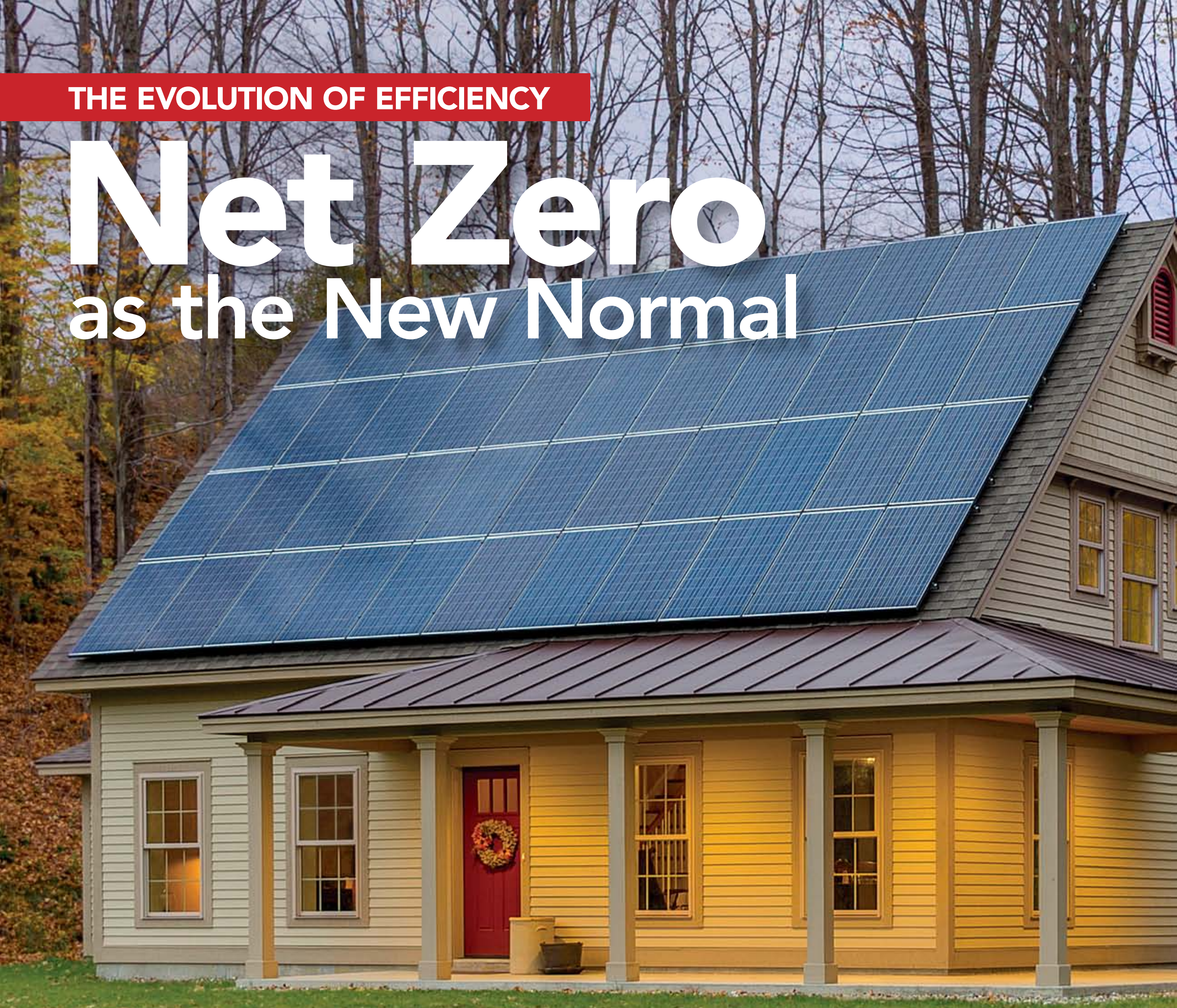
THE EVOLUTION OF EFFICIENCY

Net Zero as the New Normal



Experimentation and learning have led one builder to integrate energy-smart techniques into everyday construction

BY MARTIN HOLLADAY

Biologists note that when unrelated species occupy the same environment, evolutionary changes sometimes alter those species in similar ways. After millions of years, a swimming bird like a penguin, a swimming mammal like a dolphin, and a swimming fish like a shark tend to resemble each other: They all have sleek, smooth bodies and propel themselves with similar motions. This is an example of convergent evolution.

