PASSIVHAUS in Chapel Hill


by Stephen Hren

Stephen Hren

The traditional bungalow architecture of this home in Chapel Hill, North Carolina, belies its incredible energy efficiency and adherence to the strict principles of Passivhaus design.

Homebuilder Chris Senior wants to leave a legacy by creating homes of beauty and super-efficiency that will last for centuries. He's steering his company, Anchorage Building, toward specializing in homes that meet Passivhaus energy-efficiency requirements and use about one-tenth of the heating and cooling energy of conventionally built U.S. homes.

Passivhaus is a construction standard that focuses on minimizing heat loss with an incredibly tight building envelope and insulation levels several times greater than conventional construction. While its German name translates to "passive house," Passivhaus-designed homes go far beyond passive solar, with the result that conventional heating and cooling equipment is unnecessary in most circumstances—even in frigid climates.

A tight building envelope has two additional advantages over previous passive solar designs. It allows useful heat gain from smaller, "passive" sources of energy like human bodies (equivalent to about a 100-watt incandescent bulb) and cooking, and also helps keep buildings cool in summer with minimal effort.

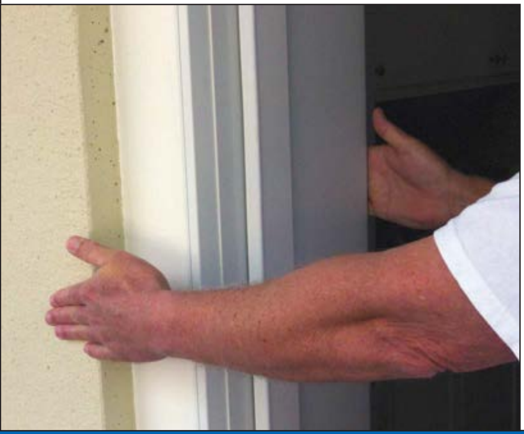
Like a conventional passive solar home, many of the windows in a Passivhaus are still south-facing, but they are fewer in number than previous passive solar incarnations, and are of highly insulating (R-7 or greater) triple-pane construction. Many Passivhaus homes, especially in Europe, are also multi-unit; reducing the number of exterior walls further reduces heat loss.

The Details Make the Difference

In 2011, Chris and Leigh Ann Senior built the second Passivhaus home in North Carolina. Designed by architect Jay Fulkerson and located on a picturesque lake in Chapel Hill, it is the couple's primary residence and was built after completing the first one for a client just a few miles away.

The walls of Chris and Leigh Ann's 2,155-square-foot home are built of 2-inch-thick concrete, which helps regulate interior temperatures. Five-inch-thick concrete vertical ribs provide additional structural support. This high-psi concrete is waterproof and has a lifespan of hundreds, if not thousands, of years, which helps justify its high embodied energy. Eight and a half inches of rigid foam insulation provide an insulation value of R-32. The inside of the wall has conventional 2-by-4 wood framing with $^{1}/_{2}$ inch of air space between it and the concrete structural wall. The interior stud walls are attached to the floor and ceiling with metal plates but otherwise float free of the concrete structural wall.

The 15-inch-thick walls have an insulation value of R-42.



