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Building HIGH-PERFORMANCE HOMES in Ohio

BY LEE CHILCOTE

The Passive House (PH) movement is just beginning to catch on in the United States, while more than 25,000 Passive Houses have been built in Europe. Although these radically energy-efficient homes may seem like science fiction to some, the future is closer than we think. Builders are taking a closer look at PH construction techniques as energy costs rise and the costs of high-performance features fall.

One of these builders is Matt Berges, a Cleveland, Ohio, contractor who made use of PH home-building techniques in two new-construction homes. The results show that ultra-low-energy homes can be built on a per-square-foot basis that is competitive with other new construction and generates savings—broadening their mainstream appeal. However, Berges believes that it's not all about the house. "The future of green building depends on engaging and motivating occupants to be more conscientious about energy usage and air quality issues. We can control ventilation, unwanted air leakage, thermal loss, and moisture, but then it is up to the occupant to make it operate efficiently and maintain good indoor air quality."

Building a Smart Home

The PH movement began in Germany in the late 1980s and has blossomed in Europe. Certified Passive Houses adhere to strict energy usage requirements. These houses incorporate passive-solar design, high-performance windows, thick insulation, airtight construction detailing, advanced energy recovery ventilation (ERV) systems, and energy-efficient lighting and appliances.

Berges was first inspired by PH design when Katrin Klingenberg presented it at the 2009 ACI national building conference. Then, in the fall of 2011, the Cleveland Museum of Natural History built a 2,500 ft^2 demonstration SmartHome. Built for about $500,000 using passive techniques, the new house was heated and cooled for just $20 per month without an air conditioner or a conventional furnace.

The project won national attention and caused visitors to marvel at its warm, quiet interior; its sealed, airtight windows; and its beautiful reclaimed wood floors. Perhaps most of all, they were impressed that the home could be kept comfortable with two wall-mounted mini-split heaters and an ERV system.

After a three-month residency next to the museum's beloved statue of a stegosaurus (or "Steggie"), the house was moved a few blocks away and sold to new owners. Its legacy lay in proving that such a home can be built on a tight budget—in this case, $160 per square foot (excluding relocation costs).

Berges was eager to put this theory into practice and quickly found two customers who shared the goal. Between 2011 and 2012, he built two new homes that incorporate PH techniques into a modern design. He also applied his technical know-how to several deep energy retrofits.

The Nissen-Butler Home

In building the two homes profiled in this article, Berges and his team set out to drastically reduce heating and cooling loads—by 75–90% of what is typical in a Cleveland home. Although the homes are not yet a year old, the first one looks as if it will be a net zero energy house—it will make more energy than it uses over the course of a year.

Berges met clients Steve Nissen and Linda Butler through his work with Environmental Health Watch, a Cleveland nonprofit that has spearheaded the affordable healthy home movement. Butler wanted some advice on how to build an extraordinarily green home. Berges suggested that she look into the PH movement, and the two later met at a Passive House Conference.

LINDA BUTLER

South face of Nissen-Butler home. Solar thermal collectors are on the garage roof, and PV panels on upper roof are out of sight.

LINDA BUTLER

Master Carpenter Ben Wanyek ensured perfection every step of the way. Here he connects the interior (below slab and foundation) air barrier to the exterior, at the boundary of the upcoming walls.

LINDA BUTLER

OSB and an ice and water shield serve as an air barrier. The two layers of 2-inch rigid foam were salvaged from a commercial roof.

LINDA BUTLER

Open-cell spray foam in vaulted ceilings provides insulation and air sealing.

After the conference, he asked what she thought. She said, "After hearing all of that, I can't imagine building a house any other way." "Great," Berges replied, "so you're going to do it?" And she said, "Yes, on one condition—if you will build it for us.'"

So began an 18-month partnership among Berges, Kent State architecture professor Joe Ferut, and Nissen and Butler that resulted in a house that serves as a model for PH construction in cold climates. The 6,000 ft^2 home (consisting of two floors and a basement) is so energy efficient that the solar collectors will likely produce more energy than the couple use over the course of the first year.

"We decided to try to build a positive [net zero] energy house rather than going with typical green because it became clear that it was possible," explains Steve Nissen, an M.D., who chairs the Department of Cardiovascular Medicine at the Cleveland Clinic. His wife, photographer Linda Butler, expresses it differently. "We wanted to prove the house could be beautiful as well as energy neutral and still have the comforts that a techie couple would want. "

It should be noted that much of the energy savings in the Nissens' home comes from their intensive focus on energy reduction.

