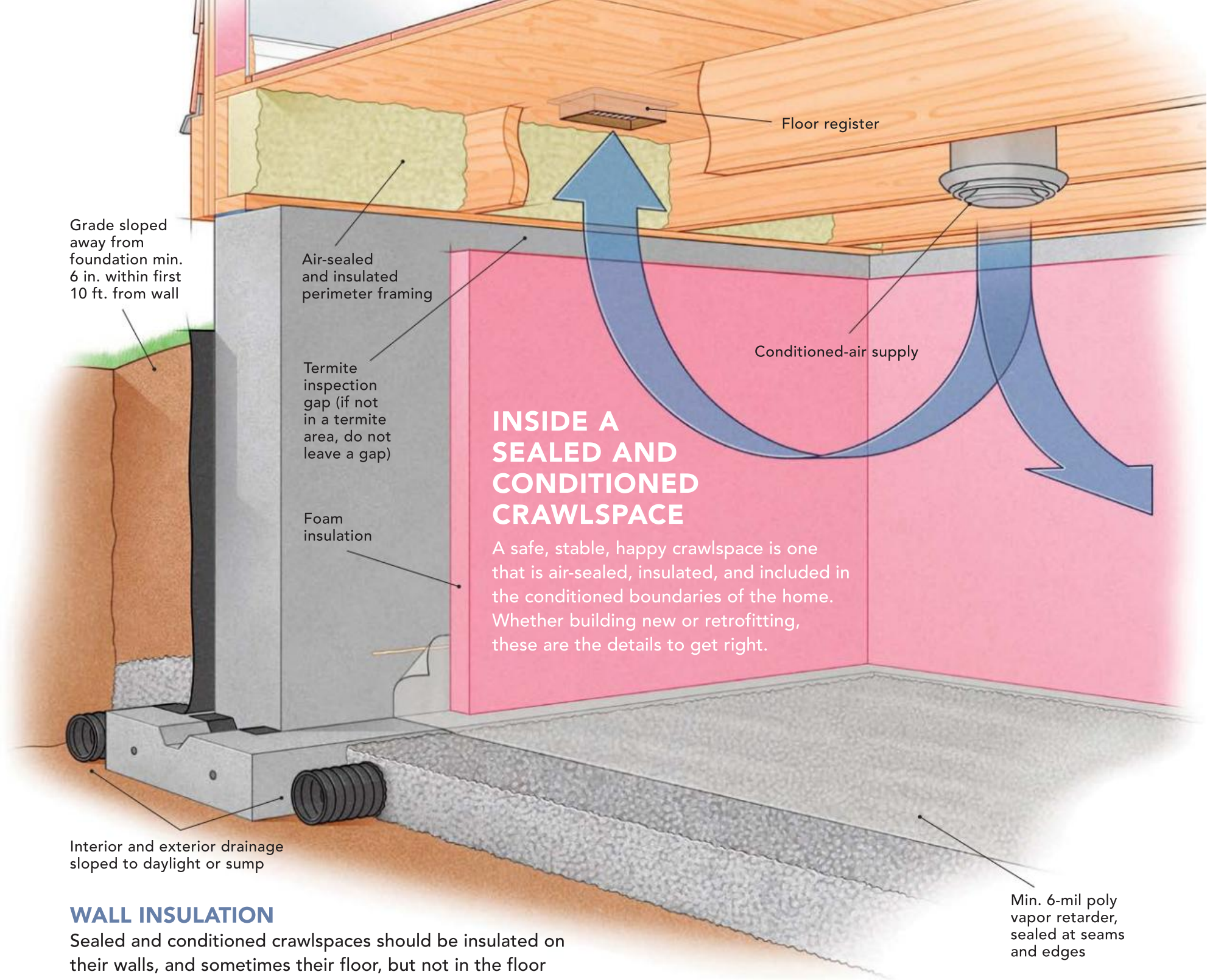
Although vented crawlspaces have earned a bad reputation over the years, they do have their place, particularly in flood-prone areas where a sealed approach won’t work or in very dry regions where it’s not necessary to condition the crawlspace. But many vented crawlspaces are doomed to fail from day one. Most include the use of fiberglass-batt insulation on the underside of the floor (the crawlspace ceiling) in an effort to separate the conditioned living space from the unconditioned space below. But fiberglass batts are air and



vapor permeable, so they do little to prevent humid crawlspace air from reaching the relatively cool framing lumber and sheathing of the floor. Moisture content in the lumber climbs, has little opportunity for drying—especially if the interior flooring is vapor impermeable—and rot sets in.

The key to a successful vented crawlspace is to treat the assembly as if the house is built on piers. Instead of fluffy insulation, choose air- and vapor-impermeable insulation such as rigid foam or spray polyurethane foam. If the humid air can't

reach the framing, you'll never have rot. Still, it's a good idea to install a Class 1 vapor retarder on the crawlspace floor, sealing all the seams and around the perimeter. Including the vapor retarder not only reduces the amount of moisture coming up from the ground, it also allows you to downsize the vent openings from the model-code-required minimum of 1 sq. ft. per 150 sq. ft. of crawlspace floor area when there is no vapor retarder to 1 sq. ft. per 1500 sq. ft., which can reduce the amount of moisture-laden air allowed into the space.



WALL INSULATION

Sealed and conditioned crawlspaces should be insulated on their walls, and sometimes their floor, but not in the floor framing. Choose an insulation that isn't sensitive to water and effectively blocks the flow of air to prevent humid crawlspace air from coming into contact with the cool concrete surfaces.

Foam-insulation materials, either spray-applied or in board form, are ideal choices for this application. The greater the permeance of the insulation, the better it will allow for inward drying. Because vapor permeance varies by type of insulation, the thickness of the insulation will vary, too. According to research sponsored by the Building America program, the following insulation options and thicknesses meet the vapor-permeability requirements for the walls of a crawlspace:

- 2 in. of unfaced extruded polystyrene (XPS; R-10)
- 4 in. of unfaced expanded polystyrene (EPS; R-15)
- 3 in. of closed-cell spray polyurethane foam (R-18)
- 10 in. of open-cell spray polyurethane foam (R-35)

Be sure to check with your local building department to determine if your chosen insulation requires a layer of gypsum or equivalent fire-retarding layer to protect the foam, and that the R-value meets local energy-code requirements.

FLOOR COVERING

Generally speaking, crawlspace floors don't need to be insulated to perform well. They do require a vapor-diffusion-resistant groundcover, though, such as heavy-duty polyethylene sheeting carefully detailed around all piers and other obstructions and taped at all seams and boundaries. This poly sheeting, which serves as the vapor retarder and air barrier, should be at least 6 mil thick, but twice as thick or more is even better. Although not an easy task for a remodeling situation, best of all is to lay the poly, tape the seams, and then pour a thin layer of concrete over it and seal the perimeter and control joints to ensure it stays protected over the long haul.

If the floor of the crawlspace is below the level of the exterior grade, it's best to include a drainage system and slope the floor toward the drain or collection point, just like in a basement. As always, pitching the exterior grade away from the foundation is a must.

AIR "CONDITIONING"

To satisfy building-code requirements and eliminate moisture problems, the air in sealed and insulated crawlspaces must be conditioned. There are several methods to choose from, and all will work. The choice depends on budget, availability of a furnace or central air conditioner, desired energy use, and more.

Provide supply/return air

By connecting the crawlspace to the ductwork of a furnace or air-conditioning system, it's possible to condition the crawlspace air, removing moisture. If there are already ducts running through the crawlspace, this is an attractive solution, and likely the most common approach to a healthy crawlspace. This strategy works well for removing moisture as long as the heating and cooling equipment are sized properly for the house they're operating in. An oversize air-conditioning system, for example, can meet the temperature set point faster than it can actually remove excess humidity from the air. As a rule of thumb, Building Science Corporation (BSC) recommends that the air handler should run for at least 5 minutes per hour.

When using this supply-air approach, you need to deliver 50 cfm (cubic feet per meter) of airflow for each 1000 sq. ft. of underfloor area. You also need to provide a planned pathway for airflow between the living space and the crawlspace, such as a jump duct or transfer grille, to equalize pressure between the two spaces. BSC recommends a minimum of two 4-in. by 8-in. transfer grilles. Note that in order for this approach to succeed the crawlspace must be properly sealed and insulated.

Some argue that trying to condition the air in the crawlspace based on the conditions of the living space above can be trickier than it sounds, because the conditions are different.

Exhaust air to the exterior

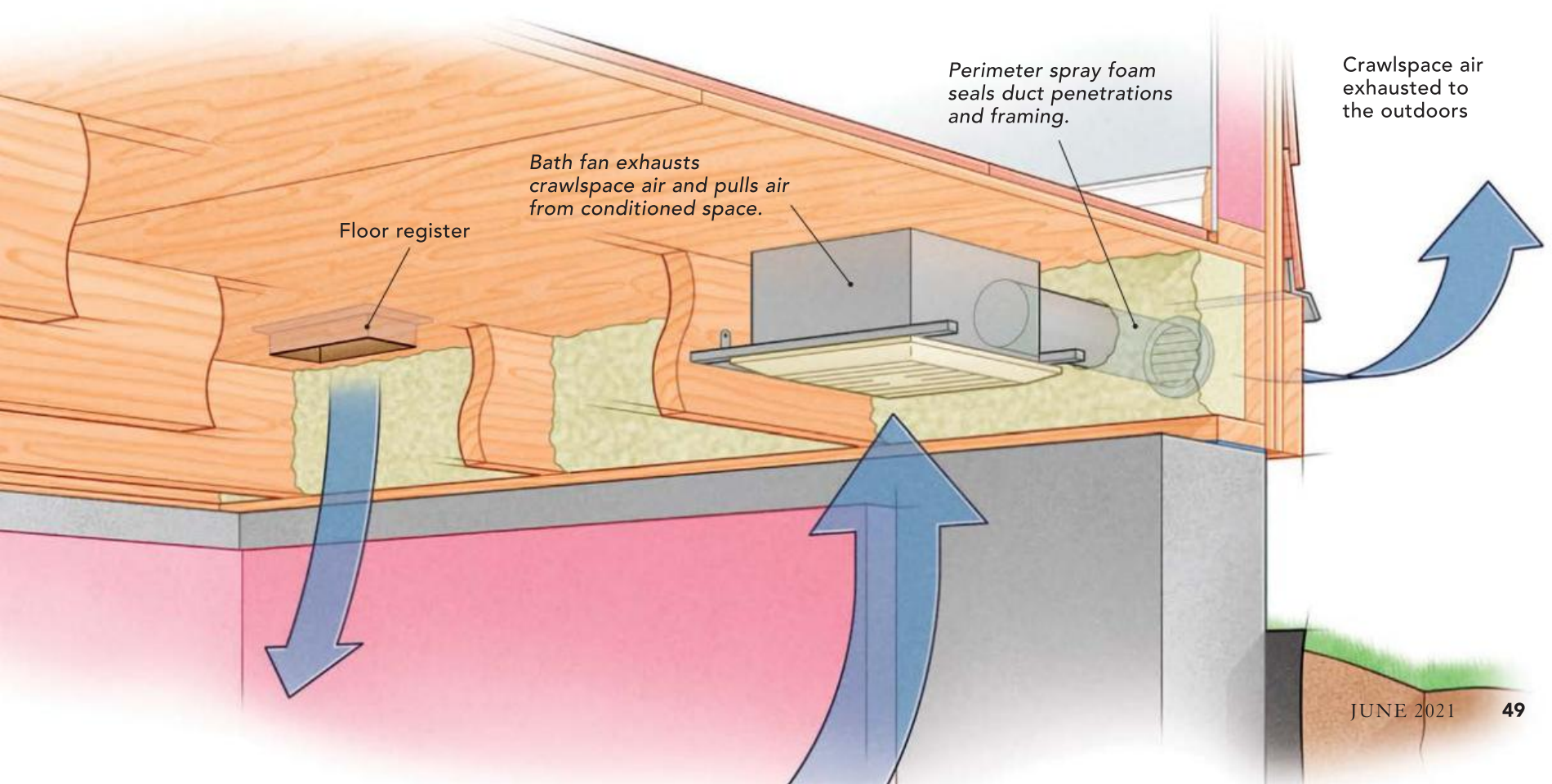
If you don't have ductwork or an air handler, then exhaust-only crawlspace ventilation can be an attractive solution. The idea is to install a small fan in the crawlspace that exhausts to the exterior. Replacement air enters the crawlspace by way of grilles in the floor or through short ducts and grilles in partition walls, bringing conditioned air into the crawlspace.

According to BSC's Joseph Lstiburek, the exhaust-only approach works well for houses with moldy crawlspaces that are being retrofitted. "Sometimes there are limited funds available to completely decontaminate a moldy crawlspace," he wrote. "Continuously depressurizing the crawlspace relative to the house uncouples the crawlspace from the house. Of course the original moisture problem causing the crawlspace mold needs to be addressed. An exhaust fan does not solve ground water problems. But installing a ground cover, sealing crawlspace vents and running an exhaust fan to the exterior does address most other issues."

Add a dehumidifier

According to building scientist Allison Bailes III, choosing a dehumidifier to condition a sealed and insulated crawlspace is a no-brainer. "It's controlled by the conditions in the crawlspace, not the house above, so this method will do the best job of keeping the crawlspace dry," he wrote in a blog post. "If you want dry air in your crawlspace, a dehumidifier is the way to go." If you go with this approach, the IRC requires dehumidification sized to provide 70 pints of moisture removal per day for every 1000 sq. ft. of crawlspace area.

Bailes suggests that a standard off-the-shelf dehumidifier may be sufficient to keep a small crawlspace dry. For medium to large crawlspaces, it's best to go with a more robust model, like the ones made by Therma-Stor (see pp. 60-65).



A large, dark-framed window on a light-colored house. The window reflects a landscape with green fields, trees, and a blue sky with clouds. The text 'Trombe Wall Solution' is overlaid in white on the reflection. To the left of the window is a section of the house with horizontal siding. Below the window is a gravel area.

Trombe Wall Solution



An indirect solar-heat-gain strategy addresses the challenge of orienting a passive-solar house's views northward

BY KILEY JACQUES

The owners of this certified Passive House in Ann Arbor, Mich., cherish their nearly five-acre property, which backs up to wildlife-rich woods and fields. Seeing that natural beauty from the house was a top priority. They wanted most of the glazing on the north side in order to optimize their views of nature in that direction and to ensure privacy on the other sides of the house, which are subject to potential eyesores from future development. Orienting windows to face north typically limits a home's ability to reap any potential benefits from solar gain, but they wanted to use that free energy to help heat their Passive House in colder months. The solution was to incorporate a passive-solar storage and delivery system in the form of three Trombe walls.

