Tight House, Tight Budget

A Virginia design/build firm achieves Passive House certification for $150 per sq. ft.

BY DANIEL ERNST

Adam Cohen's firm, Structures Design/Build, built the first certified Passive House public-school building in the United States. Called the Center for Energy Efficient Design (CEED), it is located in Franklin County, Va., a rugged, rural area more famous for its bootlegging history than its architecture. For Adam, the school was a work of passion and a charitable endeavor. He walked away from this light-commercial project excited about the prospects of bringing Passive House to the local residential market.

Striving for cost parity

Adam realized right away, however, that the association of energy-efficient construction with high costs was a primary obstacle in reaching his goal. To sell the Passive House con-

Photo: Tara Lilly

cept in the local market, he would have to drive down the price to a point where it was equivalent to conventional construction.

He spent the next two years analyzing financial data from his firm's past projects. He identified fewer than a dozen job phases that could improve the cost-effectiveness of residential projects significantly. He also used the Passive House Planning Package spreadsheet (PHPP) to determine the optimum enclosure for the local climate. With both the energy-model outputs and the financial data, he then set about designing a theoretical Passive House that would achieve cost parity with conventional construction.

This meant that he would need to take the predicted monthly energy savings and invest this money back into construction equity. The homeowners would pay the same amount each month; they would just spend more on capital and less on utilities. This would make their investment cash-flow neutral.

From theory to reality

Just as Adam was finalizing the details of his affordable Passive House concept, Jason and Stephanie Specht requested a consultation. They had recently purchased property and were looking for a builder who could create a custom design without raising the price beyond their budget. They had some ideas about floor plans and finishes, and they were determined to create a house that suited their proposed building site. Energy efficiency, however, was not a big concern. They would already be asking for a lot from a builder; energy efficiency seemed like a stretch.

Shortly into the consultation, Adam saw his chance. He introduced the Passive House concept and then posed a question: "What if it didn't cost any more to build and operate an energy-efficient house?" He followed that with a more intriguing question: "Would you rather spend your money on equity or electricity?" Although the answer to that question was obvious, Jason was skeptical. He had not heard of Passive House, and the idea of affordable energy efficiency sounded too good to be true.

As a banking professional, Jason had all of the tools and knowledge necessary to prove or disprove Adam's proposition. He spent several weeks learning the language of the Passive House movement, an arduous task for someone not in the construction business. Armed with a better understanding of energy efficiency, he ran his own financial calculations. The result? Energy efficiency indeed appeared to be financially viable.

After settling on the idea, Jason and Stephanie met with Adam on the building site to start the design process. Over the next few months, the newly formed team worked through decisions on building size, foundation type, floor plan, and exterior style. The 1800-sq.-ft. house would include three bedrooms, two and a half baths, an attached garage for vehicles, and storage space for outdoor equipment.

The last step was securing a construction loan. Jason was frustrated to find that the loan officers he met with were unfamiliar with energy-efficient mortgages (EEMs), even when their banks advertised them, and they were not particularly interested in his project. He eventually found a local bank that took his loan application seriously, even though it did not offer EEMs. After submitting the house plans for the bank's appraisal process, Jason and Stephanie were delighted when the appraisal came back at a value equal to the contract price—without any need to justify energy-efficiency improvements or provide financial calculations.

A structure free of thermal bridges

Adam specified an insulated raft foundation for the house. It was a concept he had seen in Germany and one that he had used previously in light-commercial projects. This type of foundation is free of thermal bridges, and just as important, is less expensive than other foundations, such as those that include a basement or crawlspace. The thickened-edge EPS profiles are proprietary, but the slab insulation is composed of standard termite-treated EPS sheets cut and joined to the edge pieces with an adhesive spray foam.

To keep costs low, Adam designed a fairly standard 2x4 frame, which was built off-site as a panelized wall system. He used engineered floor trusses for the second floor, as well as raised-heel trusses for the roof. For the walls, he created a continuous air barrier with Zip System sheathing and tape. At the second-floor ceiling, he attached OSB sheathing to the bottom chord of the roof trusses and then sealed the seams with mastic and tape. Underneath the OSB, 2x2 furring strips were added to provide a service cavity for wiring and lights.