"It takes a low-energy occupant to have a low-energy house," says Berges. "Steve and Linda were my first customers who were more excited about energy savings and efficiency than I was."

They purchased each appliance and lighting fixture based on its energy performance. After moving into the house, the couple closely monitor daily energy production and usage. Steve tracks the solar-panel production on apps on his phone and analyzes daily energy use.

"We've become sun worshipers and obsessive about turning off anything that drains energy. It's like a daily competition to see if we can help the sun give us free energy," says Butler.

Here's a snapshot of how they achieved such high-performance results in this home.

Passive-solar design. The Nissen-Butler home was designed to maximize use of passive-solar heating (and shading). The home is oriented to the south to maximize the daylight that enters the generous-sized windows. The architect-designed overhangs above the windows ensure that the home doesn't overheat in the summer. Only a single window faces west, which is the most difficult direction to protect from the low setting sun. Motorized internal blinds are programmed to go up and down on timers each day.

Insulation and airtightness. Berges made certain that an airtight complete and continuous thermal envelope enclosed the house from below slab to the top of the roof. The house features 8 inches of below-slab foam (R-40), a very well-insulated foundation (R-52), 4 inches of exterior foam with a double-stud wall interior fill (R-55), triple-glaze windows (R-11), multipoint locking doors (R-15), and an extremely well-insulated roof (R-69). These specs result in minimal leakage and allow for easy control of interior air. The house exceeded the PH airtightness standard by 100%, resulting in a blower door reading of 0.3 ACH_{50}.

Solar electric and solar thermal. The home has two sets of solar panels. A set of three solar-thermal panels on the garage provides hot water for the home. A larger array of panels on the upper roof provides electricity.

LINDA BUTLER

Thick, vaultlike doors with multipoint locks and latches.


LINDA BUTLER

A PV solar array was installed on the upper roof by Re Power Solutions.


LINDA BUTLER

The only ductwork in the house was for fresh air intake and stale air exhaust (4-inch ERV ducts).

On a recent day, Nissen reported making 29 kWh of electricity and consuming only 11 kWh.

ERV. For ventilation and fresh-air distribution, Nissen and Butler chose the best available—the German-made Zehender ERV, which included an add-on water coil with a ground loop. On the coldest winter day in 2013, the air outside was 6°F. The ERV processed the cold air in two steps, using just 55 watts of power. First the air passed through the radiator-like geothermal heat exchanger that contained circulating 50°F water from the below-slab ground loop. From there the air is passed through the ERV, which recovers energy from the 68°F stale exhaust air. The fresh air emerged from the ERV at 62°F!

Mini-split air source heat pumps. The Fujitsu mini-split was chosen to provide the final step in bringing air to a comfortable temperature inside the house. Two small units (even though, on paper, just one could have satisfied the demand) provide auxiliary heating and cooling as needed in winter and summer. However, on a sunny winter day, the heating system isn't necessary, since the large south-facing windows, and lower sun angle, allow the sun's warmth to extend throughout the house.

Lighting. Although heating is typically our largest expense in a cold climate, once that load is reduced, electricity usage becomes the next big target. The Nissen-Butler home uses all-LED lighting. Nissen even upgraded the microwave and refrigerator bulbs with LEDs. Even on cloudy days, the large windows bring ample natural lighting into the house, so lights are not even turned on until it is dark outside.

Appliances. The appliances are all highly efficient. The home features an induction cooktop range, as well as a ventless condensing dryer. However, the couple rarely use the dryer, preferring to dry their clothes on a large drying rack in their spacious, second-floor laundry room (which sits below an exhaust vent to the ERV).

Windows. The couple spared no expense on windows, ordering the best available (U .08, SHGC .50)—Energate windows from Germany. The shipping costs alone make this level of upgrade impractical for many projects, though when the demand increases and products like this can be made in the United States, prices will drop. The tilt-and-turn windows seal like a vault when you close and lock them, and virtually no air leakage occurs as a result.

Not only are the Nissens happy about their energy cost savings, but they also feel confident that their new home has been worth the investment. If one includes the 2,000 ft^2 finished, fully insulated basement, the 6,000 ft^2 home cost $160 per square foot to build. "We were amazed that in a climate as rainy and snowy as Cleveland, we were able to produce enough solar power to spend just $50 on electricity during an entire year," Butler says happily. "The comfort bubble here is just extraordinary." (For more on the Nissens' experience in their new home, see "A Note from the Homeowners.")