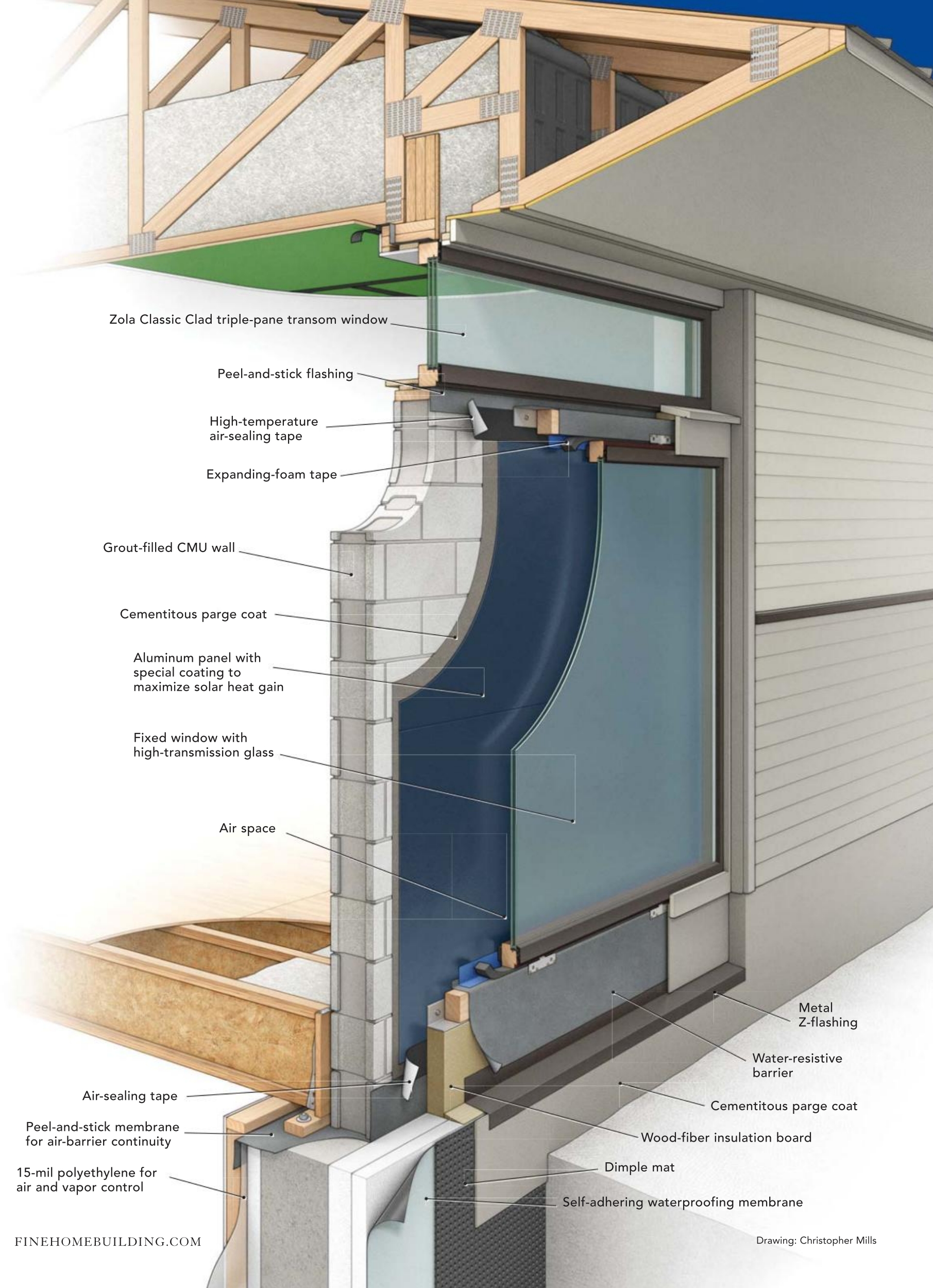
Passive solar in a Passive House

There is a distinction to be made between Passive House, the building standard, and passive-solar design. The former emphasizes an exhaustive list of requirements to reduce energy consumption, while the latter is focused on nontechnological means of harvesting, storing, distributing, and controlling solar energy. While a debate continues around the viability of using passive solar in superinsulated, high-performance homes, there are five basic fundamentals of passive-solar design: 1. At least one side of the building needs an unobstructed view of the sun and should be oriented toward it (due south in the Northern hemisphere); 2. Windows are required on the sun-facing exposure to allow in direct sunlight during the heating season; 3. A medium is

Continued on page 54



Optical illusion. The three large-format windows on the backside of the house are actually the outer layer of the Trombe walls. They are functional in that they let light in to heat the concrete-block walls behind them, but they offer no views.



MASS AND GLASS

TROMBE WALL CONSTRUCTION

From outside to inside, a Trombe wall consists of a layer or more of glass, a narrow air space, and a masonry wall coated with a dark, heat-absorbing material. Energy from the sun passes through the glass, gets absorbed by the dark surface, and is stored in the wall, where it can be distributed to the interior. Mike Mahon, owner of Adaptive Building Solutions, is a strong proponent of the Trombe system. Before constructing these walls, he drew lessons from a project he'd heard about, in which the builders poured concrete into forms—as would be done for a basement wall—and stacked a second level on top. They had a tough time keeping the wall from leaning because it didn't have structural supports, so here, Mahon and his crew used grouted concrete masonry units. They framed the floors, walls, and roof before tackling the Trombe walls. "That approach enabled us to build the walls with controlled precision," Mahon says, adding that filling the cores creates density for increased thermal mass. The wall is capable of giving off radiant heat for 10 to 12 hours; had the crew left the CMUs hollow, they wouldn't have nearly as much capacity to store and deliver heat.

After the walls were up, they installed a "selective surface"—in this case aluminum coil stock with an indium-tin-oxide coating on one side. The selective surface improves the wall's performance by reducing the amount of energy reflected or radiated back through the glass—about 90% of solar energy is absorbed and conducted inward. "That coating is basically a one-way valve for energy," explains architect Michael Klement.

Mahon points out that this component could be made less costly by simply painting the wall surface black. He also describes working with the tin-oxide coil stock as tricky because it needs to be cut from a roll into panels, and is sensitive to fingerprint oils. To ensure a solid surface for the panels, he screeded the CMU wall flat with a thin coat of mortar. To install the panels, he applied contact cement to both the wall and the back side of the panels, and used a minimal number of fasteners as temporary support to prevent sagging until the cement set up. Regarding the material, Mahon offers this advice: "Get it right the first time to avoid wasting panels, which you can only get in 100-ft. rolls—and they are expensive."

Given the assembly, the Trombe wall has windows on the exterior only. For both air-sealing and flashing around the rough openings, Mahon used 2-in. Hannoband expanding-foam tape, a more-flexible alternative to low-expansion spray foam. The windows are detailed like those in a supertight envelope—for a Trombe wall to work properly, it must maximize total heat gain from the sun while minimizing any losses during cold temperatures.



ADVANTAGEOUS ANGLE

Trombe walls can be used in conjunction with windows, eaves, and other elements to balance solar-heat delivery. The upswept soffits allow sun to enter the upper windows and the Trombe walls for maximum heat absorption during the heating season. In the cooling season, the overhang blocks the sun to prevent overheating.



SOLID CORE

Filling the concrete blocks densifies the walls, which increases the thermal mass for holding and transferring heat.



SELECTIVE SURFACE

Applied to an aluminum panel, a indium-tin-oxide coating made by Almeco Group absorbs radiant heat from the sunlight that hits it and conducts it inward to the wall.



TIME LAG

High-performance homes that rely on solar panels do not generate energy at night. The solar energy collected in a Trombe wall takes 8 to 10 hours to conduct through the concrete mass to the interior, at which point it begins to radiate heat into a room.

Continued from page 51

needed to absorb heat from the sunlight in the heating season; 4. The design should allow for the stored heat to be distributed where it's needed through natural conduction, convection, and/or radiation; and 5. There has to be a way to stop or limit solar gain during the cooling season, when it could overheat the building.

The most common passive-solar designs take a direct-gain approach, using the interior space itself as the medium to absorb and distribute heat. In these designs, the long axis of the house is oriented in an east-west direction and most of the windows are arranged on the sun-facing exposure to allow in sunlight. Extra interior thermal mass, usually in the floors and/or walls opposite the sun-facing windows, absorbs heat from the sunlight throughout the day and releases it at night. The rooms people occupy most get arranged on the sunny side of the house to take advantage of the warmth and daylight, and the utility rooms, bathrooms, closets, stairways, and hallways get pushed to the shaded side, where glazing is kept to a minimum to minimize heat loss. Roof overhangs are usually designed to shade the sun-facing windows during the summer months and allow low winter sun to beam straight in.

Given the homeowners' stipulations for views to the north, this project couldn't use the direct-gain strategy. Instead, Michael Klement,

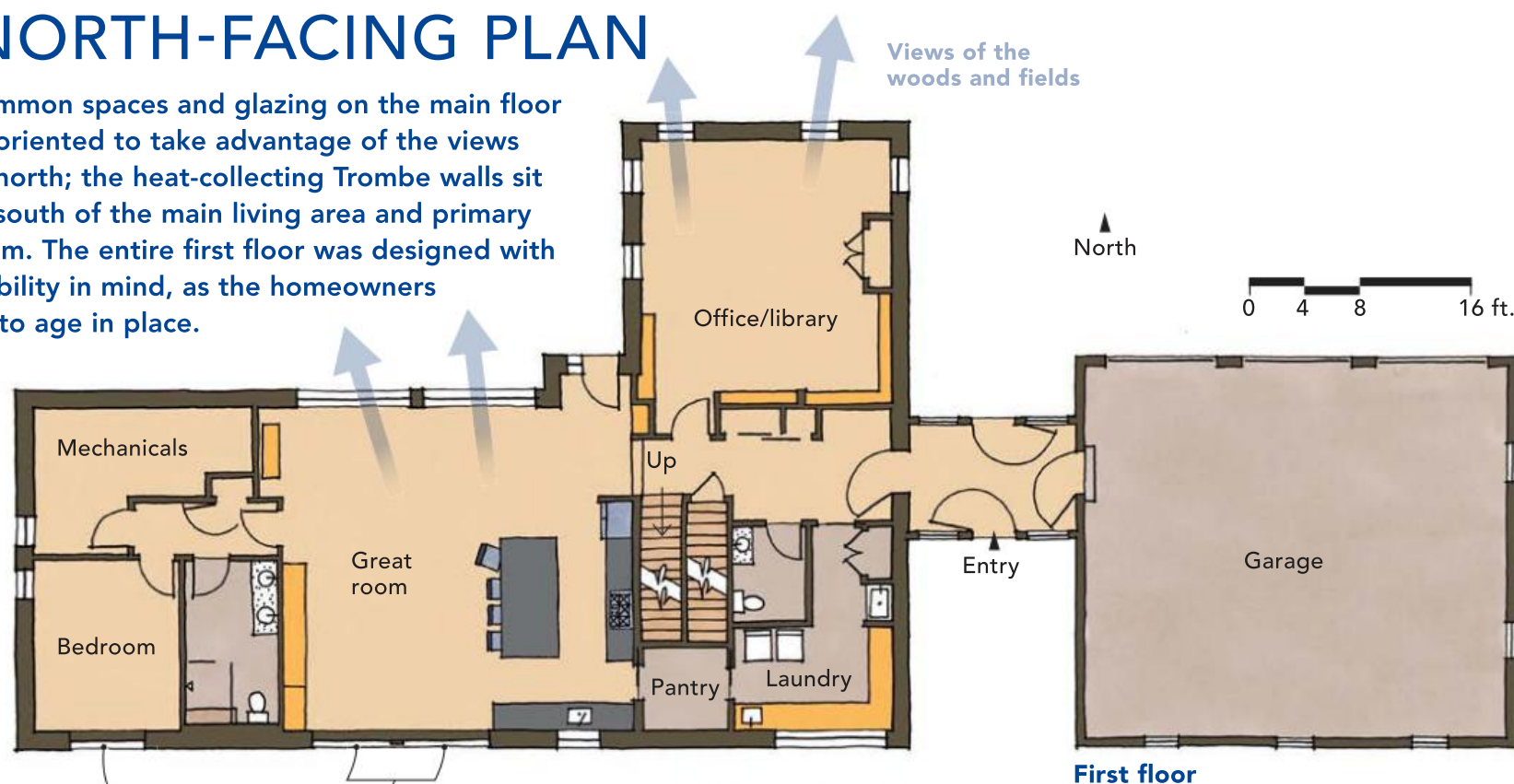
principal of Architectural Resource, took an indirect-gain approach, using a space-heating passive-solar wall system popularized by French inventors Jacques Michel and Felix Trombe in the mid-1900s: Trombe walls. A Trombe wall consists of a sun-facing masonry wall behind glass, with an air space in between them. It blocks sunlight from entering the living space directly, but it doesn't waste it. The masonry is ideally coated with a dark, heat-absorbing material that collects heat from sunlight and stores it in the wall. There are various approaches to distributing this stored energy. One is to use vents to move the heat to the interior using natural convection; another is to utilize conduction to move heat to the wall's interior surface, where it's radiated into the space; another tactic is to combine the two techniques.

Klement designed three south-facing Trombe walls for this single-story house using grouted concrete masonry units faced with indium-tin-oxide-coated panels that absorb nearly all of the possible heat from the infiltrating sun. Two of these walls are in the main living area, and the third is in the primary bedroom. This allows for harvesting passive-solar energy from the south while keeping the preponderance of conventional glazing on the north side to take advantage of the view.

"The beauty of the Trombe wall," says builder Mike Mahon, "is that it's a nonmechanical form of free heat. As long as there's sun-

A NORTH-FACING PLAN

The common spaces and glazing on the main floor are all oriented to take advantage of the views to the north; the heat-collecting Trombe walls sit to the south of the main living area and primary bedroom. The entire first floor was designed with accessibility in mind, as the homeowners intend to age in place.



BUILT FOR ENERGY EFFICIENCY

Climate zone 5 R values slab, R-30; foundation walls, R-30; above-grade walls, R-50; roof, R-90

Blower-door results 0.6 ACH50 **HERS score** 14

Total energy demand 10,896kwh/yr

Energy use intensity (EUI) 6.3 kBtu/sf/yr

EUI with PV 1.4 kBtu/sf/yr **PV array rating** 7.0kw

Total PV production 8734kwh/yr



Second floor

SPECS

Bedrooms: 3

Bathrooms: 3

Size: 4970 sq. ft.

Location: Webster Township, Mich.

Architect: Architectural Resource

Builder: Adaptive Building Solutions

shine, it won't fail. It can never break down. It's basically a thermal battery."

Architecture as a problem-solver

According to Klement, the design concept for the house was "21st-century Craftsman Prairie"—after the Prairie School architectural style of the late 19th and early 20th centuries. It is visually distinct for its long, extended horizontal lines meant to emulate the plains, and the two-story center section, which houses the guest bedrooms. The hip roof is notably detailed with 5½-ft.-deep overhangs with a pronounced knife edge. The overhangs are key. During the hot summer months, the walls (and interiors) are fully shaded; come late December, low winter sun is able to reach the Trombe walls thanks to upwardly angled soffits.

Of course, high-performance building materials and mechanical systems contributed to the house's energy efficiency and tight envelope, which measures 0.6 ACH50. The southeast uniform roof plane supports a 7kw PV array, and the outdoor mechanical units (see below) are stationed on that elevation. The drive serpentine around to the northeast end of the house, where the main entry is located. An airlock breezeway, which is outside the thermal envelope, connects the house to the three-car garage. The airlock is a nonmechanical energy-saving element that Klement has started including in recent



“The beauty of the Trombe wall is that it’s a nonmechanical form of free heat. As long as there’s sunshine, it won’t fail. It can never break down. It’s basically a thermal battery.”

—Mike Mahon, owner of Adaptive Building Solutions

projects. The pressurized space includes two hermetically sealed doors that prevent substantial amounts of conditioned air from escaping when people enter and exit; Klement notes that the vestibule also serves as a decontamination zone during the COVID-19 pandemic.

“These days, solutions rely on throwing energy at problems,” says Klement. “When possible, I prefer revising pre-fossil-fuel techniques for saving energy.” □

Kiley Jacques is senior editor at Green Building Advisor. Photos courtesy of Architectural Resource.

Energy-saving systems

The all-electric HVAC system includes components considered to be on the cutting edge of new technologies. Heating and cooling are handled with a Mitsubishi M-Series exterior compressor, which powers two ducted and two ductless minisplit interior heads. The multi-zone inverter-driven system automatically adjusts to provide con-

sistent thermal comfort. Compared to conventional systems with their leaky ductwork, it delivers more of the conditioned air it produces, which saves energy and lowers utility bills. A Zehnder ComfoAir 550 Luxe HRV handles the ventilation. Because the supply air is heated close to room temperature, occupants don't feel the unpleasant

drafts associated with some ventilation systems. It is coupled with a Zehnder ComfoFond-L eco brine geothermal heat exchanger, which extracts heat from the outside air and transfers it to the ground during summer months; in winter, it preheats the outside air using the heat stored in the ground—resulting in heat recovery with an efficiency of



up to 95%. The hybrid electric water heater, one of Rheem's Professional Prestige ProTerra models, is said to be four times more efficient than a standard electric

tank, and can save up to \$480 annually in energy costs. The upfront costs of the entire package are steep, but energy and cash savings over time are guaranteed.

