The Passive Green

"Use less energy" is the mantra of a stringent German building standard that's catching on

BY JEFFERSON KOLLE

Passive House is a performance-based building standard that can result in a house that consumes as little as 10% of the total heating and cooling energy used by a house built to the 2006 building code. If you're an architect or builder, imagine the reaction you'll get from clients when you tell them that you can either build a house that uses energy by the dollar or one that uses it by the dime.

To achieve their impressively low levels of energy consumption, certified Passive Houses rely on proper solar orientation, an airtight envelope, lots of insulation, mechanical ventilation, and the reuse of heat.

Designing and building a Passive House requires using proprietary energy-load software aimed at keeping energy use low and includes construction that can be painstaking. A flubbed detail can mean the difference between reaching the standard or not.

Lower lifetime energy use

The Passive House standard was developed in Germany (where it's known as "Passivhaus") in 1996 by physicist Wolfgang Feist, who was inspired by and fully acknowledges the influence of the groundbreaking, superinsulated houses built in the United States and Canada in the 1970s. In this country, Feist's work has been championed by German-born architect Katrin Klingenberg, who started the Passive House Institute US, also known as PHIUS (www.passivehouse.us) in Urbana, Ill.

Upwards of 20,000 Passive Houses have been built in Europe, and while there are fewer than two dozen in this country, there are many on the drawing board, and the

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House Without Gizmos

THREE REQUIREMENTS MAKE IT SIMPLE

The standard is strict (it's German, after all), and the performance numbers are very low. Unlike other programs that have multiple criteria for certification, the Passive House focuses on just three things: air infiltration, Btu consumption, and kwh usage. The new energy-efficiency section of the International Residential Code (IRC) deals only with air infiltration, and the government's Energy Star program, while more strict than the IRC, is still a long way from the Passive House standard. Here's the nitty gritty.

Air infiltration

The Passive House standard for air infiltration can be no greater than **0.6 air changes per hour** (ACH) at 50 pascals, which means the house is virtually airtight. The IRC's current energy code requires 7 ACH at 50 pascals. Energy Star requires less than 5 or 6 ACH, depending on the climate zone.

Btu consumption

The annual energy use for heating and cooling cannot exceed **4755 Btu per sq. ft. annually.** The average new home built to current code consumes nearly 10 times that amount. Energy Star has requirements for appliances and mechanical systems that can still amount to nearly eight times the Passive House requisite.

Energy usage

The maximum total energy use of the house, which includes heating, cooling, and electricity, cannot exceed **11.1 kwh per sq. ft.** While there are no specific energy-use standards for code-built and Energy Star homes, estimates put their usage around 30 kwh and 20 kwh, respectively.

MASSIVE BUT PASSIVE

This house on Martha's Vineyard goes a long way toward dispelling the myth that a Passive House will, by matter of course, look more like an institution than a cozy dwelling. Beyond the beautiful design lie the hallmarks of a Passive House: an R-35 basement, R-45 walls, and an R-62 roof, along with triple-glazed windows, minimal heating and cooling equipment, and energy bills to match.

Location: Martha's Vineyard, Mass.

Architect: Craig L. Buttner—Architect P.C., Boston (www.clbarchitecture.com)

Builder: Clancy Construction (www.lclancy.com)

Passive House consultant: Katrin Klingenberg, PHIUS

Size: 4000 sq. ft.

Annual heating/cooling cost: $400-$600

movement has gained converts quickly as energy prices have increased.

Armed with the mantra "First, use less energy," Passive House advocates say that rather than getting hung up on the amount of energy it takes to build a home, it is more important to look at how much energy the home will use during its lifetime. Statistics differ, but on average, a typical code-built house will use 10 times more energy to heat, cool, and operate its various systems for 40 years than the amount used to build it.

To get an idea of how little energy a Passive House uses, it helps to look at the Home Energy Rating System (HERS) index, a software-generated number that predicts a house's energy based on its design.

Houses built to the 2006 International Energy Conservation Code (IECC) score a 100 on the HERS index. Energy Star and LEED homes can't surpass 80 or 85, depending on their climate zone. Net-zero homes score the lowest, at 0. A Passive House scores between 20 and 30 on the HERS index.

While a net-zero house may use less total energy than a Passive House, it achieves that score by adding energy made with alternative-energy sources into the calculations. The Passive House standard disallows site-generated alternative-energy sources in its computations and relies instead solely on its low energy consumption. As Klingenberg notes, "A Passive House can become a net-zero house with the addition of a very small renewable-energy system." The standard doesn't change from one location to another, but the way a house is built does.