Berges believes that what he learned from the Nissen-Butler residence can be applied to other homes and buildings. "The features they chose are not necessarily affordable for everyone, but Nissen and Butler accepted the fact that they're pioneers, and they were willing to pay a premium to demonstrate what was possible," he says, citing the fact that the German-made windows have since come down in price and will continue to fall as demand goes up. "Someday, these higher-performance products will be produced in the U.S.A."

A NOTE FROM THE HOMEOWNERS

From August 7, 2012 (when the bidirectional meter was installed), until May 21, 2013, we drew 4,600 kWh from the grid and sent 2,700 kWh to the grid. We consumed 16 kWh per day. Between May and August 7, we will have made at least 2,200 kWh (based on last year's production).

I estimate that from August 7, 2012 to August 7, 2013, we will have drawn about 5,000 kWh from the grid and sent 4,900 kWh to the grid. Whether we are net zero will depend on the weather, but it should be close.

Our total energy consumption was about 17 million Btu (5,000 kWh x 3,412 Btu/kWh). The PH standard requires the use of less than 38,100 Btu per square foot per year (total primary energy). We could have used several times as much energy and still met the PH standard. It's just amazing.

—Steve Nissen

The Strauss Home

After completing the Nissen-Butler home, Berges sought to apply the lessons he learned to a more affordable house. In 2012, he built the Strauss family home in Rocky River, a suburb located just west of Cleveland. This more modest 3,300 ft² home (counting the finished basement) was built for approximately $85 per square foot.

Anna-Katrin and Mark Strauss sought to build a cutting-edge home but could not find a builder who was interested in completing the green-building features they wanted for the budget they had in place. Then they met Berges, who saw it as a welcome challenge, given his interest in energy-efficient and affordable homes.

"We talked to a couple of builders, and they all said, 'You can't afford to build this home; you'll have to cut out all the green stuff,'" says Anna-Katrin Strauss, who designed the home herself (on her way to becoming a licensed architect). "We said, 'No, no.'" They stuck with their original vision and are now thrilled with their new home.

Berges found the energy-conscious Strauss family to be the perfect clients for an ultraefficient home plan, which they knew was somewhat unconventional. Together, they agreed to trust what the energy modeling was telling them—installing only one single-head ductless mini-split to meet the low loads. They used internal fans as well as the ERV for distribution and mixing.

The results are striking. The Strauss home is elegant, green, and simple, with an open, loftlike interior on the first floor, three large bedrooms on the second floor, and a kid-friendly playroom, laundry-utility room and home office in the finished basement.

Here's a look at how the Strausses incorporated PH design into their home.

Passive-solar design. The site was slightly challenging for passive-solar design, in that the front of the house faces north (where the owners wanted to minimize windows). South-facing windows at the rear of the house make up the largest percentage of the glazing, and summer shading devices will soon be added to south-facing first-floor windows and doors. The roof was also designed to face south for the sake of future solar, and overhangs were designed to shade the second-floor glass in summer.

Insulation and airtightness. The Strauss home has 4 inches of below-slab insulation (R-20), foundation insulation (R-22 continuous, plus R-13 cavity), 3½ inches of exterior foam (R-21 continuous, plus R-15 cavity), energy-efficient windows (U 0.18–22), multipoint locking doors (R-7), and a well-insulated attic (R-55). The airtightness meets the PH standard, at 0.6 ACH_{50}.

Mini-split air source heat pump and ERV. This home has roughly the same heating and cooling loads as the Nissen-Butler home, at around 12 kBtu per hour for heating, though in this case the

ANNA-KATRIN STRAUSS

A generous front porch helps disguise the home's basic square footprint. The home's tight and fill lot created some construction challenges.

THE HOME PERFORMS

Starting with our first full month of occupancy, here are our energy consumption figures:

December 2012	1,176 kWh	April 2013	662 kWh
January 2013	1,012 kWh	May 2013	646 kWh
February 2013	875 kWh	June 2013	381 kWh
March 2013	731 kWh	July 2013	349 kWh

Numbers went down pretty drastically after we did a full scan of the house with the Kill-A-Watt to eliminate energy "vampires." But for a family of four with two adults working from home, two kids home pretty much full time, washing cloth diapers, and so forth, I think the results are pretty great!

If we figure that February was our first full month after our "vampire hunt" and use that as our first true usage number, we have six months of true data to work with. If we add up these numbers and divide them by 6 to find the monthly average, we end up with an average monthly use of 607 kWh. Multiply that by 12 and we've got 7,284 kWh. Multiply that by 3,412 Btu/kWh and we've got 24,853,008 Btu per year.