Christine Williamson

This forensic building scientist demystifies her discipline for architects and construction professionals

BY AARON FAGAN

Christine Williamson may have followed in the footsteps of her father, building scientist Joseph Lstiburek, but she is forging a path all her own. Williamson graduated from Princeton and then went on to study architecture at the New School of Architecture + Design, graduating with a master's degree in Architecture. She's a practicing forensic building scientist who investigates failures in enclosures, mechanical systems, and material. As a consultant, she offers risk mitigation on everything residential, from custom homes to high-rise towers. She has also worked on well-known buildings outside of the residential sphere.

Williamson has become one of the industry's most in-demand speakers, well worth catching at the next local or national conference you attend. She shares her experience and expertise freely via her very creative Instagram handle @buildingsciencefightclub—it is worth joining social media for. And her website, which bears the same name, is an educational platform for architects to learn the building science that will make their work as durable as it is beautiful. Williamson may be focused on educating architects, but it's safe to say that anyone in construction should be listening to what she has to say.

AF: Is building science becoming more widely understood by nonspecialists?

CW: I don't actually know. As a practitioner, the focus is always on acquiring deeper technical competence. As I've advanced in this profession, I've found the industry—not just building science, but the whole building industry—is phenomenally complex. And you really only get to understand small parts of it. There are wonderful practitioners who are very talented, but the band of their experience is really narrow.

A lot of the failures we see in building science can be better understood as consequences of poor decisions voluntarily made. I don't want people to have to deal with the negative consequences of their decisions, and there are a lot of areas of life where we humans prioritize our short-term interests over our long-term interests.

AF: The epigraph for your father's *Builder's Guide* series begins, "When we build, let

us think we build forever." Yet you've said, "We shouldn't be designing buildings that never fail." Are these statements compatible?

CW: I like seeing that John Ruskin quotation repeated. I find it not so much to be an instruction for every type of building—not every building is a monument or intended for multiple generations—but I think nobody would deny that when we get an opportunity to work on a project that is intended to last that long, it's a humbling and inspiring experience. I had a chance to work on the restoration of Belvedere Castle in New York's Central Park, which was designed by Frederick Law Olmsted, whom I learned about in architecture school, and what a humbling and joyful experience to know I touched something that will be around for many more generations. And lots of other people did, too! I just love that.

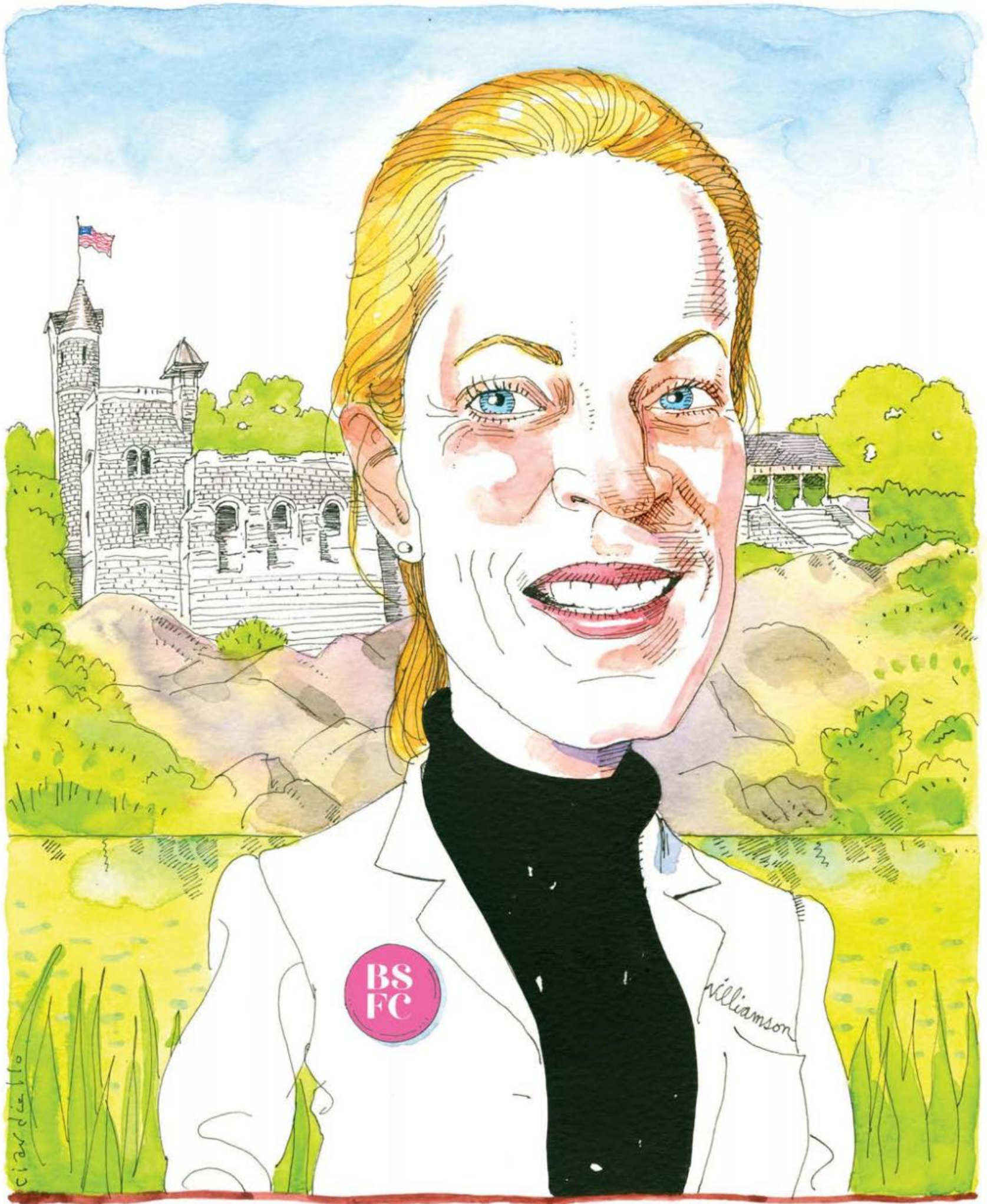
I also like that the quotation is addressing something cultural, not scientific. Our

job day to day is to respond to very practical concerns, and we're working within a culture that is more immediate. Then there are other people—*Fine Homebuilding* readers. They have to remain practical and employed, but there's a deep culture of pride that accompanies their day-to-day work. It's a different way of approaching things. I think that's what that Ruskin quotation encourages us to have: a culture of care.

So I think we would be better if we collectively valued those things more, but also I think it would be silly to think that this quote applies to every setting all the time. If we built to that standard all the time, there'd be a lot of people who don't live in homes who otherwise might. So, sometimes there are trade-offs that reasonable people make.

AF: A realistic response to nature rather than a platonic ideal.

CW: I learned from fabulous teachers, including my own father, but what I was



engaged in day to day was not this “let us build forever”—type stuff—it was in making daily decisions about products and details. This is one of the things I try to teach well. Something that’s phenomenally frustrating for practicing architects is this acknowledgement that no one individual controls all of the variables. That’s where professional judgment is particularly helpful. I think when you’re in a more academic setting, it’s easier to pretend that you have these infinite resources and that a single person gets to make all the decisions, and that that person is enlightened and shares your particular set of values. Those are some pretty big suppositions! Ask practicing professionals and I don’t think any have had a client whose values have perfectly aligned with their own.

I think people find building science really helpful as an intellectual tool or a scientific tool to make some of these decisions with more confidence and awareness. Most reasonable people understand the concept of risk, and they’re willing to take on some risk, but it’s a whole lot better when they know where the risk is, and then they can weigh whether or not it’s appropriate. The stuff that really makes people uncomfortable is the unknown. People feel pretty good about managing risk they understand.

AF: I’ve heard you speak about organizational problems versus design flaws or installation errors. Would you share more about what that means to you?

CW: Speaking of tools to help people make decisions better, one of the most helpful tools to help architects understand their buildings better, and make better design decisions on the front end, is understanding construction sequencing—how the actual building gets put together by different trades. One of the things that’s fascinating about buildings is nobody knows how to build them. Nobody. No single person knows how to build an entire building. Even if you’re building a log cabin. Did you machine the tools that cut down the trees? Did you grow the trees? Go back far enough, and there are a lot of hands in what we’re doing. But it’s extremely helpful to understand how the job gets divided up into different parts and the order in which

those parts are installed—it really helps architects draw better details. If you can account for construction sequencing, you can make it less likely that you’ll have an installation error. The general contractor’s job is to coordinate among a whole bunch of different trades. The more you understand construction, not even building science, the more it will help you draw or design in a way where the delineation between one person’s area of responsibility and another’s

“People feel pretty good about managing risk they understand.”

is clearer, and the clearer it is, the less likely you are to have installation errors.

AF: What’s the low-hanging fruit for us to make the housing industry better?

CW: From a performance perspective, I think there’s no question that it’s air-sealing: comfort control, pest control, acoustic control, and having control over separating the inside air from the outside air is going to be key. And then I would say attentiveness to general detailing to that end. There are some ways we put things together that seem almost designed to make it harder to air-seal. But I think our progress on this front is one of the reasons we’ve seen so much success in how our residential buildings, on average, continue to use less energy per square foot than they have in the past. Our codes are pretty great in that regard.

It’s also no coincidence that better air control also produces enormous comfort benefits for occupants, such as a quieter and less dusty home. Especially for people with allergies or asthma, there’s a real value to indoor-air quality for health and quality of life. I think people are a lot more inclined to think about indoor-air quality, particularly now after COVID-19 and the California wildfires. Air control and air barriers are partial design solutions for that. We’ve come a really long way, and we’re going to continue to see improvements. I think it’s one of the achievements in our industry.

AF: Historically, so much emphasis has been given to the amount of insulation for thermal comfort, but what’s the point of insulation without air-sealing?

CW: Yeah, people are really surprised by that when I teach. Air control is a greater contributor to thermal comfort and energy performance than insulation levels. When I learned it, it was a very powerful way of ranking priorities in design. If you were to list indicators of how energy-efficient a building will be, the top three enclosure-related things at are: First, what is the glazing ratio—how much glass is on the building and how good is that glass? Second, how well is it air-sealed—how well have they separated the inside from the outside? Third, how well insulated is it? And that order is surprising to a lot of people—I think many people would reverse it.

Another thing I challenge people to do—because people know that they like light—is calculate the window-to-wall ratio in their own house, just as a point of reference. They hear that something is 40% glazed, for example, and that doesn’t sound like that much. But when they realize they only have 15% glass in their house and that it’s comfortable and bright and happy, they understand. I don’t ask them to do this because people are bad at math. It’s a simple calculation, but it’s helpful to attach meaning to the numbers.

AF: What are some of the most misunderstood building-science principles by architects and builders?

CW: That we’re in the business of keeping water out, when we’re actually in the business of managing it. If you fill up your bathtub with water, take a bath, and then drain it, and then the next time you want to have a bath, you fill it up again—nobody considers that to constitute a failure. You drained it. That’s part of how the system is designed to work. The bathtub has a drain, and it’s intended to be used. When we add drainage to our walls, suddenly people view that as a secondary feature that should only come into play when there’s been a failure. But the drainage isn’t to account for failure, the drainage is part of a functioning system. Maybe it seems like splitting hairs to make that distinction, because functionally what

matters is whether the drainage is there or not, but from a practical perspective, it's a failure to understand that this is part of the proper functioning of the system, and that failure to understand winds up leading to a lot of problems—bad window detailing, and all kinds of other bad decisions. For example, people think cladding is supposed to be completely impervious to water and then detail it that way, but that specification is usually not the case.

That's the biggest misconception. We don't design anything not to fail ever, we design it for the conditions we intend to use it for.

AF: People don't necessarily think of a house as a system. Is there a way to encourage people to think about building more along those lines?

CW: No. I agree our homes are systems like a lot of things in life and they're very complex, but unfortunately, I'm not sure people will ever change. People pay attention to the system when there's a failure. When you do something well, it just becomes part of the background.

One of the images I find really telling and insightful is the G. K. Chesterton quote, "Don't ever take a fence down until you know the reason why it was put up." The older I get, the more I see that played out, over and over again—where in the idealism and excitement of youth you want to change things and make them better and different. The truth is a lot of things that we seek to change are part of systems we don't understand yet. That's why I like that line; the instruction is not "don't take down the fence" or "don't change it." The instruction is don't change it until you understand. I think that's true for our industry as a whole. The Chesterton is really similar to the Ruskin quotation in that, if you're waiting to fully understand the fence before we take any action, maybe we never take any action at all, so we can't quite abide by that in its entirety all the time. But it's also true that we would do well to understand systems before we propose changing them, especially dramatically.

There are a lot of young people who are attracted to architecture as a profession, especially with respect to green building, the Passive House standard, and moving

our industry to be more environmentally responsible. I think the passion there is wonderful, but I also think my advice is—and it sucks to hear; I felt the same when I heard it—you're not competent to change the industry yet. Understand it first. Then we can work on changing it. Seek to understand why something is the way it is before we go in and change everything.

AF: The popularity of your Instagram account Building Science Fight Club is encouraging. I appreciate the way you demystify specialized terminology.

CW: We end up confusing the metric or terminology we use for what it's intended to represent. We strive for ever lower blower-door test numbers, for example, and we can sometimes lose sight of what it is that we're actually trying to do. The blower-door test is meaningless in and of itself. I don't care

// No single person knows how to build an entire building. //

what a blower-door test does. I don't know, I don't care what it is in my house. What I do care about is what that test was intended to help me do, which is to design a more energy-efficient, comfortable interior environment. I think this happens frequently in our profession with credentialism as well—we mistake understanding the terminology for understanding the concept itself.

I've been really pleased that Building Science Fight Club has gotten so big for a bunch of reasons. On a kind of personal level, I struggled along the way to learn these concepts myself. Having the Instagram account get so popular is sort of an acknowledgement that a lot of other people have the same struggle, so these people are all acknowledging it is hard. I love that people actually are benefiting from it and enjoying their professional practice more as a result. And it makes me so immensely happy that people actually use the information to better serve their clients, to feel better on the job site, to design more competently and confidently, to interact with their clients better, and to interact with their colleagues better.

Also, I really enjoy teaching. That's a joy I sort of discovered partially through Instagram, and I've since started teaching for money. So, Instagram has become a little preview of the teaching I do for professionals. Instagram is informal, though, and these concepts really can't be compressed down to a few minutes.

But it's still helpful. You learn both ways. Sometimes you're cracking a textbook, sometimes you're attending an actual lecture, but a lot of the learning you need to do is experiential. This is really what I set out to mimic when I started on Instagram—a forensic site visit. The most concentrated time of learning in my career was when I was working for a woman named Fiona Aldous, an Australian who practices building science in the U.S. She was a phenomenal mentor and teacher to me. We would walk a job site together, and I would ask her to tell me what she saw. I wanted to know what her inner monologue was. I wanted to hear how she was thinking and processing things. Those moments weren't long—a small snippet from somebody who has experience in a particular area walking through the ins and outs of just one thing.

You still need that other intensive component in a different context—at a different time, that's still important—but the little snippets add up to a lot. So, I was trying to kind of imitate that. I would train myself when I was not with Fiona. I would look at a job site that was not my own, just stand there and look at it for a little while, and say, "OK, what's the structural system?" And I would say it to myself, out loud: "This is a concrete and wood-framed building with one story below grade. The waterproofing would have had to be a blind-side system that was applied first."

Just say what you're seeing. It's a great way of learning, because it teaches you to see stuff. This is good advice for young people who are practicing: Learn the names of things. Because when you know the names of things, you see them. And if you don't know what it's called, you won't see it. □

Aaron Fagan, a former associate editor for *Fine Homebuilding*, is a freelance writer and the author of three books of poetry, including *A Better Place Is Hard to Find* (The Song Cave, 2020).

Dedicated Dehumidification



To control indoor humidity, consider a separate system

BY SCOTT GIBSON

Ken Gehring was the president of a Wisconsin company that produced heat-recovery water heaters and other devices for the dairy industry when, in the early 1990s, his research helped him recognize a budding problem for many homeowners: The air in their houses was too damp, and air conditioners weren't solving the problem.