Stick-built walls are full of thermal bridges. To achieve a thermal break, Adam wrapped the house with 6-in.-thick nail-base insulation (a single layer of EPS foam adhered to a single layer of OSB sheathing). Carpenters fastened the nail base to the frame with structural screws and adhesive, then added Home Slicker Plus Typar, which established a rainscreen gap and a weather-resistant barrier

Efficiency starts at the foundation

1 The house sits on an insulated raft foundation with a thickened-edge slab created with proprietary forms. 2 The forms extend around the entire perimeter of the house. 3 Two layers of EPS foam insulation carry the thermal break across the entire foundation. 4 A layer of 10-mil polyethylene sheeting thoroughly sealed at penetrations acts as both a vapor barrier and an air barrier. With the sheeting and a system of rebar in place, this foundation is ready for concrete.

Drawing facing page: Dan Thornton

ENERGY MODELING IS MANDATORY

It's impossible to build to Passive House specifications without modeling the entire process. The software the architect used predicted 457kwh of average energy use per month, almost exactly the actual figure over a 14-month period.

Sheathed and ready for first blower-door test. *Once the Zip System sheathing is taped, it acts as a weather-resistive barrier and an air barrier. The architect likes to complete the first blower-door test before cutting window and door penetrations. Iterative testing provides a better understanding of leakage paths.*

Exterior insulation eliminates thermal bridging. *The house received a continuous layer of nail-base insulation, which workers fastened to the frame with structural screws and adhesive. Home Slicker Plus Typar underlayment created a vented rain screen under the fiber-cement siding.*

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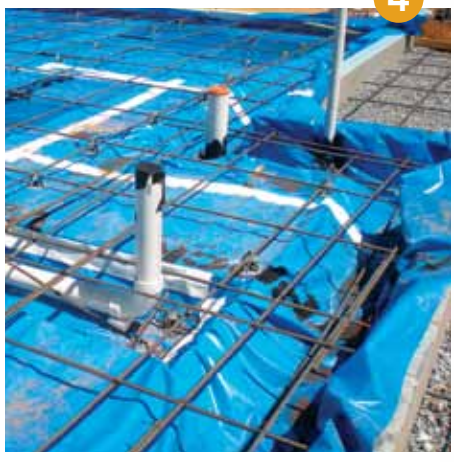
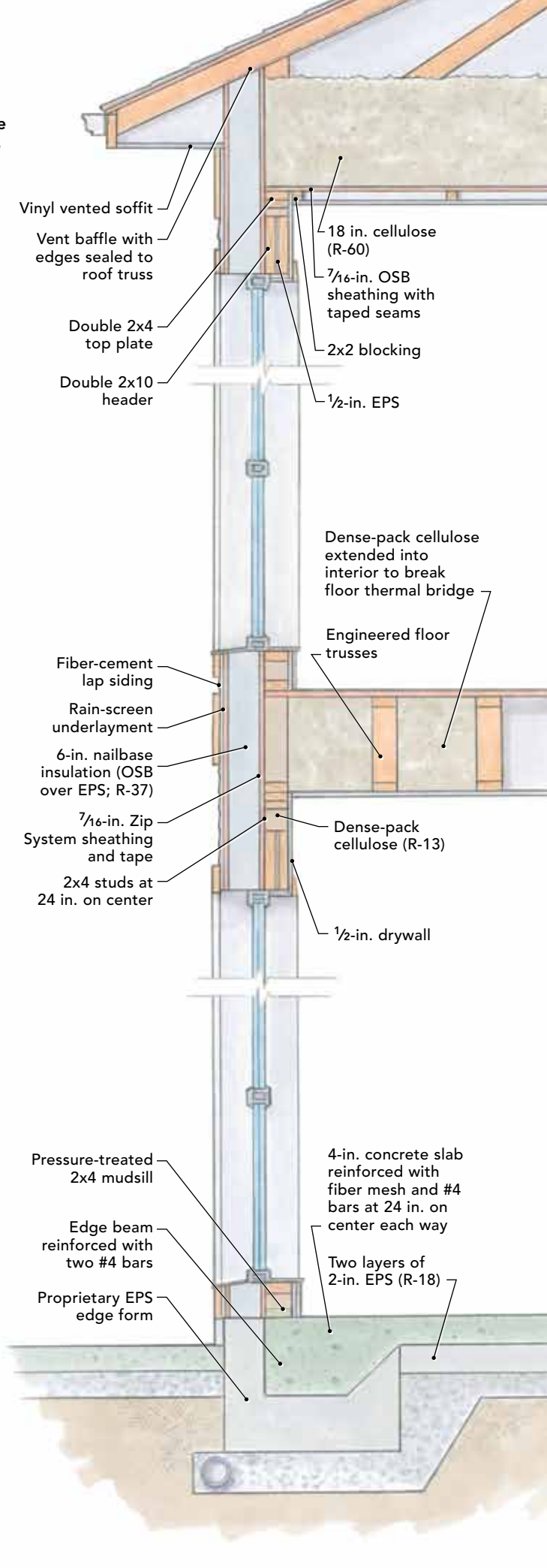