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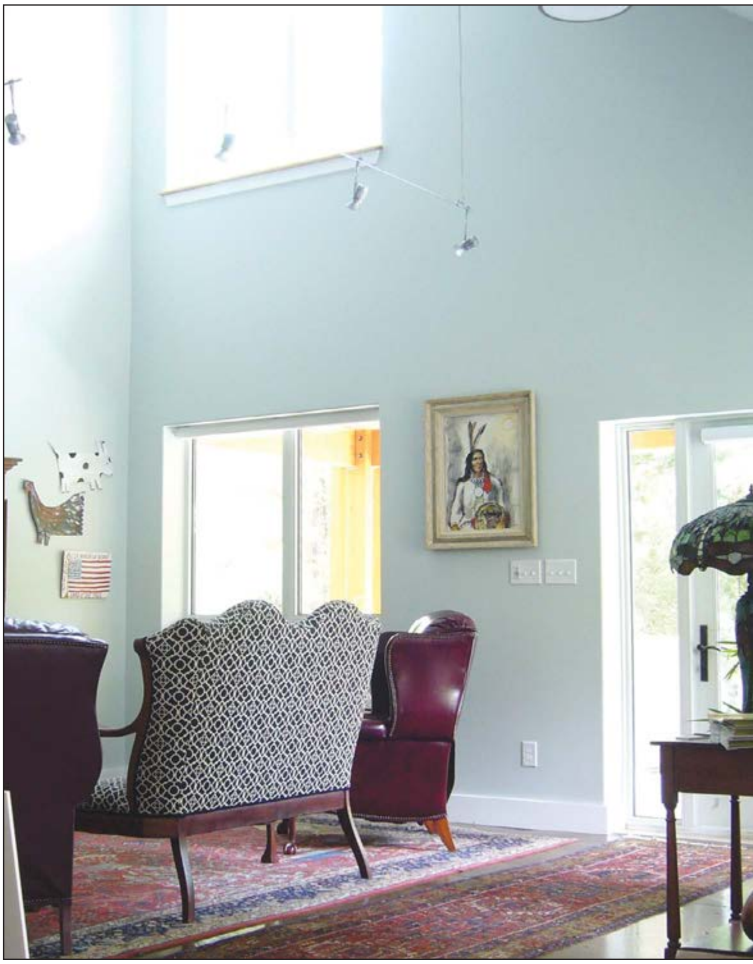

The home's open floor plan allows for easy distribution of heating and cooling without ductwork.

Plumbing and electrical were run through these interior walls, which were then filled with dense-pack, blown-in cellulose insulation for an additional R-10. This gives the walls a total of R-42—the Passivhaus standard for this climate. The resultant 15-inch-thick walls give the home a fortlike feel and buffer sound transmission from outside.

The majority of the windows (100 square feet of glazing) are clustered on the home's south side to optimize solar heat gain. Chris and Leigh Ann chose Thermo-Tech triple-pane, argon-filled windows with a solar heat gain coefficient of at least 0.5 and a U-factor of about 0.15.

While insulating the walls and floor was fairly straightforward, super-insulating the roof proved to be challenging. Although somewhat distrustful of the long-term stability of oriented-strand board (OSB), using wooden I-joists (made, in part, of OSB) gave the 14-inch depth necessary for insulating to Passivhaus standards. Since wood is a fairly good conductor (relative to insulation), reducing the width of the roof rafters to $^{1}/_{2}$ inch from a conventional framing lumber dimension of $1^{1}/_{2}$ inches greatly reduces thermal bridging.

Courtesy Anchorage Building

The floating framed walls inside the concrete shell help minimize thermal bridging and heat transfer, and provide wall space for running plumbing and electrical.

Three-quarter-inch CDX plywood was used to sheath the roof, and a self-adhering membrane applied over the sheathing provides a water- and air-tight seal around every nail or screw used to attach the roofing material to the sheathing. A layer of 2-inch-thick open-cell icynene insulation applied to the underside of the roof sheathing helps complete the air seal. Two-by-fours span the underside of the I-joists, to which drywall was attached, and the remaining $13^1/2$-inch space was filled with blown-in cellulose for an R-value of 62.

Pairing Comfort & Efficiency

The home's passive solar design, plus superior insulation and airtightness, reduce the reliance on mechanical heating systems. Heat from passive solar gain and a Fujitsu ductless heat pump is distributed via airflow through a heat recovery ventilator (HRV). The HRV passes stale indoor air through a heat exchanger, which transfers about 75% of the heat to fresh, incoming air. Although an airtight home is highly energy efficient, an HRV is necessary to ensure good indoor air quality. The 200-cubic-foot-per-minute HRV eliminates the need for bathroom vents, since the HRV also eliminates excess moisture from the home with the rest of the indoor air.

Passivhaus—Past & Present

German physicist Wolfgang Feist is credited as the originator of the Passivhaus concept, having completed his first Passivhaus prototype in 1991. Later in the decade, he received a grant for the completion of a comprehensive five-year survey of existing super-insulated buildings across Europe. This survey became the inspiration for creating a set of achievable standards for building insulation, with the potential for vastly reduced energy use.

During the last two decades, tight, super-insulated windows—pioneered mostly by German manufacturers—with greatly reduced radiant heat loss have made possible building envelope tightness that fits the strict Passivhaus standards. Triple-pane sashes, reductions in thermal bridging through the frames, and low-e coatings have resulted in windows that offer insulation values up to R-10.