Air conditioning makes indoor air cooler, but it also makes it drier as airborne moisture condenses on the cold fins of the evaporator coil. If the air conditioner runs long enough, the air inside the house should dry to a comfortable level—roughly 50% relative humidity. But as Gehring came to realize, the AC equipment in increasingly tighter houses wasn't coping with increased moisture levels. The equipment ran just long enough to reduce the air temperature to the set point on the thermostat, but not long enough to remove much moisture.

Oversized AC equipment, which many experts say is a rampant problem in U.S. homes, makes the situation worse. The faster the air temperature drops, the less moisture the equipment is

able to extract from the air. The temperature can drop to the set point in a matter of minutes, prompting the AC to cycle off, but the air still feels uncomfortably clammy.

HVAC contractors and engineers consider cooling loads in two parts: the “sensible” cooling load (temperature), and the “latent” cooling load (moisture removal). As newly built houses gradually became better insulated and better air-sealed, the problem of inadequate latent-load management grew worse, not better. Protected from outdoor conditions more effectively, house interiors didn't get as warm as they used to in summer. The sensible load was smaller, requiring less AC run time. But the latent loads were about the same as they had been, so the imbalance became more pronounced.

Plus, in the shoulder seasons of spring and fall, AC might not be needed at all in many parts of the country because air temperatures are relatively mild. As a result, air conditioning doesn't run, and without it, there is zero moisture removal unless other means are employed to deal with it. The end

START WITH THE RIGHT EQUIPMENT

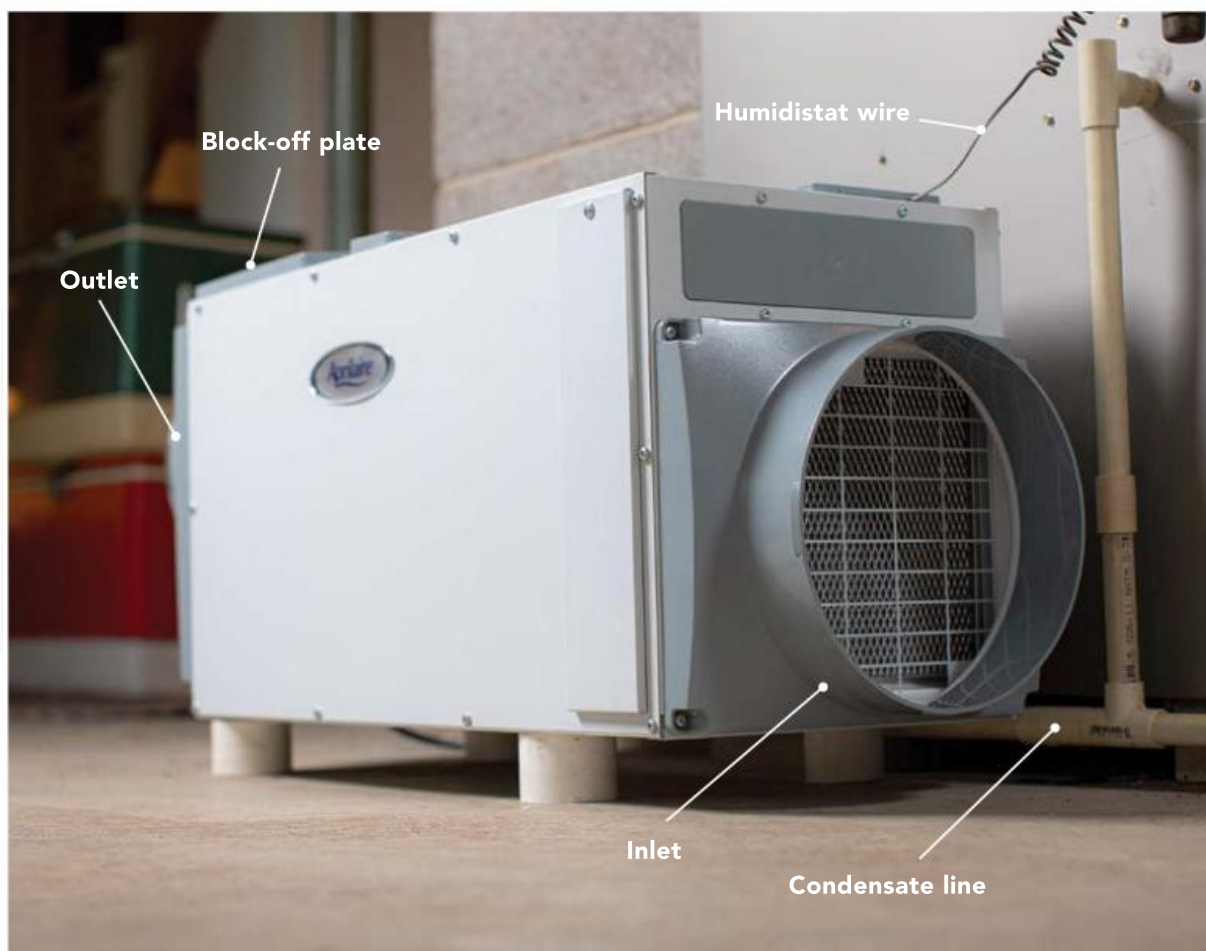
A dehumidifier from the appliance store is often fine for keeping a basement room dry, but these consumer-grade appliances won't have the long life of the high-capacity dehumidifiers offered by dehumidification-equipment specialists and HVAC-equipment manufacturers. These heavy-duty machines have replaceable components and longer warranties, and they can be controlled with remote humidistats. They can be installed unducted, with their own ductwork, or integrated into central HVAC systems. High-capacity dehumidifiers can also control humidity in really wet spaces like rooms with a pool or spa.

Right tool for humidity control.

With longer-lasting components, heavy-duty cabinets, and provisions for ducted installation, high-capacity dehumidifiers can dry wet basements and crawlspaces or be used for whole-house dehumidification.



Improved control. High-capacity dehumidifiers are often controlled with remote-mounted humidistats that keep track of humidity levels and run the dehumidifier as needed to keep the indoor air at the specified relative humidity. Some models are compatible with HVAC controls from other manufacturers.



Protective filtration. The filter on a consumer-grade dehumidifier is meant to keep the evaporator coil from clogging with dust or pet hair, not to improve indoor-air quality. But high-capacity units can have high-performance air filters that protect the equipment and clean the dehumidified air. This Santa Fe model has a 2-in. thick, MERV-13 filter.

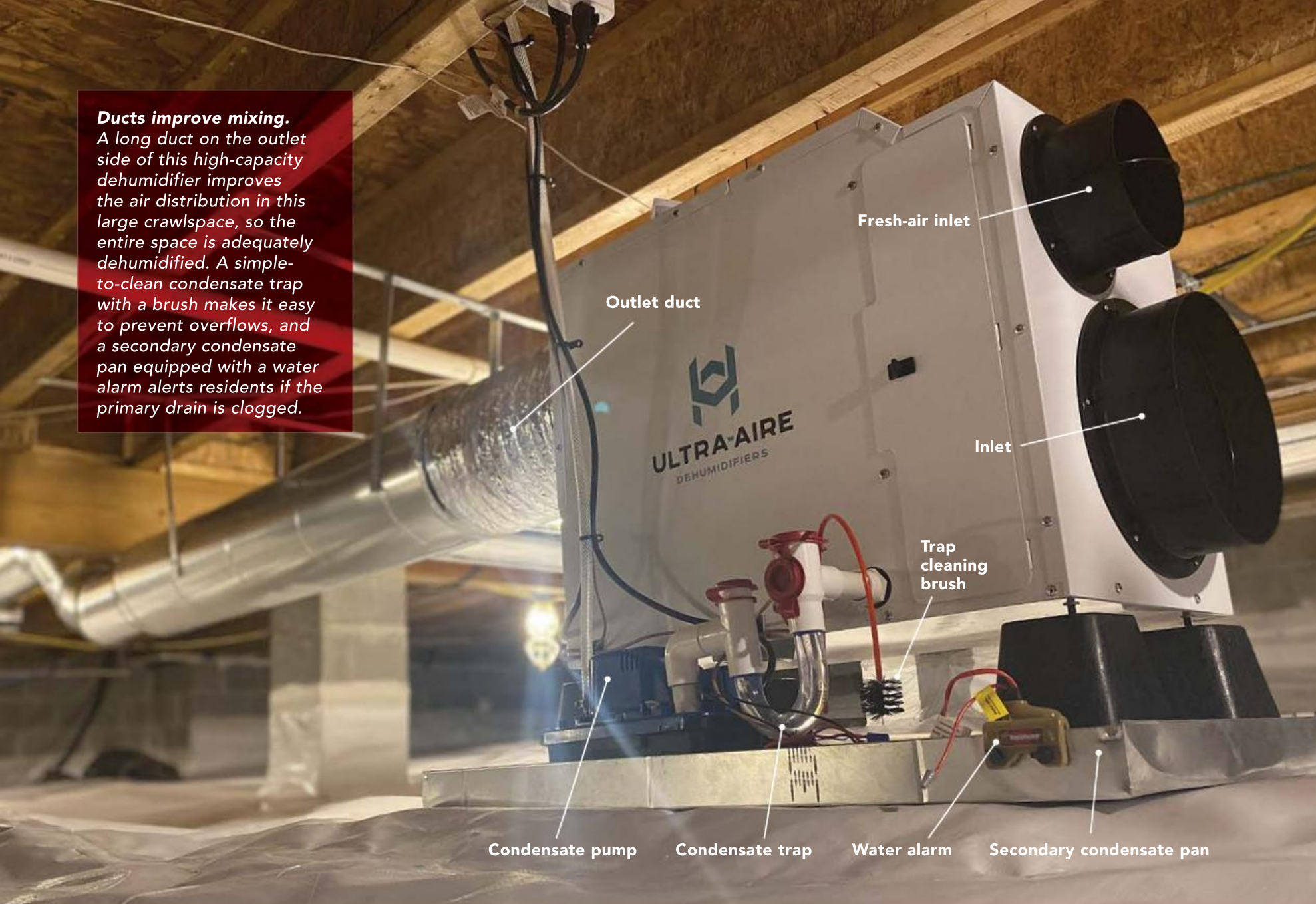


Hidden in plain sight.

At 33 pints per day, the Ultra Aire MD33 has less capacity than most high-capacity dehumidifiers, but it's the only one that can be built into a 2x4 or 2x6 stud wall (see it here hidden under the painting to the left). The maker says it can dehumidify up to 1200 sq. ft. Common applications include basement living spaces, condos, and senior housing units.

Ducts improve mixing.

A long duct on the outlet side of this high-capacity dehumidifier improves the air distribution in this large crawlspace, so the entire space is adequately dehumidified. A simple-to-clean condensate trap with a brush makes it easy to prevent overflows, and a secondary condensate pan equipped with a water alarm alerts residents if the primary drain is clogged.



result was that houses were being built more carefully and were, overall, more comfortable and energy efficient. But they were getting wetter.

Into this void Gehring's company, Therma-Stor, introduced what is credited as the first ventilating dehumidification unit, a device that could dry a large space and could be ducted to dry and filter air throughout the house. A few years later, Aprilaire introduced its own line of dehumidifiers, and the two companies now supply about 90% of this growing market segment.

Dedicated dehumidifiers allow humidity to be controlled separately from temperature; indoor air can be drier without resorting to overcooling, a condition that raises problems of its own. The question is, do you need one?

Damp houses are unhealthy

There are many potential health problems associated with high indoor moisture lev-

els, and ongoing research has provided an evolving view on the relationship between damp indoor air and poor health. In 2004, there was sufficient evidence to link damp indoor air to just a few conditions, such as wheezing, coughing, and worsening of asthma. By 2011, the list was much longer and had grown to include eczema, the development of asthma, allergic rhinitis, respiratory infections, bronchitis, and shortness of breath. Damp indoor air also can promote the growth of mold and dust mites.

The moisture content of indoor air is usually measured as relative humidity (RH), which is the amount of moisture relative to its potential saturation at that air temperature. A relative humidity reading of 50%, for example, means that the air contains 50% of the maximum moisture it could hold at that temperature. But RH is a moving target because warm air holds more moisture than cold air. Air with 100% RH at 32°F has

a relative humidity of only about 24% when the air is warmed to 70°F.

A more precise measure of moisture in the air is dew point. This is what the air temperature would have to be for the RH to equal 100%; moisture will condense on surfaces that are at or below this temperature—that's when dew forms on the grass, and droplets of water materialize on a cold glass. The higher the dew point, the more humid the air. Unlike RH, the dew point is not dependent on temperature. Dew points of 60°F and above feel muggy and are common in much of the eastern United States in the summer. By the time the dew point has reached 70°F, the air is what weather forecasters would call "oppressive."

So what's comfortable, and what's healthy? Allison Bailes III, a Georgia building consultant, says the optimal range is between 40% and 60% RH, although it should not stay at 60% for extended periods of time. John

ADDING DUCTWORK ADDS OPTIONS

Connecting ductwork to the inlet, outlet, or both sides of a high-capacity dehumidifier helps dry larger spaces more uniformly and allows you to install the dehumidifier in a mechanical closet or other non-living space to reduce its noise impact on the rest of the home. Like all HVAC ductwork, dehumidification ducts should be sealed and installed so the runs are as straight as possible. Any curves should be smooth and long-radius and maintain the duct diameter. Flex duct should be pulled tight and its ends sealed to minimize air and pressure loss. High-capacity dehumidifiers can be configured vertically for overhead ducts found in basements or horizontally for attics and crawlspaces.

Convertible duct collar.

Carrier and other manufacturers' outlet collars can be placed on the top of the unit for overhead ducts or on the front for low-headroom areas like attics and crawlspaces. A plastic block-off plate covers the unused outlet.



Vertical and horizontal options.

Ultra Aire and Sante Fe, both Therma-Stor brands, offer both horizontal and vertical high-capacity dehumidifiers for basement, crawlspace, and attic applications.

Bloemer, executive advisor and engineering fellow at Aprilaire, says most people will still be comfortable when the indoor temperature is 74°F and the RH is about 60% (a dew point of roughly 59°F); when the temperature reaches the mid-70s and the RH is 65%, people will begin to feel uncomfortable and moisture issues may develop.

And where dew points are high, the need for dehumidification is higher. The eastern half of the U.S., and particularly the Southeast, are the nation's most humid. In many parts of the West, the air is much drier and the need for dehumidification equipment that much lower.

Choosing a dehumidifier

There are different mechanisms that can be used for dehumidification, from desiccants to ionic membranes, but the most common type of dehumidifier for residential use is a self-contained unit that works on a vapor-

compression cycle similar to a conventional air conditioner. The device draws indoor air over an evaporator coil that has been cooled below the dew point, the moisture in the air condenses to a liquid state on the coil, and the dehumidifier expels heat (much of it the latent heat released when airborne moisture changes phase from water vapor to liquid water) as a byproduct. Dehumidifiers are rated by the volume of water they can remove from the air in a 24-hour period.

"The industry really has three buckets," says Bloemer. "In a basement you might get away with a 70-pint unit. A whole home, you typically are in the 90- to 95-pint range. A large home [5000 sq. ft. or more], you might get into the 150-pint range."

Nikki Krueger, building science and business development manager for Therma-Stor, says general sizing recommendations are based on square footage, but there are many variables: how leaky the house is,

where it's located, what the overall ventilation strategy is, and how many people live there. Therma-Stor's Ultra Aire line includes eight models with capacities ranging from 33 pints to 205 pints per day. Efficiency ranges from 5 pints per kwh of electricity to 7.6 pints per kwh, depending on the model.

Krueger says that in new construction, Manual J calculations should be available to show latent and sensible cooling loads. The ACCA's Manual S—which is used to select heating and cooling equipment—recommends that dehumidification equipment be sized to take care of 85% of the latent load on the assumption that AC equipment will take care of the rest. Still, there's plenty of leeway in choosing capacity, Krueger says. The big downside to more capacity is higher operating costs, but the penalties for oversizing are less significant than they would be for heating or cooling equipment. "You can't really oversize a dehumidifier," Krueger says, "but you can undersize it."