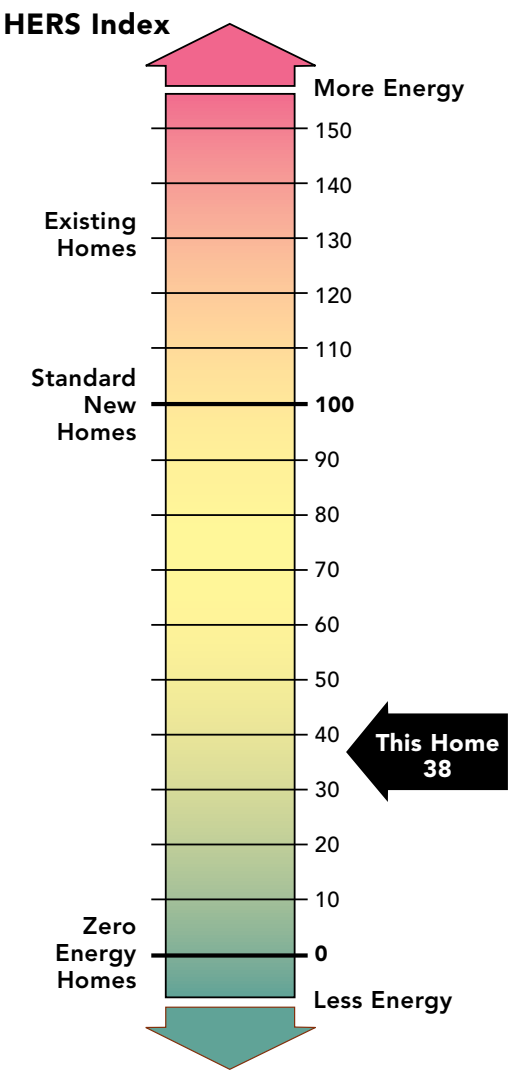
Comparison shopping for efficiency

The EPA's fuel-economy label is a great way to compare the fuel efficiency of different vehicles, but how are prospective homebuyers supposed to compare the energy costs of different houses?

The Home-Energy Rating System Index (HERS Index) is a graphical tool developed by Residential Energy Services Network (RESNET) that measures the energy efficiency of a house. It's easy to understand: the lower the score, the more energy efficient the house.

A house certified by the Passive House Institute US under its PHIUS+ program typically will earn a score between 30 and 40, which means it is projected to consume 60% to 70% less energy than a code-built house of the same relative size and shape. The Spechts' house earned a score of 38.

An energy rating also can help homeowners identify the places in their current home where energy-related upgrades will make the most difference. To learn more and to find out if there is a certified rater near you, visit RESNET's website (resnet.us).



for moisture management of the structure and the fiber-cement siding. A deep layer of cellulose on the second-floor ceiling, an inexpensive way of insulating a vented attic, completed the thermal enclosure.