Adding in gas water heating, we have used an average of 0.88 mcf each month, which equals 880,000 Btu per month, or 10,560,000 Btu per year. Added to the electrical use, that's 35,413,008 Btu per year. Divide our annual usage by the 38,100 Btu/ft²/year Passive House requirement and we would still qualify if our house were only 929 ft², so at 2,300ft² plus a finished basement I would say we are more than safe!

—Anna-Katrin Strauss

ANNA-KATRIN STRAUSS

The home's foundation walls were waterproofed and clad in rigid insulation before backfilling, and another layer of rigid foam and insulated stud walls was added to the interior.

ANNA-KATRIN STRAUSS

The framing was sheathed with Zip System sheathing, followed by two layers of rigid foam and another layer of sheathing, before siding was applied.

ANNA-KATRIN STRAUSS

Insulation was blown into stud cavities, combining with exterior rigid foam insulation to create an R-value of 36.

load was met with just one mini-split. Two internal fans were installed for distribution to bedrooms. The mini-split and distribution system heats the house very efficiently. The owners will see how the single-head mini-split does in the summer, and they have a simple plan in place to add another mini-split if it ever proves necessary.

The ERV used in the Strauss house was made by UltimateAir, in Ohio, and is one of the few that are efficient enough to be PH qualified. In this house, rather than ducting the ERV supply to each and every room, Berges introduced the fresh air right below the mini-split on the first floor, while continuously taking stale air out of the kitchen and bathrooms.

This balance of efficiency and affordability was achieved by using a slightly less efficient ERV (compared to the more expensive system used in the Nissen-Butler home), with substantially less duct work and with a smaller, more compact shell.

Lighting and electronics. The home incorporates high-efficiency lighting and light fixtures, using primarily LED bulbs. In addition, the Strausses used a kWh meter to see why their initial electrical usage was higher than expected, and found various opportunities for improvement in their plug load. For example, they set smart power strips to "sleep" when they were not being used, once they discovered the 40W continuous phantom load coming from their cable system DVR.

Appliances. The Strauss family used an induction oven and cooktop, a condensing dryer, and the most efficient appliances they could justify. They also incorporated a laundry room design that includes built-in racks for line drying to further reduce appliance energy usage. There is an ERV exhaust vent to take moisture out of the laundry room and a distribution fan that pulls air from the second-floor ceiling and blows it into the basement. The ERV exhaust and the circulation fan allows them to hang-dry their clothes, rather than using the dryer. The couple elected to install a gas power-vented water heater, and plan to upgrade to solar hot water and a backup electric tankless in the next five years.

ANNA-KATRIN STRAUSS

ANNA-KATRIN STRAUSS

The back wall of the open scissor stair was clad in prefinished plywood fitted with bolt hangers for installation of an interior climbing wall.

Windows. The casement windows that the Strauss family chose are not quite as high performing as those in the Nissen-Butler home, but they are nonetheless very energy efficient (U .2). They are Ohio-made and were much less expensive than the ones made in Germany.

Water usage. With the idea of someday putting in a system to collect wastewater and reuse it, the shower drains were designed to run separate from the toilet drains before they "Y" together in the basement. Water lines to the toilets are isolated so that they can later be supplied from the future water collection system. These systems will

ANNA-KATRIN STRAUSS

ANNA-KATRIN STRAUSS

The interior of the Strauss home has an open loftlike feel for family-friendly living.

soon be made available at more affordable prices, and when they are, this house is ready for one.

The Strauss home proves that with the right design, contractor, and energy-conscious owners, high-performance homes can be cost competitive with conventional new homes while generating significant energy savings. (For more on the Strauss home performance, see "The Home Performs.")

"I think a big part of what allowed me to build the Strauss home for $85 per square foot was the optimal size and shape of the home–it is a simple square," says Berges. "The other factors that contributed to the cost-effectiveness of the project were the flexible owners, and my willingness to build for less because of my interest in the project."

Lee Chilcote *lives in Cleveland, Ohio, and writes for a range of regional and national magazines.*

>> learn more

Contact Matt Berges, Cleveland Home Builder, through www.BergesLLC.com.

Berges is a housing specialist with Environmental Health Watch. Find out more at www.EHW.org.

For more photos and technical information from the Nissen-Buttler home see www.LindaButlerphoto.com.