Prices for whole-house dehumidifiers—not including installation—can range from about \$1150 for a 70-pint Aprilaire for a small home or condo to over \$2600 for an Ultra Aire 155-pint model designed for spaces up to 3500 sq. ft.

Installation options

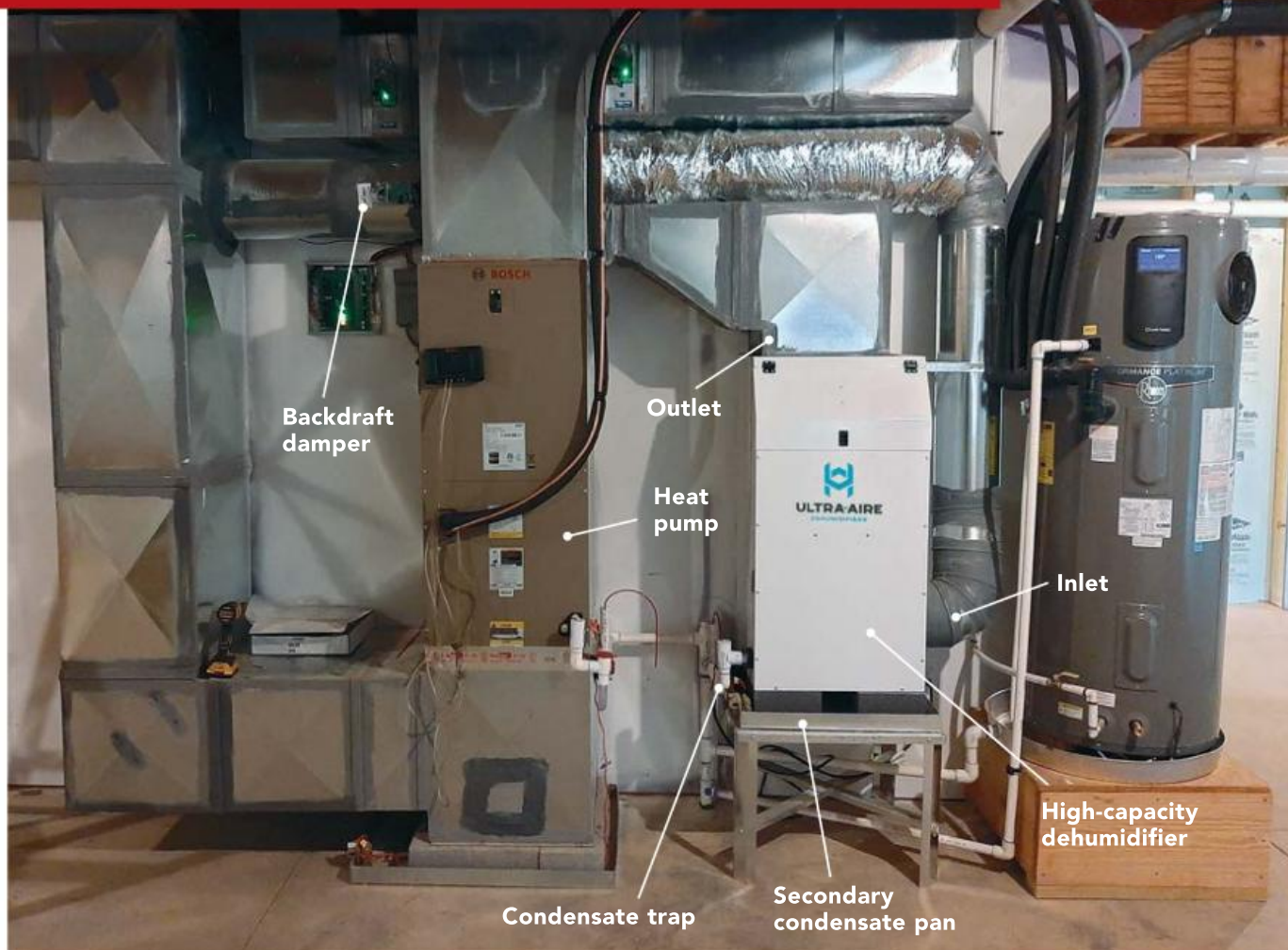
At its simplest, a dehumidifier can be parked in a basement, crawlspace, or closet without any ducts or outdoor-air inlets. Condensate is gravity-fed or pumped to a sump or drain. Given enough time, and with an open floor plan, an unducted dehumidifier will bring RH levels down throughout the house. This approach doesn't work as well in houses with a lot of interior walls and doors.

The most common way to install a high-capacity dehumidifier in a house with a forced-air heating system is to connect it to the existing ductwork for distribution around the house. A separate duct can be connected to the outdoors to bring in fresh air.

Although a dehumidifier can share ductwork with other ventilation equipment, according to David Treleven of Therma-Stor, the gold standard for installation is to have the dehumidifier installed separately with its own ductwork. As Treleven explains, when the appliances are installed independently of each other, they can operate simultaneously without causing static-pressure problems and without requiring

TIE IN TO HVAC FOR WHOLE-HOUSE DEHUMIDIFICATION

Connect a high-capacity dehumidifier to the trunk line of an air handler, central heat pump, or forced-air furnace for whole-house humidity control in the milder seasons. The inlet side of the system starts with a tap into the HVAC system's main return duct or a dedicated register in a central hallway. The dehumidifier's outlet duct delivers dehumidified air into the trunk line using the dehumidifier's built-in blower. A backdraft damper on the dehumidifier's outlet duct prevents blowing conditioned air from the air handler into the dehumidifier.



Whole-house control. The outlet side of this Ultra Aire unit connects to the plenum over a high-efficiency central heat pump. The inlet side is connected to the main return duct. The stand-alone dehumidifier helps control humidity at night and in the shoulder seasons when the heat pump runs less frequently.



Systems can be small. Installers faced with a small mechanical room can still often squeeze a small high-capacity dehumidifier on a 2-ft. by 2-ft. wall section and connect it with flex duct. Compact models also exist for low-clearance attics and crawlspaces.



Keep outside air out. Ductwork must be well-sealed when the dehumidifier is in an unconditioned space. Otherwise the inlet side could bring in humid outdoor air though leaks in the ductwork or lose dehumidified air to the outdoors through leaks on the outlet side.

oversized ducts. The downside to this approach is higher cost.

Jacob Straub, chief innovation officer for Ripcord Engineering in Portland, Maine, says dehumidifiers are often combined with other HVAC systems to save space and money, but it's probably not going to be the best option from a performance standpoint because dehumidifiers and ventilation equipment have different purposes.

"A ventilation system is a ventilation system, and these dehumidifiers are really latent-heat-management systems," he says. "Combining that latent-load-management machine with the ventilation machine not only gets complicated in some ways, but it may or may not work well. Let's say, for instance, you had a condition where you weren't going to run the ventilation system at a high rate. Well, if you have your dehumidifier connected to that, it means you're not going to be dehumidifying when maybe you need to. That's the downside of tying things together."

Factoring in whole-house ventilation

Many high-performance homes are equipped with whole-house ventilation systems. One type is an energy-recovery ventilator (ERV), which is designed to exchange moisture as well as heat as air streams cross paths in a heat exchanger. The idea is to save energy. In a hot and humid climate, an ERV will remove some of the moisture from incoming air and duct it outside with the exhaust air. This helps lower air-conditioning loads inside the house.

Some homeowners may look at an ERV as a kind of dehumidifier. But these devices will, in fact, raise indoor humidity levels, not lower them. "The ERV will never dehumidify your house because it can't do anything about the moisture that's already in your house," says David Butler, an Arizona-based building systems engineer and principal at Optimal Building Systems. "What it can do is mitigate the amount of moisture you're introducing with ventilation. An ERV is not anything like a dehumidifier, it just reduces what you otherwise would have introduced into the house."

ERVs can make indoor humidity much worse if installed improperly, Butler says. For example, when an ERV exhausts air from the bathroom, it will pick up very damp air when someone is showering. Even

though outdoor air may be very humid, it looks like drier air to the ERV, which will dump the moisture it's extracting from the bathroom back into the incoming air stream and into the house.

Heat-recovery ventilators (HRVs) are different. They capture more incoming or outgoing heat than an ERV but do nothing to recover humidity. Because of their advantage in what Straub calls "sensible heat recovery" (the percentage of heat from exhaust air that is transferred to incoming air during the winter), HRVs are sometimes the first choice for residential designers who are focused on saving Btus and money.

"ERVs are not dehumidifiers, but what they do is help manage the latent load," Straub says. "They manage sensible and latent load. If you choose an HRV in a low-load home you probably need to think about using a dedicated dehumidifier if you plan on running a cooling system in the summer, because you're not going to have the latent management capability you would have with an ERV and a cooling system."

First, try to keep moisture out

A dedicated dehumidifier may be the only practical way of controlling indoor humidity, but Butler believes there are other ways of minimizing a moisture problem.

"Pretty much anywhere in the country other than the West, you're going to have huge summertime latent loads," he says. "The way to manage those is to keep the moisture out to begin with—source control."

This amounts to paying a lot of attention to the building enclosure and air-sealing the structure carefully. Pitch the grade away from the house and manage water coming off the roof. Indoors, make sure dryers and range hoods are vented to the outside and use spot exhaust in the bathroom, kitchen, and any other area where moisture may accumulate. Don't over-ventilate, which can draw outdoor moisture inside. A popular cooling strategy in some parts of the country where

houses often lack central air conditioning is to open windows at night and use box fans in the windows or a whole-house fan in the attic to bring in cooler nighttime air. But the minute the windows go up, moisture-laden air is coming in.

Butler isn't so sure that an air-conditioning system is bound to fail in keeping up with latent loads, even in humid parts of the coun-

try. The key, he says, is to design the system correctly. That is, don't oversize the AC equipment and make sure it's adjusted for optimal moisture removal. Even Gehring, father of the ventilating dehumidifier, would agree that a well-designed AC system should be able to keep a house comfortably dry—at least during the day. But, he adds, as the sun goes down and the sensible load drops off, the AC starts to cycle on and off, running for 15 minutes and shutting off for 30. And the minute the system is off, nothing is drying the air. That's where a dedicated dehumidifier starts to shine.

Kristof Irwin, a professional engineer, former builder, and a principal at the Austin, Texas, consulting firm Positive Energy, would argue

that health and comfort should be paramount considerations in this equation, but are often overlooked by an HVAC industry that is too focused on the lowest first cost and thermal comfort rather than air quality. People living in a house are not unlike fish in a home aquarium, he says, completely immersed in their environment and subject to all of its biological hazards. The difference is that fish are provided with aerators to improve oxygen levels and filters to remove contaminants. "We treat our fish better than we treat ourselves," he says. □

Scott Gibson is a contributing writer in Portland, Maine.



Aprilaire
Madison, Wis.
aprilair.com

Carrier
Palm Beach Gardens, Fla.
carrier.com

Honeywell
Charlotte, N.C.
honeywellhome.com

Lennox
Richardson, Texas
lennox.com

Therma-Stor
Madison, Wis.
thermastor.com

Trane
Davidson, N.C.
trane.com

SOURCE BOX



A Better Way

Portland, Oregon, provides a model for deconstructing houses that is better for people, the planet, and profit

BY ASA CHRISTIANA

As people and money pour into thriving cities and blight spreads through others that struggle, an increasing number of old homes are crunched by the excavator and dumped in the landfill. Asbestos-wrapped ducting goes undiscovered inside walls, lead is hidden in layers of paint, and when the excavator shovel comes crashing down, a wide array of toxic substances are released as airborne dust. At the same time, valuable building materials go unrecovered, with a high cost in embodied carbon. None of these things is good for the health of people or the planet.

In 2016, pushed by neighborhood organizations tired of this kind of “crunch-and-dump” demolition, Portland, Ore., passed the nation’s

first deconstruction ordinance, making piece-by-piece dismantling mandatory for all homes built before 1916. In January 2020, the cutoff year was expanded to 1940. So far, more than 300 homes have been deconstructed in the city.

The rules are simple and the benefits far-reaching. The ordinance prohibits the use of heavy machinery for the structural work and requires that it be done by a city-certified deconstruction contractor, who must submit receipts for the donation, sale, or proper recycling and disposal of all materials. This guarantees a process that creates less dust, enables more-effective abatement of hazardous materials, and allows valuable materials to be salvaged for reuse.



By all accounts, Portland's program has been a success, keeping neighborhoods quieter and healthier, reducing the waste stream, feeding the city's retail reuse marketplace, and creating a new category of skilled labor. More importantly, the idea has caught the attention of municipalities across North America, many of whom have connected with Portland for advice and guidance, and launched deconstruction programs of their own.

The problems with mechanical demolition

Traditional demolition is generally seen as unskilled labor, to be accomplished in a day or two by the construction crew—or subbed

out to lower-paid laborers, who cut corners or ignore existing rules altogether. Making matters worse, municipalities lack the staff to enforce demolition regulations and respond to complaints.

Another problem is that the rules vary by locale. Most places lack an ordinance for lead abatement during whole-house demolition, for example, saving those for occupied spaces. And while many demolition permits require walls to be sprayed and debris to be kept wet to keep dust down, practices vary widely in the field.

According to a 2013 study in *Public Health Reports*, dust from mechanical demolition sends unsafe concentrations of lead, arsenic, chromium, copper, and manganese up to 400 ft. from the project

DECONSTRUCTION, STEP BY STEP

Dismantling without machinery allows for more thorough abatement of lead and asbestos and makes it easier to salvage materials, as shown in this deconstruction project in southwest Portland.



ASBESTOS IS FIRST

Asbestos abatement is done by a separate subcontractor certified for the task. Siding and duct wrap are two common targets.



SOFT STRIPPING

The deconstruction contractor starts by stripping out cabinets, doors, lighting, plumbing fixtures, and cabinets. There's not much resale value in these items, but all are donated to a local nonprofit reuse center.



LUMBER-PACKAGE PRIZE

The piece-by-piece dismantling of interior trim, floors, and walls reveals a treasure trove of old-growth fir in the studs, beams, and planking.



WATCHFUL EYES

Representatives from the city, the builder, and a third-party certification group are on hand for the first day of structural work.



A SAFE, QUIET PROCESS

The neighborhood is relatively unaffected; prohibiting the use of heavy machinery for the structural work keeps noise levels down while reducing toxic dust.



NOTHING LEFT BUT THE FOUNDATION

After every bit of building material has been removed—and either recycled, sold, or properly disposed of—the foundation and hardscaping sit untouched until new construction begins. At that point, they are typically demolished by the excavator and recycled.

site. Draw an 800-ft.-diameter circle around any urban lot, and it's likely to include 50 or more homes. In cities economically pummeled by outsourced manufacturing, the inventory of outdated, failing structures is immense, and the effects of mechanical demolition extremely harmful to those living close by. In 2018, after blood tests revealed alarming levels of lead in children, Detroit paused all demolitions in its worst-affected zip codes until better mitigation measures could be introduced.

"There is no safe level of lead in the body, and children are most vulnerable to the potentially devastating health effects," says Jordan Jordan, manager of the deconstruction program at Earth Advantage, a Portland nonprofit that provides training and certification for green-building practices. "Elderly people and those living with health problems also suffer disproportionately from toxins and particulate matter dispersed by traditional demolition."

Toxicity isn't the only blow to the environment from dirty demolition. Lost to the landfill are valuable, reusable building materials—from old-growth studs and planking to cabinets, architectural finishes, and vintage fixtures, each embodying the fossil fuels it took to produce them. "Most of the greenhouse gases associated with new building materials [are emitted during] manufacturing, not transportation and installation, so if you can reuse them, that's a very good thing," says Bryce Jacobson, a solid-waste-system planner for Portland's metro region.

In Portland, construction and demolition debris accounts for 30% of the waste stream. Aside from "rendering hundreds of tons of reusable material worthless," Jordan says, mechanical demolition also damages healthy soil, trees, and other mature landscape features, and it harms watersheds with toxic runoff.