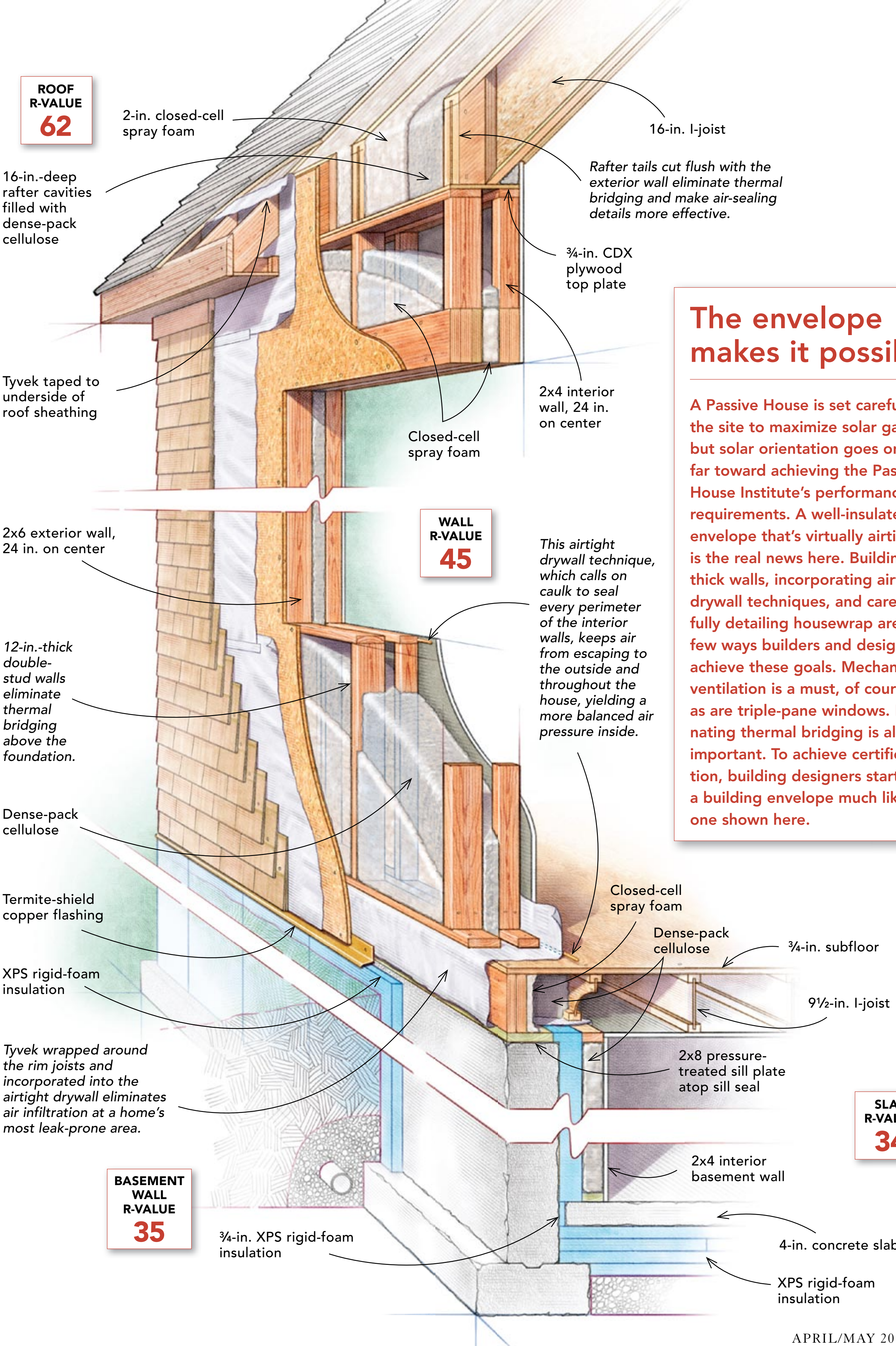
Lose—no, use—almost no heat

To lower energy consumption to this degree, a house must be airtight, superinsulated, without thermal bridging (see "How It Works," pp. 16-17), equipped with a heat- or energy-recovery ventilation system and ultra-high-performance doors and windows, and designed for passive-solar and internal-heat gains.