Passivhaus came to North America when, in 2003, architect Katrin Klingenberg designed and built a private residence in Urbana, Illinois, to Passivhaus criteria. Klingenberg later founded the Passive House Institute U.S. (PHIUS) to promote the concept in North America. Ironically, she never had her first few projects formally certified to Passivhaus standards. The honor of the first certified Passivhaus building built in the United States belongs to the Waldsee Biohaus, a German language school in Bemidji, Minnesota.

In little more than a decade, Passivhaus has blossomed into a full-grown movement in Europe, with more than 20,000 residences completed (mostly in Germany and Austria) and many more in the works. In the United States, there are an estimated 75 completed structures (not all yet certified), with about 100 more in various stages of planning and building. Unlike the more intimidating LEED standards, builders find Passivhaus' clear and simple guidelines easy to follow—and with integration with the existing HERS rating system, straightforward to certify.

One criticism of Passivhaus has been that most of the insulations used to achieve a high-performance envelope are fossil-fuel-based. Advocates counter that it is better to use fossil fuels once (in a product's manufacture) to create extremely low-energy buildings rather than use them every day in inefficient housing. Innovative builders are using recycled cellulose insulation, along with foam-based ones, to create a tight, superinsulated home while minimizing the use of fossil-fuel-based products.

Stained and polished 4-inch-thick concrete floors provide thermal mass to moderate temperature swings and store heat from the sun.

The Seniors enjoy the sunny deck on the south side of the house.

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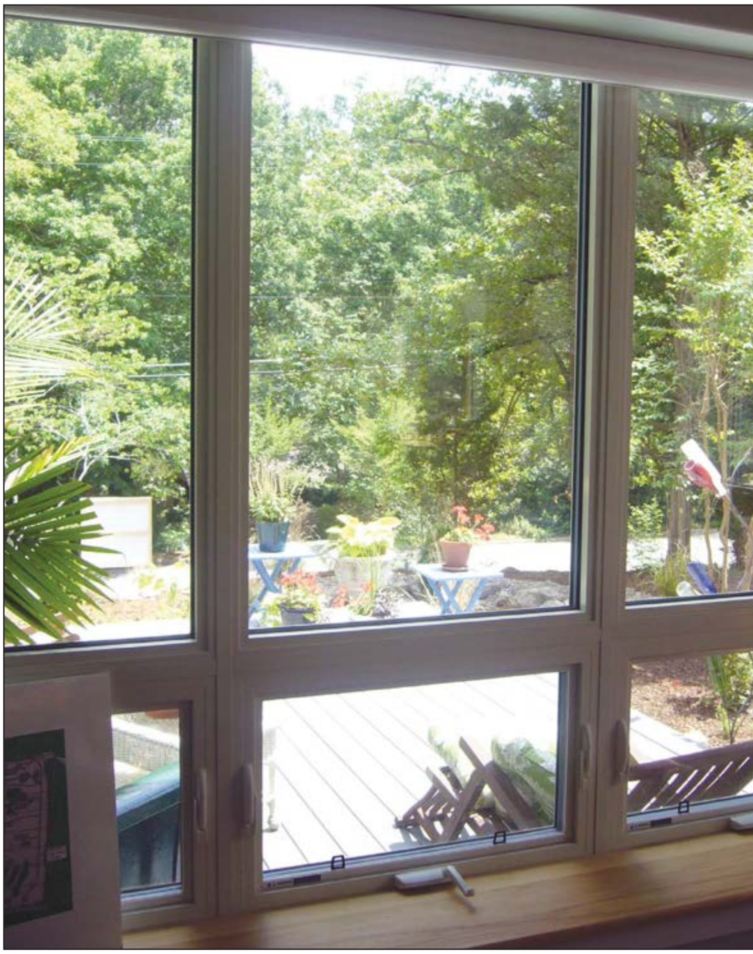
To maximize the home's efficiency and minimize its energy use, energy-efficient appliances—like an Electrolux electric induction range, a Bosch Axxis front-loading clothes washer, and LED track lighting—are used. Chris and Leigh Ann also prewired their home for a future PV system.