The process and the payoff

The first step in a typical deconstruction project is asbestos abatement, carried out by a specialized contractor. Next, while waiting for the permit, the deconstruction contractor can get started on "soft stripping," which refers to things like pulling out cabinetry, doors, appliances, lighting, and plumbing fixtures for donation. Those are often picked up by a local nonprofit on the same day.

Once the permit is granted, lead abatement can begin. The focus is on exterior siding and trim, where paint contains the highest lead concentrations. This step is now required in Portland for both deconstruction and demolition of all homes built before 1978; a rule that was inspired, at least in part, by the deconstruction movement. All deconstruction contractors are certified for this work.

After exterior lead abatement, the tough work begins. The roof, siding, interior trim, floors, tile, and lath/plaster or dry-wall are stripped away piece by piece to reveal the "lumber package," which is the most valuable material for resale. In old Portland homes, the studs, beams, and wall and subfloor planking tend to be old-growth fir, with tight, beautiful grain no longer available from fast-growing modern forests. In homes outside the Pacific Northwest, other desirable woods

are often exposed. In the end, all that's left is the foundation and hardscaping, which will be broken up and recycled properly when excavation begins.

Better abatement and incentive for salvage

One of the many benefits of deconstruction is the continued abatement of lead and asbestos as the project progresses. If lead-painted trim is found on the interior, it goes in the same plastic-lined dumpster as the exterior trim. If lead paint is on the plaster, that can go down a chute to the basement, to be collected safely later. As asbestos-

wrapped ducts are revealed, they are marked with red paint and the asbestos contractor returns for them.

For deconstruction contractors, the sale of salvaged materials is built into the bid, helping to offset the premium for deconstruction over mechanical demolition. Clients also receive a tax benefit for donated materials.

For Dermot Lovett, who has been deconstructing historic houses in Portland for 20 years—both remodels and tear-downs—the new ordinance means more business, better awareness, and less explaining. “We recycle plastic bags and bottles,” he says. “The very least we can do is recycle houses. The material in these homes is stunning. Our old-growth forests are no longer there, but the lumber still exists in these old houses. If we crunch it and throw it in the landfill, we are losing those forests.”

Third-party certification establishes street cred

One of Portland's early steps toward an ordinance was hiring a local nonprofit to make key industry connections and provide critical training. Earth Advantage (EA)—a Portland-based organization that certifies sustainable building practices—played matchmaker between local builders, developers, and reuse shops; they trained deconstruction contractors, providing invaluable feedback to city officials along the way. When the facilitator role was no longer necessary, EA turned its newly won expertise into a third-party standard for deconstruction. Called Safe + Sustainable Site Certification (S+S), the program offers local builders a way to certify their deconstruction projects, whether mandated by the ordinance or not. It enables them to market a comprehensive commitment to sustainable building practices.

The additional S+S requirements and \$750 fee made sense for Josh Salinger of Birdsmouth Design-Build. (He is building a Passive House on the deconstruction site documented in this article.) “Certifying the process means the community doesn't have to take our word for doing the right thing,” Salinger says. “They'll know that a third party has verified that all of the processes have been done correctly and kept us to our word.”

Among the elements mandated in the S+S standard are clear and effective communication with neighbors and neighborhood associations, increased measures for job-site safety, erosion control and other site-protection measures, better management of hazardous materials and dust, and more-detailed deconstruction methods.

Although the S+S program is currently focused on projects in the greater Portland metro area, the company is interested in finding nonprofit partners and supporting pilot programs nationwide. To learn more and get in touch, visit safe-sustainable.org.



Green jobs and lessons for other cities

The process is better for workers, too. Lovett's field employees get competitive wages and benefits, and much safer working conditions than the typical demolition crew. For example, they wear respirators well after lead and asbestos have been abated, to keep drywall dust and fiberglass out of their lungs.

Notably, Lovett has more competition these days. With 12 certified deconstruction contractors and counting, Portland's ordinance has created a new category of green jobs, with a knock-on effect for the city's entire salvage ecosystem, including private retailers who sell reclaimed wood, local contractors and furniture makers who use the material, and nonprofit donation centers like Portland's ReBuilding Center—the city's largest and longest-operating reuse center—and the Habitat for Humanity ReStores.

Portland's deconstruction discussion turned serious around 2013, in conversations between employees and city officials at the ReBuilding Center. The tipping point came two years later, when demolition permits were peaking at 600 to 700 homes annually.

“It got ugly,” Jacobson says. “A wave of established neighborhoods were at war with developers. That's what got our ordinance going. The idea is the little house still gets replaced, but [the ordinance] adds additional care and increases the cost for redevelopment.”

Portland's neighborhood associations joined forces and met with the mayor and city commissioners, who in turn met with developers and industry professionals and made recommendations to the city council. In this way, the ordinance was shaped and passed.

A key condition for success was the strong local market for salvaged materials. Portland's long-standing DIY movement has always embraced reuse, and reclaimed wood and vintage items have always been a big part of the Portland aesthetic. They are seen in coffee shops, boardrooms, and living rooms around town, and are now exported to hip spots across the U.S.

As for the builders, “a few were ruffled by costs going up,” Jacobson says. “But once they saw that there was going to be equal enforcement for everyone, and accommodations for special cases, they were OK. And after they tried it, they saw it wasn't so difficult.”

Because of the money rolling into Portland—from California and beyond—the new ordinance and the premium paid for the process haven't slowed the pace of development. But neighborhood associa-

tions are pleased with the new normal—enjoying the health benefits, the reduced noise, and the knowledge that old houses will be recycled and reused.

Each time another friendly yard sign reading “I’m required to be deconstructed to maximize materials for reuse!” goes up, it announces the new demolition process. Neighbors wander by and ask questions, and that increases awareness.

Green shoots far afield

Shawn Wood is Portland’s Johnny Appleseed for the deconstruction movement. He is the construction waste specialist for Portland’s Bureau of Planning and Sustainability, and is responsible for leading the earliest discussions at the ReBuilding Center. In fact, it’s his phone number on the deconstruction yard signs. Well before the first ordinance passed, Wood was the point of contact for other cities looking to follow suit. “There was a lot of fanfare when Portland ‘cracked the nut,’” he says.

Shortly after the first ordinance passed, Portland was chosen to host the annual Deconstruction and Reuse Conference, held by the Building Materials Reuse Association (BMRA). EPA officials attended, Wood says, and helped set up the Bay Area’s Deconstruction Work Group, which draws interested parties from around the U.S. and Europe to its quarterly meetings.

Soon after the work group was launched, Palo Alto, Calif., made deconstruction mandatory for every demolished structure in the city, regardless of age. Soon after that, Vancouver, B.C., issued a deconstruction ordinance for all homes built before 1910, as well as a penalty for any demolition that doesn’t meet basic reuse and recycling requirements.

A mandatory ordinance isn’t the right path for every municipality—at least initially. Denver, Milwaukee, Minneapolis, Pittsburgh, San Antonio, San Francisco, and Seattle, among other cities, now offer some type of support for deconstruction practices, including online guides, links to local reuse organizations, and cash incentives

in some cases. Minnesota’s Hennepin County, for example, offers up to \$5000 to homeowners choosing deconstruction.

Conditions for success

Portland, Vancouver, and Palo Alto had a number of critical elements in place to make a mandate feasible: a metro government committed to waste reduction and recycling, the ability to absorb higher construction costs, and a robust market for salvaged material.

In Milwaukee, Wis., however, which passed an ordinance similar to Portland’s in 2018 covering homes built through 1929, the conditions were different, forcing the city to issue a stay on enforcement one year later. Because the city owns most of the aging inventory, the projects were city-run, with higher wage requirements, among other impediments. Secondly, the city lacked a robust salvage marketplace. Without the ability to take the lumber sale off the bid, costs were prohibitively high. “It’s all labor,” Wood says, “just hand-demolishing with no financial payoff.”

Portland experts agree. “There is currently a lot of focus on salvaging—keeping stuff out of the landfill—but less emphasis on reuse, which means that there aren’t sufficient resources to circulate those materials back into the community,” says Jackie Kirouac-Fram, executive director of Portland’s ReBuilding Center.

Reuse doesn’t have to happen locally, Wood points out, citing a nonprofit program in Baltimore that pays for deconstructing row houses by selling the reclaimed southern yellow pine to a company called Room & Board for a line of sustainably-sourced furniture.

“We can do whatever we want in Portland to fight climate change,” Wood says, “but if other places don’t follow suit, it’s a waste of time.” □

Asa Christiana is a contributing editor and freelance writer in the Pacific Northwest. Photos by the author.

/// Green building has a glaring blind spot when it comes to redevelopment: The embodied energy lost by putting an entire building in a landfill has a decade-long payoff period. ///

—Jordan Jordan, Earth Advantage deconstruction program manager



Old forests reclaimed. This big stack of old-growth-fir studs came from the house in southwest Portland featured in this article. Salvage Works kiln-dries every piece of reclaimed lumber it sells, and has a big bandsaw that can skim off lead paint.

HOUSES

ARCHITECTURAL CHALLENGES AND SOLUTIONS

BY DESIGN

CURATED BY KILEY JACQUES



FIRE-READY AND NONTOXIC

This solar-powered ranch sits on a four-acre parcel within the Wildland Urban Interface (WUI) of Sonoma County, Calif., which means it had to meet the required WUI fire-resistance standards: Roofs must be noncombustible and siding must have reduced flammability. “Wood can still be used, but exposed structural members must be a minimum 4-in.-nominal thickness, and wood siding must be at least 1-in. nominal thickness,” architect Bill Wolpert explains, adding that exterior soffits must be enclosed. Here, he spec’d a metal roof with continuous mineral-wool insulation and extrathick board-and-batten siding. Mechanical systems were put in the crawlspace, where a 10-mil reinforced vapor retarder was added to keep moisture in check and reduce the number of vents needed. Fewer vents means fewer opportunities for embers to get into the assembly.

Energy efficiency and indoor-air quality were also key objectives. A heat-pump water heater serves the domestic hot-water demand as well as the radiant Warmboard hydronic floor heating system, which in the main living area is covered in slate. Extra insulation in the roof and natural cross-ventilation from strategically placed windows and doors keep the house cool without the need for mechanical cooling equipment. Large sliders open onto a south-facing patio; on the north side, a shady courtyard-inspired outdoor space provides respite on hot days.

Designer Green Building Architects, greenbuildingarchitects.com

Builder Artisan Builders, artisanbuilders.net

Location Sonoma County, Calif.

Photos Eric Rorer





/// We design tight attic spaces that do not require ventilation. Continuous insulation over the roof helps that work without resorting to all foam. ///

—Bill Wolpert, Green Building Architects





ONE WALL AT A TIME

This house belongs to Jesper Kruse, founder of Maine Passive House. He built it in 2000, and recently completed a retrofit that meets the Passive House EnerPHit standard.

The 15-year-old Brosco wood windows needed upgrading, but Kruse felt it didn't make sense to put high-performance windows into a 2x6 wall; he needed to improve the walls too. He started with the south wall and worked his way around the house, one wall at a time, as budget allowed.

He added Larsen trusses to the existing shell and filled them with dense-pack cellulose, installed 10 in. of rigid foam to the exterior of the frost walls, replaced the old windows with Ecliptica units, air-sealed with ProClima membranes and tapes, and installed a Lunos ventilation system. The truss roof had 16 in. of loose-fill cellulose on the attic floor, which was moved out of the way in order to add a membrane for air and vapor control. Now, warm, moist air from the conditioned space below is discouraged from entering the attic.

Visually obvious changes include reverse board-and-batten vertical pine siding and cedar clapboards treated with black-tinted Seal-Once wood sealer. The front door was relocated; the deck was extended; the woodstove was moved into the open kitchen rather than the den, which was always too hot; and the opening between the kitchen and dining area was reworked to allow for barstool seating. This house is a good example of how approaching a project methodically can achieve high-quality construction on a modest budget.



Designer/builder Maine Passive House, mainepassivehouse.com

Location Maine **Photos** Emily Delamater, courtesy of Maine Passive House

FLOOD-READY PASSIVE HOUSE

This deep-energy retrofit is the first certified Passive House and net-positive residence in Cold Spring, N.Y. The unique nature of the site—which includes an easement across the front of the property for pedestrian access to a nearby state park—and the condition of the existing one-and-a-half-story house made it an exceptional undertaking.

During Hurricane Sandy, the original home flooded with over a foot of river water, which ruined the uninsulated basement and boiler. The rest of the house had also seen better days. The plan was to build within the same footprint; salvage what was possible of the nontraditionally framed and poorly built structure; and improve energy performance, thermal comfort, and flood resilience.

Toward that end, the builders added 12 in. of recycled EPS rigid foam on top of the existing slab, added a vapor barrier, and poured 3 in. of new concrete on top of it. This sandwich-like assembly raised the floor above the flood line. Mechanicals were mounted 4 ft. above the floor, cementboard was used on the interior walls to ensure a more water-tolerable surface, and rigid-foam insulation was installed on the exterior of the original block foundation walls and given a stucco finish.

Of course, raising the slab reduced the basement height, but because the existing 2x4 wood frame was jacked up off the foundation, and 4 in. of Foamglas insulation was installed to create a thermal break between the stem wall and the framing, the studio has a comfortable 8-ft. ceiling height.

The majority of the existing framing and sheathing was retained, and the west-facing windows are all in the original locations. Larsen trusses were installed to the outside of the original frame and filled with dense-pack cellulose to meet Passive House-level energy performance.

The pre-patinaed zinc roof wraps down onto the wall on the south-side balcony, creating a waterfall effect; the material was chosen for its rich luster and because it facilitated easy installation of a 5kw solar array. An arbor was incorporated into the reframed deck for a semi-sheltered outdoor living space, and the locally sourced hemlock siding was given a light *shou sugi ban* finish.

On the interior, a new stair with black walnut slat screens organizes the compact floor plan—connecting all three floors, while allowing natural light to filter through the rooms. (Previously, the only connection between the floors was via rickety outdoor deck stairs.) The location of the existing center beam and new stair resulted in an asymmetrical layout, which means one of the two new bedrooms is much smaller than the other. It is just one of many restraints that give the house its quirky and endearing character.

Designer River Architects, riverarchitects.com

Builder Nugent CM, nugentcm.carbonmade.com

Location Cold Spring, N.Y.

Photos Brad Dickson, courtesy of River Architects ("Before" photo courtesy of River Architects)







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SPEC

NEW AND NOTABLE PRODUCTS



VAPOR-PERMEABLE FLASHING TAPE

ZIP System Flashing Tape from Huber is a favorite among builders for reliable seals on sheathing seams, window installations, and other building-envelope details. But many cold-climate high-performance homes require vapor-open building materials to let accumulated moisture escape as the seasons change. To address this issue, Huber recently released their new Vapor Permeable Flashing Tape, which is compatible with all Zip System sheathing products—plus it can be used with wood windows as well as vinyl, aluminum, and galvanized metal. What makes this flashing tape distinct from other products in the line is its 3-perm rating—much higher than the standard ZIP System flashing tape. Made of a UV- and heat-resistant adhesive and a vapor-permeable monolithic backing, the tape is worth adding to your materials list if you're building to Passive House standards or just want to ensure that your well-insulated home is as durable as possible. The vapor-permeable tape comes in 3¾-in. by 90-ft. rolls. Contact a Huber rep or your local lumberyard for pricing and availability. —Lana Melonakos-Harrison, assistant editor

ROLL THE TAPE
PARA APLICAR
USE EL RODILLO



ZIP
system™
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SITE-BUILT PORTAL-FRAME SOLUTION

A typical stud wall relies on properly fastened sheathing for lateral resistance to racking. But when walls are skinny, such as on a facade with a garage door or big windows, those skinny walls have to pick up the slack. There's a broad spectrum of options to deal with this issue, from expensive factory-built shear panels to the affordable but limited approach of following the IRC's prescriptive Portal Frame with Hold-Downs (PFH) method. Now Simpson Strong-Tie has a solution somewhere in the middle, and with some impressive capabilities.

