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Building High-Performance Homes in Ohio

Streamlining Multifamily Upgrades

Net Zero in New England

Energy Savings Through Lighting Control Settings

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 ft² 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).

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

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."