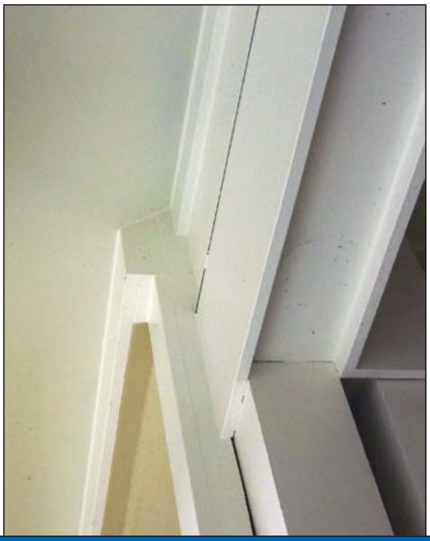
Meeting the Standard

There have been a plethora of green building standards over the past two decades, and rightfully so—buildings are a major energy user and contributor to global climate change. In the United States, 76% of all electricity is used for heating, cooling, appliances, and lighting. Among standards set by the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification, Living Building Challenge, and the 2,000-Watt Society, Passivhaus standards stand apart in their simplicity and adaptability to individual climates to achieve the same energy-use goals regardless of location. This adaptability is similar to how today's building codes function—and Passivhaus standards are probably the easiest of the green standards to transfer to our existing code-enforcement mechanism. Unlike LEED certification (and other holistic strategies, like the Living Building Challenge), Passivhaus focuses only on energy use. Renewable energy or sustainable material use is not brought into the equation, as it is for LEED and other certification programs. This single-minded purpose generally results in a 90% reduction in typical heating and cooling use and a 70% reduction in overall energy use compared to homes built according to today's conventional standards. Even compared to the standard LEED-certified building, the overall reduction is still about 30%.

It's hard to say that we should have just one green building standard or another, because of so many new and innovative building materials, the acceptance of grid-tied PV systems, and a broader understanding of how a building functions as part of the living landscape. Fortunately, the PHIUS understands that trying to become established in opposition to the existing green building standards is counterproductive—they are trying to make it simpler to integrate Passivhaus certification with the existing Home Energy Rating System (HERS) Index.



Triple-pane, argon-filled windows take up about 100 square feet of the south-facing wall.



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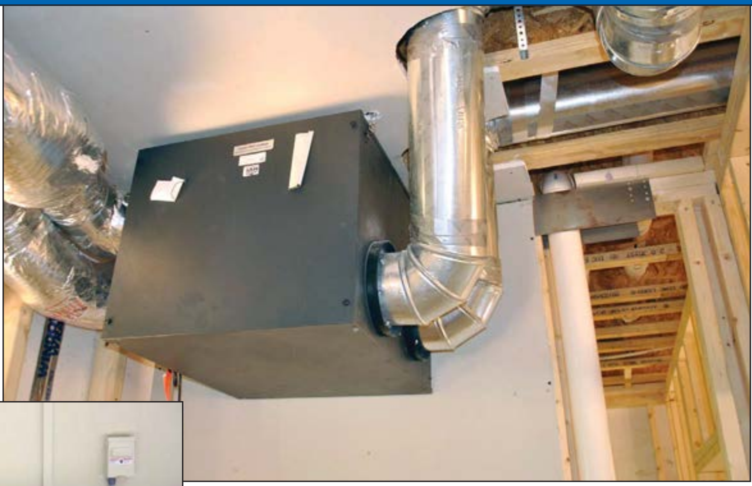
Insulating roofs to Passivhaus standards can be challenging because of the high R-values required and the amount of space this takes. In this home, a 10-inch strip of 1.5-inch-thick foam board, which has been carefully incorporated into the trim pattern, beefs up R-values under the eaves.

HERS rates a home or building's energy efficiency—a typical resale home scores 130 on the index; a conventional new home usually scores 100. A negative score implies that a home produces more energy than it consumes—a concept that may be met with some skepticism by green building professionals, since this number does not account for a home's embodied energy—energy used to extract materials, produce products, and transport them to the building site. While the Seniors' home does not have a HERS Index score, its blower door test resulted in 0.51 ACH at 50 pascals of pressure, or about one air exchange every two hours. For comparison, an Energy Star home based on the EPA guidelines will have a typical value of 3.5 ACH at 50 pascals—that's one-seventh as air-tight as the Seniors' home. Since HERS raters are now common in most parts of the country, this may help make the Passivhaus certification accessible to all potential builders.