The Strong-Wall Site-Built Portal Frame System (PFS) is a kit that allows framers to build their own portal frame, similar to the PFH method—but the new Simpson Strong-Tie system can meet code in as little as 9¼ in. of wall width. The kit includes hold-downs, metal straps, structural screws, and standoff bases to accommodate built-up 2x10 or 2x12 posts. Yes, you read that right—this system is designed to rely on sandwiches of wide dimensional lumber and sheathing spacers or double LVLs as the posts. The headers are made of two plies of either LVL or solid-sawn lumber, with spacers required in some configurations spelled out in the product's ICC-ES Evaluation Report, ESR-4455. PFS is available in single and double kits, for about \$75 and \$120 respectively. —Justin Fink, builder-at-large



SIZED-UP ELECTRIC HEAT PUMP

Continual advances in technology are making new HVAC systems a popular way to update home comfort and energy efficiency. One great option is Mitsubishi Electric Trane's expanded line of SUZ heat pumps. The manufacturer added three new capacities this year, bringing the total for this improved line of outdoor units to seven: 9,000, 12,000, 15,000, 18,000, 24,000, 30,000, and 36,000 Btu per hr.

Mitsubishi's Hyper-Heating Inverter technology (H2i) enables the heat pumps to operate at performance levels in outdoor temperatures as cool as -13°F, with the potential to provide up to 100% of their rated capacity at 5°F. The technology is adaptable to a variety of indoor units and air handlers—all of which are Energy Star certified—allowing homeowners to reduce reliance on fossil fuels and opt in to a more sustainable and reliable mode of energy consumption. —L.M.H.





AIRY AND BRIGHT SKYLIGHTS

With spring upon us, we are all too eager to open up our homes and let the longer daylight hours and fresh air drive out the musty and the stale. These dreamy Awaken Skylight windows from Marvin seem like a great addition to any home to make it more comfortable and functional for all times of the day. The one-of-a-kind skylights come with built-in and tunable LED lights that match the spectrum of natural light, adjustable according to the user's wants and needs through an app, wall switch, or smart-home system. In a society in which our activities don't always correspond with the sun, customizable skylights seem like an invaluable way to improve how we experience our surroundings. In terms of air quality, the glass panels rise up and out, bringing fresh air in more efficiently than with a typical hinged skylight. A perimeter screen keeps bugs and any floating debris from coming into your sanctuary. Ultrex pultruded fiberglass frames and insulated safety glass panels ensure that the skylights are sturdy, secure, and energy efficient. Marvin offers a few popular finish options to make the skylights a seamless addition to the outside and inside of any home, including a classic stone white color for the interior and either ebony or gunmetal on the exterior. Awaken skylights come in sizes up to 48 in. wide and 90 in. tall, and align with standard rafter sizes, making the installation process even easier. —L.M.H.



XPS INSULATION WITH A LOWER CLIMATE IMPACT

The climate impact of extruded polystyrene (XPS) in insulation has helped steer some builders toward other rigid-foam options, including expanded polystyrene (EPS) and polyisocyanurate. To reduce its contribution to global warming and to comply with updated regulatory standards, Owens Corning has reformulated its XPS. This new version, Foamular NGX—short for Next Generation XPS—went on sale in the United States and Canada on January 1. Unlike older versions of Foamular, NGX is made without the blowing agent HFC-134a, a compound with a global-warming potential (GWP) more than 1400 times that of carbon dioxide. Instead, the blowing agent used in Foamular NGX has a GWP of less than 80, while still maintaining a rating of R-5 per inch. It's available with compressive strengths of up to 100 psi and thicknesses of between $\frac{3}{4}$ in. and 4 in. in various common sheet sizes.

In states that have banned HFC-134a, Owens Corning will be allowed to sell boards made with the old formulation until supplies run out. —Scott Gibson, contributing writer

askthe YOUR QUESTIONS—PRO ANSWERS experts

Insulating a wall with no sheathing

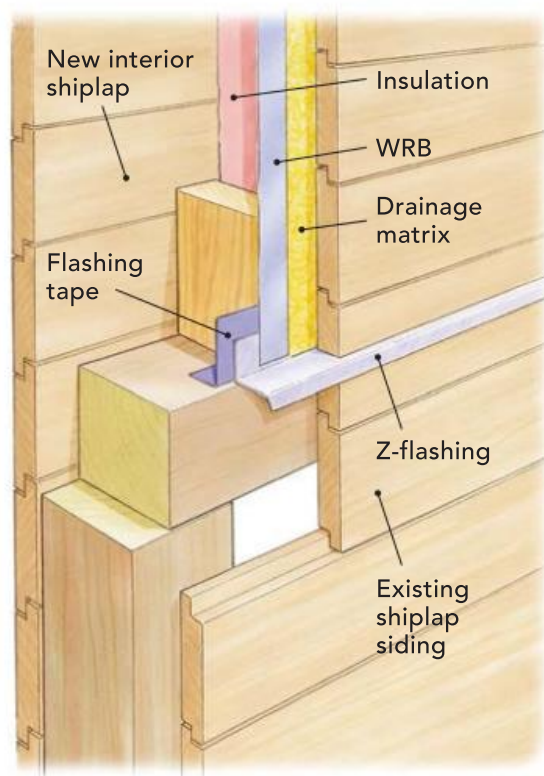
My clients have a new, two-story post-and-beam barn with shiplap pine siding and an unfinished interior except for the ceilings, which have been insulated with two layers of 3-in. rigid foam and covered in shiplap pine. They would like to insulate the walls and cover them with shiplap as well. What approaches might work best here?

—CHARLIE KRUKOWSK
via email

Ben Bogie, a project manager with BPC Green Builders in Ridgefield, Conn., replies: This is a tough one with no quick or easy solutions, at least not any that are good practice. The key here is to always assume that water is going to make it through the siding and allow for it to drain down and out while provide some air space for drying.

The most effective solution would be to just go over the exterior of the siding with a water-resistive barrier (WRB) and continuous insulation. If you used rigid foam as the exterior insulation, you could treat it as the WRB if detailed correctly. Then re-side over that, preferably with a rain-screen between the foam and siding. This is assuming the back of the existing siding is aesthetically pleasing on the interior. This is probably the most costly approach, but also the most effective and durable.

If you're stuck working from the inside, a good option to promote drainage and drying is to apply something like a mesh matrix rainscreen material to the back side of the existing siding, and back that up with a WRB (some are available as a two-in-one



DRAIN AND INSULATE

Always assume that water is going to find its way through siding and provide a way to direct it back outside while providing inward-drying potential.

product). This should be taped at the seams and to the timbers with a high-quality acrylic flashing tape. Ideally you'd pry the siding from the horizontal timbers so as to have the drainage material and WRB pass between and down to daylight.

Easier would be to cut the siding and integrate a Z-flashing through this cut (you could bend the "up" leg of the flashing after slipping it through the wall). Integrate the Z-flashing with the WRB, and with the horizontal timbers, and you've created a way to drain any water that makes it in (see drawing, above). You could then frame a 2x wall inboard of this to contain your insulation and act as nailing for your shiplap.

You can use whatever insulation you like in there. Any need for a vapor retarder will be dictated by code and your climate zone.

Building in the Southwest

I'm a builder in Massachusetts who's planning to retire soon. My wife and I will move from the Northeast to the Albuquerque, N.M., area and build our last house. Clearly, the climates are very different. Big picture, how does that affect the materials and how we should think about the design of our house?

—JOE
via email

David Crosby, a builder and construction consultant in Santa Fe, N.M., replies: One of the foremost considerations for durability, ease of maintenance, and lower operating costs in the Southwest is climate. With an average of about 300 days of brilliant sunshine a year, it is very unusual to see cloudiness that lasts more than two or three days. And the greater intensity of the sun has implications for the way we build. There is useful info and maps from the National Renewable Energy Laboratory (NREL) available at nrel.gov/gis/solar.html.

An approach that works elsewhere in the country can result in a badly overheated house in the Southwest. For much of the country, a daily variation in temperature may be 5°F to 10°F depending upon the time of year and humidity. In the Southwest, a 35°F to 40°F variation is not uncommon, and it's entirely normal at higher elevations for plants to be growing on the south side of the house with snow on frozen ground on the north side. Calculating solar exposures and window placement and using overhangs to shade the house between the spring and fall equinoxes is inexpensive and effective. Whether a house is intended to be passive solar or not, this must be taken into account not just for thermal gain but also for materials selection and envelope design.

Stucco is common in the Southwest because it withstands the solar radiation and temperature extremes better than conventional

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siding and paint. Flashing and drainage-plane details are every bit as important in the desert, especially with synthetic stucco. When it rains here, it rains hard.

Architecture in the Southwest, especially in New Mexico since the turn of the 20th century, often incorporates low-slope roofs and parapets reminiscent of older adobe construction. For durability, ease of maintenance, envelope integrity, life-cycle cost, and working out solar exposures using overhangs and porches, you're going to be better off with a traditional pitched roof with metal or clay-tile roofing. Hip roofs with dormers on adobe homes are common throughout northern New Mexico in rural areas, but you won't see asphalt shingles very often—the intense UV and frequent freeze-thaw cycles are very hard on them. If you are stuck with a low-slope roof, it's best to observe best practices (see "Guide to Low-Slope Roofing," *FHB* #269), paying particular attention to the number, size, and location of roof drains. UV and hail resistance is also a consideration; premium-quality modified-bitumen roofs with a reflective coating tend to hold up well.

One of the most common and serious problems in modern Southwest homes is drainage. It doesn't rain very often, but

when it does you can get a lot of water in a short period of time, and it can do a lot of damage. Unlike the relatively stable soils of New England, it is common to find collapsible soils, expansive clay, poorly graded fine alluvial soils, well-graded gravel, or cobble; sometimes two or more of those types on one site. You'll want to make sure that the provisions of International Residential Code section R401.3, concerning positive grading away from the house, are observed.

Siding on top of siding

I'm hoping to add fiber-cement shake panels on top of T1-11 siding. The T1-11 is in good shape, and the house is in the mountains of western North Carolina. It has 2x4 walls, fiberglass batts, 1/2-in. plywood sheathing, housewrap, and then the T1-11. Should I use felt under the fiber cement? Tyvek? Some other housewrap? Nothing?

—BRAD421
via FHB.com

Travis Brungardt, a builder at Catalyst Construction in Prairie Village, Kan., replies: It's great to consider the risks of covering existing finishes with new ones rather than removing them. Tyvek has extremely high vapor permeance (56 perms reported) and is

specifically allowed by the manufacturer to be applied over another layer without risk. Both #15 and #30 felt have high enough perm ratings to make them safe as well.

But the real question is if you need to install anything at all. In my view, the fiber-cement siding could be applied directly over the existing T1-11, assuming it's in good shape, with no risk of trapping moisture or hurting performance in the middle of the walls. The risk is at the transitions, specifically at the door and window openings. It would be safe to leave the existing trim in place, but I suspect you plan to replace it to stand proud of the new siding. Pulling the trim will almost certainly damage the WRB detailing, and you'll have to address that. Taping over the existing window flashing tape with a compatible tape is pretty safe. You have to clean the existing tape carefully to allow for good adhesion, and be meticulous in proper detailing and laps, especially at head-flashing corners.

I would also take this opportunity to air-seal from the exterior. You could add another layer of Tyvek and meticulously detail it, or seal the T1-11 panel seams to reduce air leakage. I would suggest caulking these at a minimum.

The bottom edge is probably harder. Likely, the panels will sit too far out from the foundation to create an effective air barrier with sealant. This is a good spot for a vapor-permeable tape like Siga Fentrim 430, which will adhere tenaciously to the foundation with no primer needed. Attaching it to the T1-11 is harder. Best would be to apply it to the Tyvek or plywood behind the T1-11. If there is a bottom trim board, remove it and tape to the plywood sheathing. If not, separate the T1-11 from the sheathing with a flat bar and carefully cut off the bottom inch of T1-11 to expose the sheathing. Tape, then hang the new siding low enough to cover the gap.

This is a good opportunity to introduce a rainscreen to enhance drying potential behind the new siding. You can get as fancy as you like with this, but an inexpensive and effective solution is to roll out sill gasket vertically at the stud locations and tack it up before you begin siding.



Built for extremes. Many materials and methods used in the eastern, central, and northwestern United States don't work in the sun-drenched Southwest. Asphalt shingles are very rare, and wood and paint don't hold up to the UV exposure. Shading to prevent overheating is critical, as is drainage. When it rains, it comes hard and fast.



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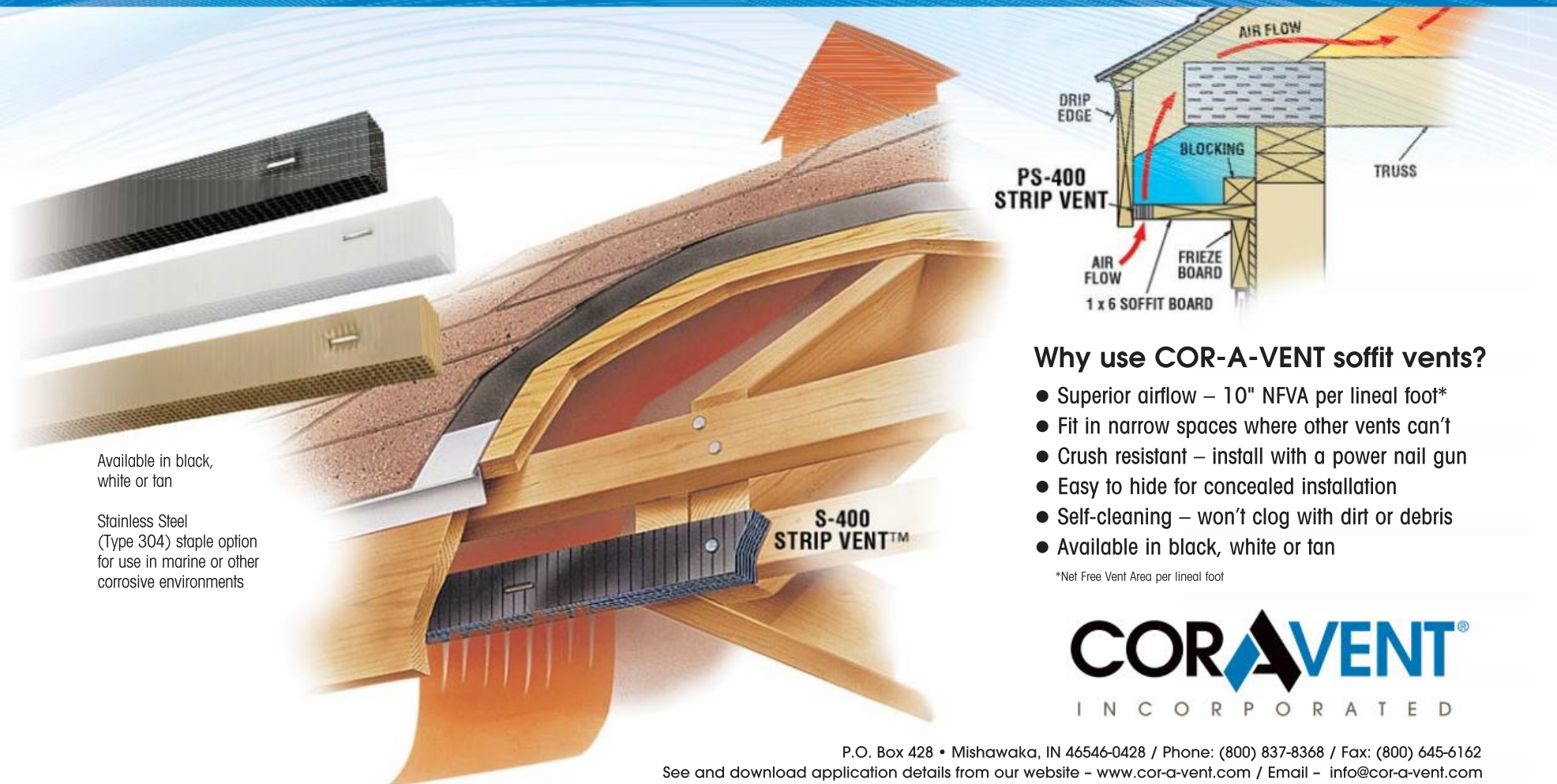
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Managing water when insulating old walls

One summer about 40 years ago, at a time when I was deciding between going to college and working while doing neither, my father hooked me up with a job insulating the walls of a shoddy summer home that was being lived in year-round. My dad knew everyone in the lakeside community where he lived, and one of his drinking buddies, whose business name ended with the word “Enterprises,” sold cellulose insulation and owned a blower. Another of his buddies owned the aforementioned summer house. And I wanted work. It was meant to be.