Balancing window cost with performance

Windows have a large impact on a house's overall thermal performance, but Adam's energy modeling required a level of performance that could not be achieved with windows from a U.S. supplier. Adam specified PVC-framed, flangeless, tilt-turn windows from Klearwall Industries, a European manufacturer that was planning to enter the U.S. market (and has since done so). Installers air-sealed the units on the interior, then flashed and trimmed the exterior using tapes and aluminum coil stock. Because Adam had reduced costs in other key places, he was able to balance the higher cost of these windows. The entry doors are also PVC-framed units from Klearwall.

Small mechanical systems provide cost-effective comfort

A ductless-minisplit heat pump was the natural choice for heating and cooling in the mixed climate of southwestern Virginia. A single head mounted high in the stairwell conditions the entire house. Grilles above and on the bottom of the upstairs bedroom doors provide a pathway for room-to-room mixing and also keep pressure differentials below target levels (less than 3 pascals).

An UltimateAir 200DX ERV provides whole-house ventilation. Adam improved

Building it even better next time

Builders of high-performance homes typically model and test their projects in an ongoing attempt to make improvements. Because the Spechts' house was a first-generation proof of concept, Adam learned several lessons along the way.

- Structures Design/Build has largely discontinued using nail-base insulation for Passive House projects that use fiber-cement siding. Instead, they wrap the frame with sheets of EPS foam and 1x4 furring strips. This system creates a robust and durable vented rain screen; plus, furring strips make it easier to detail the trim and fiber cement at penetrations and corners. Labor costs are somewhat higher for this system, but because EPS and furring strips are commodity products, material costs are lower.

- Adam thinks that Klearwall windows offer a great balance of cost and performance for Passive House projects; however, like most other technology transfers, there is a learning curve. After Adam installed Klearwall products in three different projects, he encountered some minor problems. The company sent a technician over from Ireland to train his staff on hardware adjustment and troubleshooting. Structures Design/Build continues to specify Klearwall's PVC-framed windows but no longer uses the company's PVC product for entry doors. "There was too much movement in the frames, and they required seasonal adjustment," Adam says. He now

HERS Index graphic: courtesy of RESNET. Floor-plan drawings: Martha Garstang Hill.

the performance of the ERV by installing UltimateAir's liquid-to-air heat exchanger on the supply side of the ERV. This system uses a small pump to circulate fluid through a passive ground coil, then through the ERV heat-exchange coil, but only when the inside-to-outside temperature differential meets the seasonal set points. This low-cost, low-tech heat exchanger tempers the incoming air during the peak heating and cooling seasons; for example, when summertime temperatures climb above 90°F, it can drop the incoming air temperature by 10°F.

Hot water is supplied by an evacuated-tube solar-thermal system coupled with an electrical-resistance water heater for backup. Volunteers from a local solar club installed the unit over the course of a weekend.