A parallel example is becoming evident in the world of residential construction. In New England, builders who have been paying attention to energy issues for the last 20 years and a subset of builders who attend conferences and constantly push their techniques to the next level are beginning to exhibit signs of convergent evolution. As these forward-thinking builders learn new concepts, experiment with their implementation, and share their successes and failures with fellow builders, homes they build are beginning to resemble each other. These net-zero-energy homes are often compact two-story designs with the long axis oriented in an east-west direction, and most have triple-glazed windows and walls with high R-values. Increasingly,

Photo this page: Gary Hall. Drawing facing page: John Hartman.

these homes are equipped with roof-mounted photovoltaic (PV) arrays and are heated and cooled by ductless minisplits. Custom builder Paul Biebel, president of Prudent Living Homes in Vermont, is a prime example of this ongoing evolution.

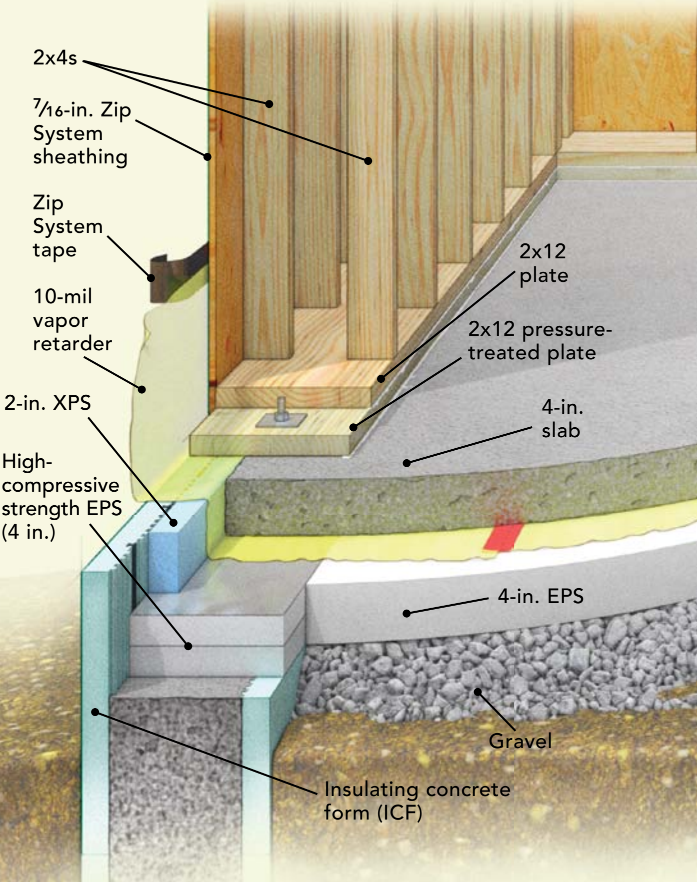
Four decades on the learning curve

The 2500-sq.-ft. house in Norwich, Vt., shown here was completed in 2015, Biebel's 39th year of building houses. "We build five or six custom houses per year, and it's probably been six or seven years since

A SMART SLAB ASSEMBLY

More than a structural base for the house, the stemwalls and slab separate the conditioned living space from the cold earth. Here, the insulation, air-sealing, and moisture-control details all must work together.

ICFs as slab-edge insulation. *By stopping the concrete pour for the stemwalls about 8 in. shy of the ICFs' top edge, the inner flange of the forms can be cut off to make room for a double layer of 2-in.-thick high-compressive-strength EPS foam atop the stemwalls, with 4-in.-thick foam added in the rest of the field. The remaining outer edge of the ICFs provides insulation for the slab edge.*



THICK, TALL WALLS

Arguably one of the simplest and most cost-effective ways to achieve a superinsulated wall, double-stud framing provides an excellent thermal break, especially when combined with the selective use of spray foam. To allow the cavity insulation to run uninterrupted from bottom plate to roof rafters, the framers built balloon-framed walls, then hung the floor system from a ledger.