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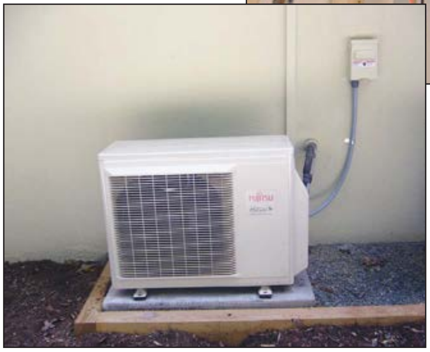

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Above: An air-to-air heat exchanger exhausts stale air and brings in fresh air, but keeps about 75% of the heat while doing so.

Left: The air-source heat pump delivers heat to the living room.

To qualify as a Passivhaus, buildings must have a tight building shell that allows no more than 0.6 air exchanges per hour at 50 pascals of air pressure. The heating load must be less than 4.75 kBtu per square foot per year (1.4 kWh/ft.^{2}/yr.), and primary energy must be less than 38.1 kBtu per square foot per year (11.1 kWh/ft.^{2}/yr.). Primary energy refers to *all* energy used for space and water heating, appliances, lighting, fans, pumps, etc. Different sources of energy have a different multiplier for their primary energy score. For example, purchased electricity has a high multiplier of 2.7 (each kWh of electricity consumed is multiplied by 2.7) to include generation and transmission losses; natural gas has a multiplier of 1.1; and grid-tied PV systems have a multiplier of 0.7. The last two requirements are verified by reviewing heating, gas, and other utility bills.

While the Seniors' home is still in the process of becoming certified (a process that takes at least a year, since an entire cycle of heating and cooling, as well as overall energy use, must be analyzed), the house already has met the rigorous building standards. A backlog of applications appears to be slowing the process as PHIUS accommodates growing interest and incorporates the HERS rating system into its standards. These growing pains can only be a good thing as super-efficient building becomes a bona fide movement here in the United States.

Access

Stephen Hren (stephenhren@gmail.com) is a builder and writer living in Durham, North Carolina. He is the author of *Tales from the Sustainable Underground: A Wild Journey with People Who Care More About the Planet Than the Law* (see www.earthonaut.net).

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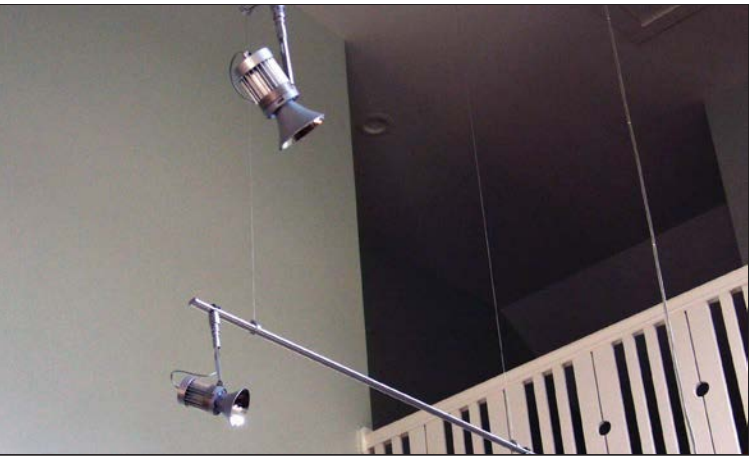

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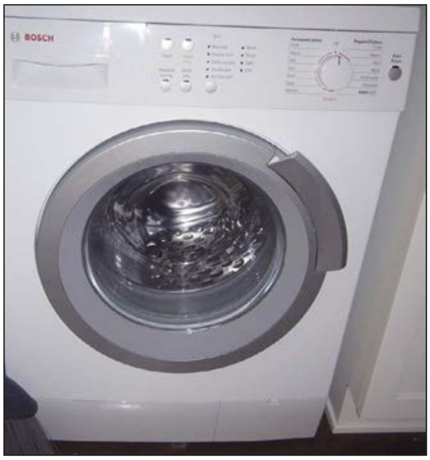

Left: The high-efficiency LED track lighting system provides significant energy savings compared to conventional incandescent bulbs.

Right: Super-efficient appliances save money, energy, and water.