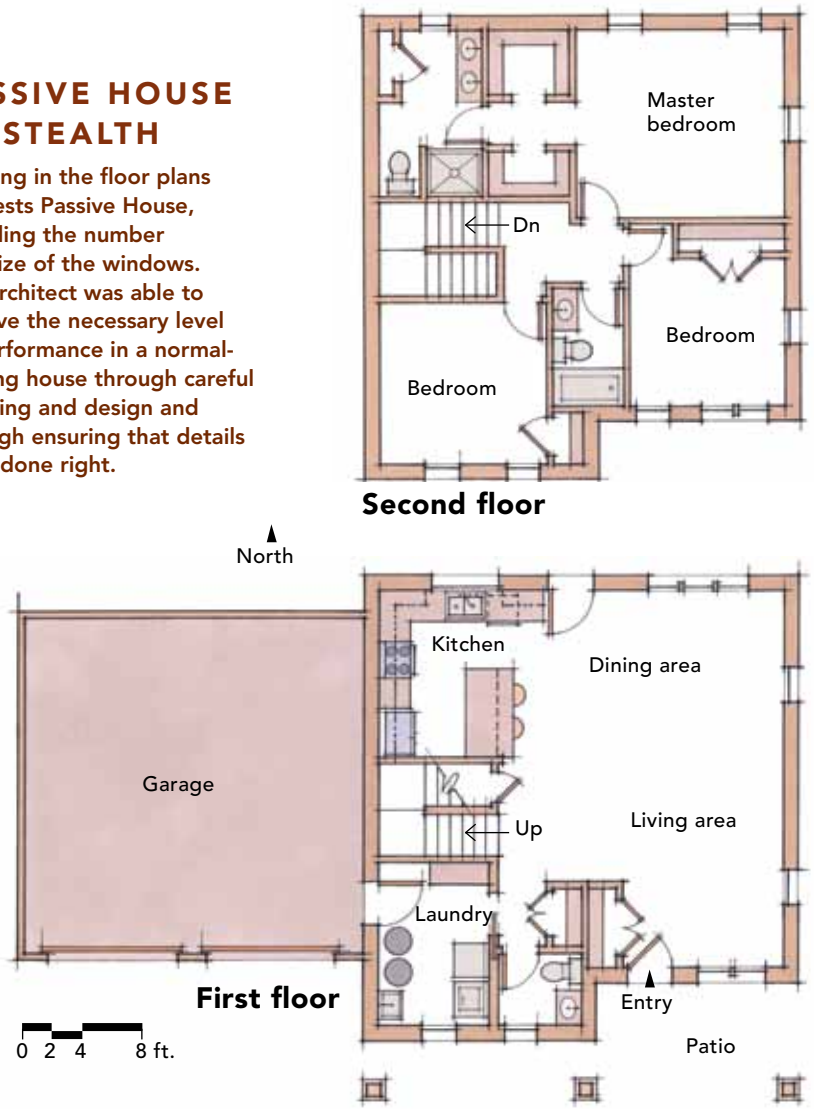
The proof is in the Passive House

The Spechts' house turned out to be aesthetically appealing, comfortable, energy efficient, and cost competitive. Adam was able to prove his affordable Passive House concept, and he has since gone on to design and build additional Passive Houses in the Roanoke, Va., area (see "Building it even better next time," below). Despite his success, he cautions builders in other regions: "The investigational process is the most important aspect of designing an affordable Passive House. What works in Virginia might not be appropriate or cost-effective in the Pacific Northwest." □

Daniel Ernst is a designer/builder in Steeles Tavern, Va. Photos courtesy of Structures Design/Build, except where noted.

PASSIVE HOUSE BY STEALTH

Nothing in the floor plans suggests Passive House, including the number and size of the windows. The architect was able to achieve the necessary level of performance in a normal-looking house through careful planning and design and through ensuring that details were done right.



SPECS

Bedrooms: 3 • **Bathrooms:** 2½ • **Size:** 1808 sq. ft. (house); 576 sq. ft. (garage)
Cost: $150 per sq. ft. • **Completed:** 2012 • **Location:** Thaxton, Va.
Designer/builder: Adam Cohen, Structures Design/Build, Roanoke, Va.

specifies an aluminum-clad wood-framed door from Kleareall's premium Eco-Clad line.

• A single wall-mounted mini-split can handle the heating and cooling load for most Passive House projects; however, closed bedroom doors can create comfort issues. Ducted systems provide better distribution and control, albeit at a higher cost. Adam is currently working with UltimateAir to develop an integrated heat pump/ERV. This integrated equipment would solve distribution issues and lower the capital costs for Passive House HVAC systems.

• Raft foundations are now the gold standard for most of Structures Design/Build's Passive House projects. Adam worked with an East Coast EPS manufacturer to design and then refine the footing profiles for the thickened edge slab. Builders interested in using these forms can contact the firm through its website (structuresdb.com).

• Because tight buildings have less drying potential, moisture control is more critical. To keep interior moisture from moving into the walls, Adam used MemBrain, an air and vapor retarder, on the interior walls of his first few Passive Houses. This product's permeability increases with relative humidity, allowing selective diffusion. After monitoring the seasonal relative humidity in several Passive House projects, Structures Design/Build stopped using this product. Interstitial condensation was just not an issue. Eliminating this additional layer was another step in bringing down the price of the firm's Passive House designs.