One on top of the other. *After the interior section of the double-stud wall is assembled, the outer section is framed atop it, with plywood flanges separating the two sections. The entire assembly is sheathed and tipped into place in one piece.*

we've built one just to code minimum," Biebel says. "Nobody likes to be a guinea pig, but we have incorporated new approaches and technology slowly over the years, little by little."

Homeowners who invest in these features from the start, including the incremental costs in a 30-year mortgage, end up with very low energy bills. In fact, these features are often cash-flow positive from day 1. Regarding the cost required to hit this mark, Biebel says, "If you add $30,000 up front to make the upgrades, you will have made that money back in six to eight years, all while having no utility bills." But it's more than avoiding utility bills; according to Biebel, it's about making a smart investment. "To me, this is about preparing for the future," he says. "What is your house going to be worth 10 years from now if it doesn't perform at that level? I see investing in this technology as protecting your investment."

It begins with the shell

Although Biebel's houses are custom, they follow a high-performance baseline. The foundation consists of perimeter stemwalls—insulated concrete forms (ICFs) from Nudura—with an additional layer of rigid foam installed along the outside edge of the slab. A 4-in. layer of foam under the slab is rated at R-20.

Biebel builds two kinds of walls: double-stud walls filled with cellulose (R-45) and 2x6 cellulose-filled walls with rigid foam on the outside (R-40) for clients concerned about interior square footage. At the base of the walls in this house, the sheathing is taped to the 10-mil Stego Wrap vapor barrier that was installed directly under the concrete-slab foundation to create a continuous air barrier up the wall and eventually across the top plate and up the inside face of the roof rafters.

The roof on a Biebel house is at least R-60, even if there's a cathedral ceiling instead of a traditional attic. This high level of insulation is achieved with 20-in.-deep trusses, which allow enough room for 2-in.-deep site-built ventilation channels and 18 in. of dense-pack cellulose. If a more conventional attic is built, Biebel ramps the R-60 minimum to a more robust R-90, simply because the incremental cost is easy to justify when blowing loose-fill cellulose on an attic floor.

Directly above the ceiling drywall on the second floor, a layer of taped Zip System sheathing creates a durable air barrier. This sheathing layer is tied into a layer of self-adhered flashing that crosses over the top plates of the exterior walls and is sealed to the sheathing on the outside face. The insulation follows the roof slope rather than the kneewall, and the drywall air barrier is hung before any kneewalls are framed.

In some places, such as on the breezeway between the house and the insulated garage, spray foam was used to insulate the roof in order to achieve a high R-value in a relatively compact space. In cases like this, Biebel applies a 1-in. layer of rigid foam to the top of the rafters or trusses to create a thermal break. Strapping and plywood are then added over the foam, forming a free-flowing ventilation channel under the roofing. "Although this isn't required with closed-cell foam," Biebel says, "we were informed by our suppliers that the shingle companies do not give a full warranty on any roof that is foamed tight to the underside."

Biebel's blower-door test results (1 ACH50) justify the air-sealing efforts. The crew tests houses after the air-sealing and insulation are complete, and then again when the house is finished. "Our numbers would probably be lower if we could install casement windows," Biebel says. "But all our customers want double-hungs."

Cellulose belt, spray-foam suspenders. *Although primarily insulated with dense-pack cellulose, all penetrations are coated first with spray polyurethane foam, and all seams in wall plates are sealed with a bead of caulk.*

In all of his builds, Biebel uses triple-glazed windows that have a whole-window U-factor of 0.19 and a solar heat-gain coefficient of 0.25. The vinyl windows shown here are Harvey Building Products' Tribute units.

"Harvey only charges $50 per window to upgrade from double to triple glazing; some manufacturers charge an additional $200 per window," Biebel says. "The window package for this house cost less than $10,000, which is half the price of the same package from some other manufacturers."

Inside the tight and well-insulated shell, the focus moves to a successful integration of mechanicals.