So, on a hot and humid New Jersey–summer day, I found myself drilling 3-in. holes in the siding of that rattletrap house, stuffing in a hose, and blowing cellulose while one of my similarly underemployed friends fed shredded newspaper into the hopper.

As my sweat mixed with cellulose dust, encasing me in a papier-mache carapace, I had little understanding of what I was doing. I had no idea, for instance, if there was blocking that would keep the cellulose from fully insulating the bays, or how important it was that the insulation be blown densely enough to avoid settling, which would render it less effective.

But that was the least of it. I never thought about water.

Not once did it cross my mind that the siding on almost every house leaks, never mind the siding on a post–World War II vacation house in a community my hopper-feeding friend’s father referred to as “the poor man’s Lake Tahoe.”

What happens to newspaper when it gets wet? It stays wet. While cellulose itself is usually treated with borates that retard fire, mold, and decay, the siding and framing of that house certainly didn’t have that protection. I’m sure I created a hell of a mess for someone down the road to clean up.

It’s all about water

Don’t get me wrong—cellulose has advantages over most other insulations, not the least

newer than the first Roosevelt administration. More than a few of them might have hosted George Washington. Every time I or the crew I am working with open up an exterior wall, we insulate it. And my first thought is never maximizing the R-value of the wall or ceiling. It is always how to insulate without creating moisture problems.

How moisture gets in

All siding leaks. Old houses survived only because the walls weren’t air-sealed or insulated, and the leaking heat and chronic airflow dried the assembly before the moisture could peel the paint off the siding or rot the framing. Doing the right thing by insulating

Warm air escaping through the upper level of a house during the winter creates suction that draws cold air in through small and large openings in the lower levels. Basements and crawlspaces that are wet during the spring and summer dry out in the winter because of this air movement. Moisture from this air moving through walls can condense on the back of cold siding or sheathing. Once the moisture has given up enough heat to change phase from vapor to liquid, it takes the same energy input to make it evaporate.

Sources of moisture also include cooking, showering, and occupant respiration. Historically, interior moisture sources have been given much

“...my first thought is never maximizing the R-value of the wall or ceiling. It is always how to insulate without creating moisture problems.”

of which is that it sequesters carbon. From a thermal perspective alone, almost any insulation added where there was none before is a benefit. But any insulation installed improperly can create moisture problems, particularly in old buildings.

For the last two years, I haven’t worked on a house

and air-sealing has the potential to destroy the building. That’s why builders of modern, high-performance homes spend so much time and effort detailing water-resistive barriers (WRBs) with flashing tapes.

Moisture from wet foundations can be transported by the stack effect up through walls.

more attention than is deserved, resulting in solutions such as plastic vapor retarders. In many cases, such vapor retarders do more damage than good by trapping moisture in the walls.

Before insulating

Installing new windows and doors is arguably the most



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You, along with our partners in the construction industry, have invested nearly \$200,000 in their future and in the future of home building. Every dollar donated to Keep Craft Alive goes directly to supporting our scholarship fund with SkillsUSA, a U.S. organization serving more than 395,000 high school, college, and middle school students enrolled in trade, technical, and skilled service programs.

Together, let's continue to encourage those with the passion for building to follow their dreams and continue to honor the men and women who keep the spirit of craft alive in design offices and on job sites across North America. As a community, let's fuel the opportunity for the next generation of tradesmen and women.

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important moisture-control action that can be taken on an old house. If I have the opportunity to replace them, I'll take it, carefully flashing the new windows and doors to direct water outward to the face of the siding. That said, replacing old windows and doors is rarely a winning financial choice in terms of payback on investment. The next-best choice for controlling moisture is replacing the exterior trim while leaving the jambs, sill, and sashes in place, and focusing on doing a great job flashing the new trim.

The next most important thing to do is air-seal. While the assembly is open, I block off open stud bays in both exterior and interior walls. This is an opportunity to install fireblocking at the same time, so I like to use 2x material or $\frac{3}{4}$ -in. plywood to close vertical bays. Many old houses are balloon-framed, and the joists rest on ribbons let into the studs. The floors and walls are directly connected, allowing air and fire to flow freely. I also block these bays. Small holes and imperfect joints in my blocking get air-sealed with spray foam.

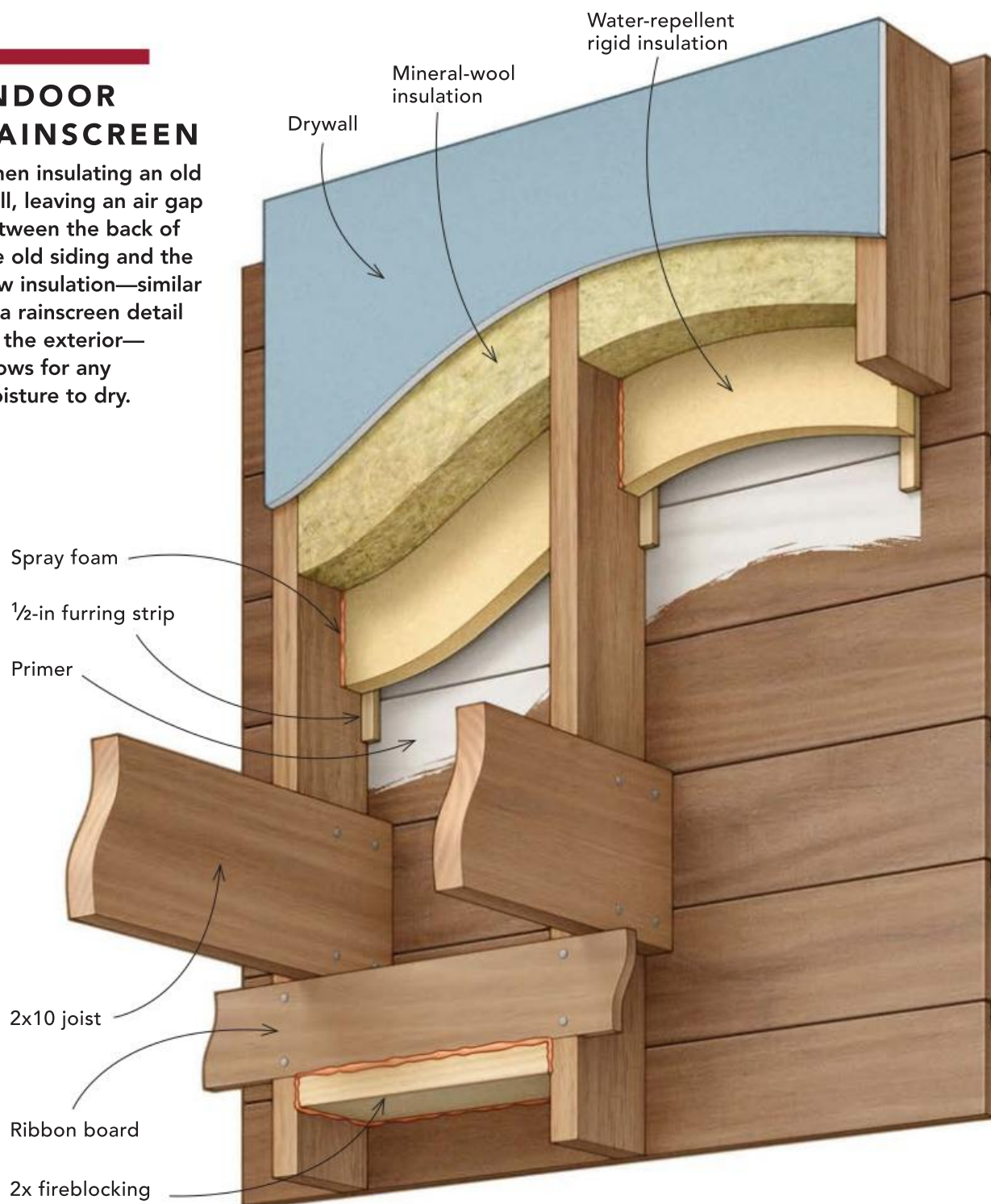
Regarding the interior vapor retarder: You need to be in a very cold climate such as northern New England before a plastic vapor retarder is required by code. In most cases, two coats of latex paint on the walls is all you need.

Allow for drying

It's a practical impossibility to keep water out entirely, but if you do a good job in the three areas I mention above, there shouldn't be much getting in. Still, water is a relentless enemy, and I like to allow for drying, if only to keep the paint on the siding. For that purpose, a coat

INDOOR RAINSCREEN

When insulating an old wall, leaving an air gap between the back of the old siding and the new insulation—similar to a rainscreen detail on the exterior—allows for any moisture to dry.



of primer rolled or sprayed on the back of the siding when the wall is open is a good idea.

Installing a rainscreen—a system of materials that creates an air gap behind the siding to encourage drying—is becoming standard practice in new construction. For the same reason, I like to keep new insulation from directly contacting the back of old siding. (That's a downside of blowing new cellulose into an old wall—leaving a gap between the two materials

isn't possible.) If the insulation is spray foam, I'll staple house-wrap to the sides of the studs in the bays to maintain separation.

Because of its environmental penalties, spray foam isn't usually on the table. A better approach is to tack some $\frac{1}{2}$ -in. vertical furring strips to the back of the siding, right next to the studs. Then, pressure-fit a water-repellent rigid insulation product from a manufacturer like Gutex or Steico between the studs and seal any gaps

with spray foam. The entire cavity can be packed with rigid insulation, or you can do an inch or two of that followed by batt insulation such as mineral wool—depending on your climate and insulation-thickness requirements for the assembly.

Old houses take thought. There are no universal solutions, and that's what makes working on them so much fun.

Andy Engel is a remodeler and former FHB editor.

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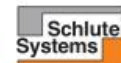
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Waterproofing Strategies

Stripping the **2020 Fine Homebuilding House** to its bare bones allowed the team not only to focus on making it more energy efficient, but also to completely upgrade the interior finishes, including in the seven full bathrooms and one half-bath. Installing Schluter Systems waterproofing products before tiling ensures all of the spaces are durable and fully waterproofed, which is particularly important in wet areas outfitted with Ditra-Heat.

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Aнна Heath's engagement in the building community belies her tenure in the construction industry. She's young, but her experiences have been intensive.

Anna got her start as a carpenter just a few years ago working under Jesper Kruse at Maine Passive House, a firm whose philosophy is grounded in mastering traditional craftsmanship, having a thorough understanding of building science, and meticulously executing every phase of a project. It's an environment primed for growth and learning, and Anna is a product of its process. She is now a lead carpenter and project manager for the company, as well as a Certified Passive House Consultant involved in the Northeast Sustainable Energy Association, Passive House Accelerator, and the local building-science community. She somehow also manages to spearhead building programs at the Center for Ecology Based Economy that are tailored to diminish the barriers to entry in the trades and create a more inclusive environment for those wanting to work with their hands.

Despite her enthusiastic embrace of the building scene, Anna wasn't always intent on a career in construction. That may come as a surprise when you consider her family history—they have been building in Maine for the last 100 years. "I never even considered it as an option," she says now. "That probably reflects a bigger cultural thing that's going on, because it didn't even occur to me. I also grew up in a generation, I think, where everyone was pushed really hard to go to college after high school—really hard." As is the case with many young people, Anna felt that college was the only real option on the table at the time.

In talking to Anna, you quickly realize her commitment to shifting the building landscape—not only in the performance, caliber, and quality of the homes that she helps construct, but in terms of who is building them and from what backgrounds they come. —Rob Yagid, executive director, Keep Craft Alive

"The thing that sustains me is that I get to be part of the community outreach and I get to be part of changing what the industry looks like. I really like being a part of that, and being a different example."

ANNA HEATH
LEAD CARPENTER
NORWAY, MAINE



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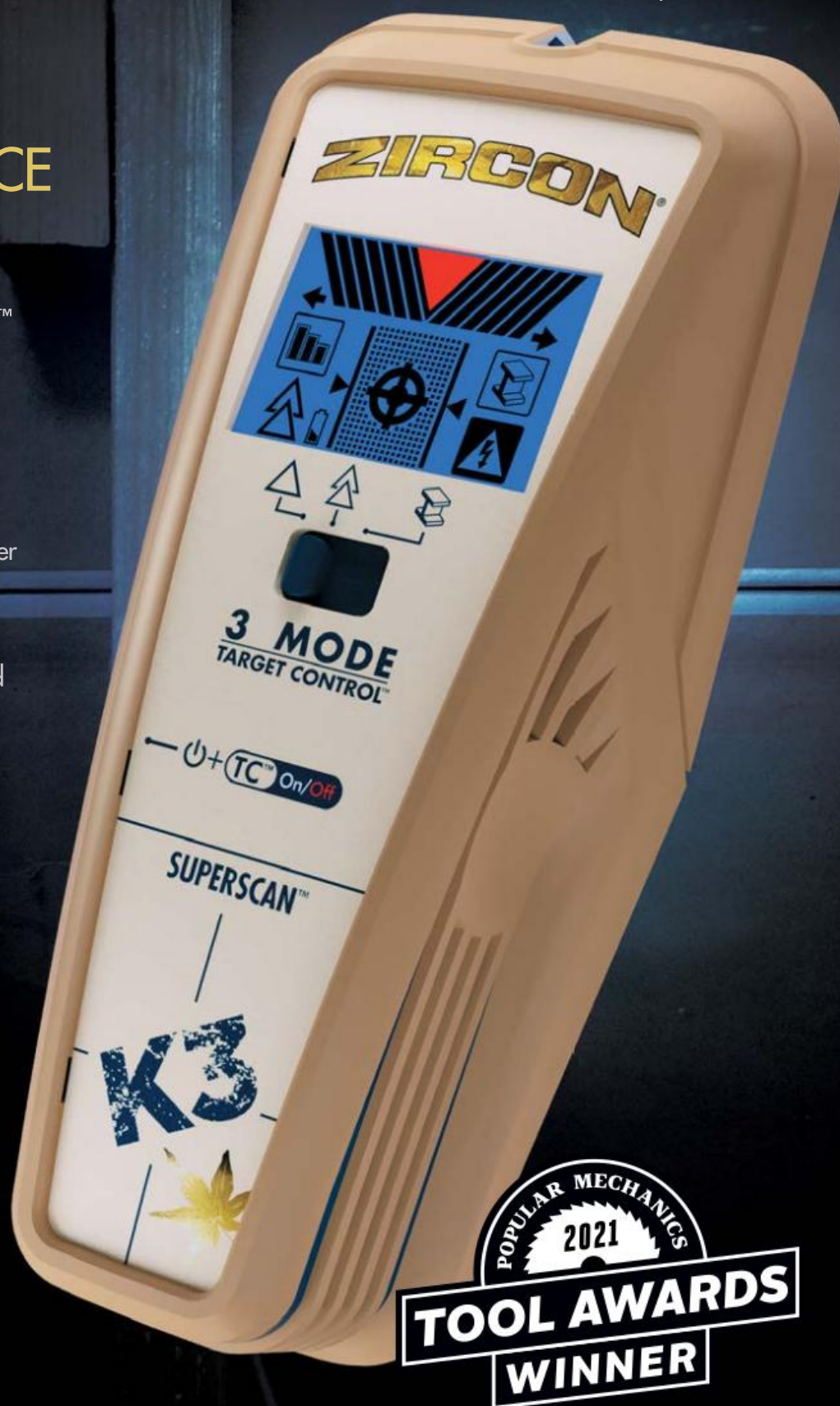
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