Starting at the foundations, Passive Houses employ a massive amount of insulation, upwards of 16 in. of rigid foam, between the ground and the concrete slab. Exterior-wall systems, which are as thick as 16 in., can be built with double-stud 2x4s or 2x6s, or vertical I-joists used as studs. In some climates, insulated concrete forms (ICFs), structural insulated panels (SIPs), and even straw-bale walls have been used. Roof systems are typically framed with I-joists of varying depths. Because of their air-permeability, fiberglass batts are not often used. Preferred choices are dense-pack fiberglass and cellulose, and polystyrene and spray-foam insulations.

Passive House builders spend a lot of time air-sealing. Brad Holmes and his brother, Kurt, recently finished building a Passive House in Duluth, Minn. (The house will soon earn a LEED platinum rating.) "We caulked every location where wood meets wood," Holmes says. The house underwent three blower-door tests before the drywall was hung just to make sure all the leaks had

Photo: courtesy of Craig Buttner. Drawing facing page: John Hartman.



The envelope makes it possible

A Passive House is set carefully on the site to maximize solar gain, but solar orientation goes only so far toward achieving the Passive House Institute's performance requirements. A well-insulated envelope that's virtually airtight is the real news here. Building thick walls, incorporating airtight drywall techniques, and carefully detailing housewrap are a few ways builders and designers achieve these goals. Mechanical ventilation is a must, of course, as are triple-pane windows. Eliminating thermal bridging is also important. To achieve certification, building designers start with a building envelope much like the one shown here.

NEAR-ZERO PASSIVE

Architect Nancy Schultz designed and built her own Passive House in some of the coldest country in North America. Even with R-55 walls and triple-glazed windows, Schultz was a bit skeptical that the house would perform as predicted by the Passive House Institute's planning software. A brief spell last winter without power or any solar backup put the design to the test. After two weeks without heat, the house still held at 50°F. "Now I'm a believer," Schultz says.

Location: Isabella, Minn.

Architect: Nancy Schultz

Builder: Ron and Sons Carpentry

Passive House consultant: Conservation Technologies (www.conservtech.com)

Size: 2100 sq. ft. heated

Annual heating/cooling cost: well below $0 when alternative energy is included

been sealed. Holmes said the tests revealed "three to four trouble spots that we're glad we found before the rock went up."

One reason to make a house airtight is to be able to control the air that enters and leaves it, which can dramatically improve the indoor-air quality (IAQ) and reduce the movement of heat through convection. One of the ways that Passive Houses reduce energy use is to use energy- and heat-recovery ventilators (ERVs and HRVs). Basically, these systems remove the heating or cooling energy from tempered air inside and transfer that energy to the incoming air. (For an in-depth explanation of how these systems work, see "How It Works," *FHB* #205 and online at FineHomebuilding.com).

Windows and doors have always been a weak link in energy-efficient buildings, but major improvements have led to the development of triple-pane windows with an extremely low U-factor. Historically, European windows have been more efficient than those made in this country, but some Canadian and U.S. manufacturers have started making windows with U-factors as low as 0.13.

Because Passive Houses are superinsulated and airtight, heat loss is kept to a minimum. The buildings don't often require a traditional central-heating system (the savings from which can offset some of the extra costs associated with building to the standard). Instead, they rely on solar gain and the heat produced by electrical equipment and the occupants, as well as the recycled heat from HRVs. Supplemental heat sources, such as a few feet of electric-resistance baseboard, electric heat mats in bathroom floors, even domestic water heaters, can fulfill the need for any additional heat on the coldest days.

Passive Houses are designed to maximize solar-heat gain when and where it is wanted, and minimize that gain when and where it is not. Passive House design also maximizes the amount of natural lighting in a building, which makes for more pleasant living spaces while reducing artificial-lighting costs.

Software minimizes guesswork

Not surprisingly, planning a Passive House involves no guesswork; rather, it's based on an energy-modeling program called the Passive House Planning Package (PHPP).

The program calculates by taking into account almost every aspect of a house, including the site's weather patterns and solar orientation; the type of construction and the materials used; the window designs and locations; the ventilation-system design; and the

Photos: this page, courtesy of Short Elliot Hendrickson Inc.; facing page, courtesy of Unilux.

Bonus savings. *Energy from alternative sources such as photovoltaic and solar-thermal-collection systems aren't calculated into a Passive House's energy use. But the Schultz house (and some others) use them to reduce energy usage and get to net zero.*

total loads of appliances, lighting, and other mechanicals. PHPP will even predict the finished home's carbon-dioxide emissions.

Adam Cohen is an architect whose company, Structures Design/Build, in Roanoke, Va., has been building energy-conscious houses for 25 years. He thinks the PHPP software has an "amount of specificity that is much more precise" than other modeling programs he has used, which, he says, "makes it easy to fudge some of the details." The precision of the program allows the user to make small design changes and immediately see how they affect the building's energy use.

Getting accredited

Unlike some of the energy-efficient building programs—LEED and NAHB Green, for example—the Passive House standard doesn't assign a rating or use a point system for the materials and methods used during construction. Instead, the Passive House standard is based wholly on a building's performance. If a house meets the standard, it is considered to be a Passive House.

Not surprisingly, the steps needed for accreditation are regimented, and although only three are required, many more are recommended. It is not mandatory to work with a trained consultant when building a Passive House, but in the long run, it'll be quicker, easier, and less expensive than doing it on your own.

Precertification starts at the planning stage; all specifications are reviewed to make certain that no major errors exist.

After the house is built, but before the walls are insulated, blower-door tests are done to ensure the airtightness meets the Passive House standard. As Holmes pointed out, the first test reveals leaks that can be corrected while the walls are open. After a crew tracks down and fixes them, a second or even third test occurs.

Contractors are required to submit "as-built" photographs to PHIUS that show the house was built to the specifications agreed upon during the precertification stage. Along with the photos, the general contractor has to submit a declaration that guarantees the house was built as planned.

Finally, a last blower-door test is performed. If the house passes the 0.6-air-changes-per-hour grade, a certificate is issued by PHIUS that says the building is a Passive House.

The cost of certification depends on whether you've used a Passive House consultant throughout the project. If you haven't used one, you'll probably need to hire one to walk you through the processes and the software at the going rate of about $150 per hour. But if you've used a consultant, or become one yourself, the cost is under $1000.

There are several reasons why the pioneering energy-efficient houses of the past century didn't catch on. Politics played a part, as did the limitations of the technologies of the time, which, fortunately, have been surpassed by today's better windows, doors, and ventilation systems. The arguments for reducing houses' energy use were certainly valid in 1974 when architect Wayne Schick coined the term "superinsulation." Thirty-five years on, the reasons are all the more compelling. The big question is how to make the ideas really take hold this time around. □

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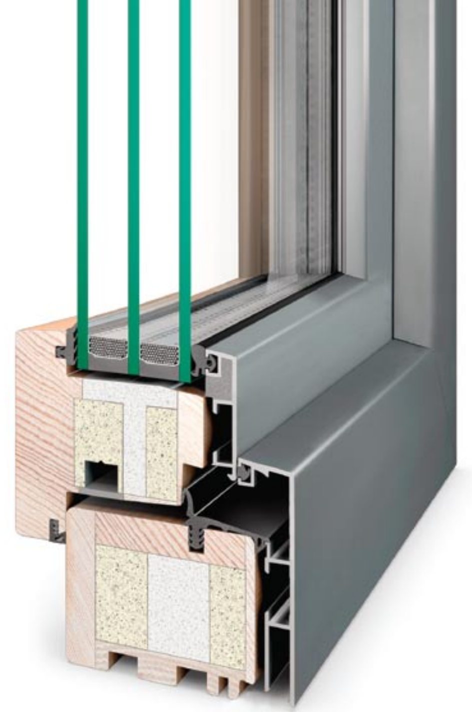

Triple-pane windows are a must, but not a requirement

Although they're not required, triple-glazed windows like the ones shown here from Unilux (www.unilux.de) are strongly recommended for cold-climate Passive Houses. Available from both German and Canadian manufacturers, windows with triple glazing and insulated frames have a low U-factor yet still provide enough solar gain to allow a house to meet the Passive House standard.

Although some manufacturers go so far as to have their windows certified by the Passive House Institute, the standard allows the use of uncertified windows. Good triple-glazed windows aren't cheap. Canadian windows cost $40 to $50 per sq. ft., while German windows cost up to $100 per sq. ft.

Whether German or Canadian, the best triple-glazed windows gain more heat than they lose. From an energy perspective, these windows perform better than an insulated wall.

—Martin Holladay is a senior editor at GreenBuildingAdvisor.com.

For more information and resources, look for a link to Martin's blog, "Passivhaus Windows," in the Magazine Extras section of FineHomebuilding.com, and for his upcoming article "In Search of the Best Windows in America" in *FHB* #213.