Learning to get the most from minisplits

Biebel has been heating and cooling his homes with Mitsubishi ductless minisplits for several years. (For more on minisplits, see "Installing a Minisplit," pp. 74-78.) This house has two outdoor units: one for the ductless units and one for the ducted system. Biebel's cost to install a ductless minisplit in a house with multiple indoor heads is usually between $3000 and $4000 per head. "A ducted system can cost twice as much as a ductless system," he says, "but we do offer it as an option for those clients who don't want to see the minisplit head mounted on the wall."

There is a learning curve to locating minisplits. "You have to think about special conditions," Biebel explains. "A house we built in New Hampshire was located at the end of a long, narrow pond, and the pond created a wind-tunnel effect. We put the outdoor unit under the deck, thinking that it was protected. But the fan and coils got packed with snow. The solution in that case was to move the outdoor unit to the street side of the house."

Noise is also an issue. "There is always some vibration from the outdoor units, so it's important to choose the location carefully," Biebel says. "When things are quiet, you can hear a vibration or hum."

Inside the house, the routes for the refrigerant and condensate lines need to be planned carefully. "In some cases, you may need custom framing to accommodate them," Biebel says. "You need to miss any important timbers or beams. Some homes require 50 ft. or more of

DEEP-TRUSS ROOF

Combining the proven benefits of traditional attic ventilation with superinsulation strategies, these deep trusses yield an R-60 roof and cathedral ceiling by way of some clever site-built details.

Superinsulated, vented cathedral. *The 20-in.-deep trusses provide space for site-built ventilation baffles that are made from ripped 2x stock and ½-in. OSB and are sealed at all joints with canned foam. The remaining 18 in. of space is then dense-packed with cellulose to provide an R-60 lid.*

Air-seal before adding kneewalls. *To provide a reliable air barrier at the ceiling plane, the underside of the roof trusses is covered with Zip System sheathing and seam tape, then covered with drywall before the kneewalls are framed.*

refrigerant line." Condensate lines either can be directed to a leaching system under the slab, or they can go right to the radon pipes, but depending on a trap connected to the DWV system is risky. "When the traps dry out," says Biebel, "you get odors."

The air handler for this house's ducted minisplit is located in a conditioned attic. Although the space is cramped, the HVAC contractor managed to squeeze in the ducted minisplit unit and the Renewaire energy-recovery ventilator (ERV) under the rafters, keeping them inside the insulated envelope to minimize thermal losses.

Mechanical beauty is in the eye of the beholder

As a designer, Biebel prides himself on his attention to integrating ductless-minisplit heads into the interior design of his houses. (The Mitsubishi head in this kitchen is centered over a base cabinet.) "To make a heat-pump head look natural takes a lot of planning," Biebel says. "One thing I've learned is that ugly is in the eye of the beholder. Some people like the minisplit heads, while other people call them ugly. Some people even think solar panels are ugly. Once we were building a house with a solar array, and neighbors stopped by to complain about the solar panels. I replied, 'What if I complained because I thought that your junky vehicles looked ugly?' They got the point and laughed."

The roof-mounted 13kw PV array on this house should produce more electricity on an annual basis than the homeowners need for lights, appliances, plug loads, domestic hot water, space heating, and cooling. "The owners didn't really need 13kw," Biebel confesses, "but

Beauty is in the eye of the PV-holder. *Some consider solar panels ugly, but these homeowners increased the size of the PV array beyond their energy requirements for aesthetic reasons, believing the house would look better if the entire roof were covered.*

MECHANICALS MAKE IT PAY

When the air-sealing and insulating are done well, the burden on a home's mechanical systems is greatly reduced. Small heating and cooling units are able to condition the home to a comfortable level, and they can be powered by the sun's energy.

More than a random placement. *Rough-ins for the minisplit's outdoor units are considered carefully, not only for aesthetic reasons but because they create noise from their vibration.*

they said that the roof would look better if we just went ahead and covered the entire south-facing slope with PV."

Biebel isn't force-feeding solar to his clients, though. "If homeowners aren't interested in going off the grid, or even in adding solar panels, that's OK," he says, "but we plan for that anyway by deciding where the solar inverters would be placed, and we provide conduits from the attic to the basement so that the necessary electrical can be installed without opening walls."

Energy will trump square footage and location

Biebel predicts that the time is coming when energy consumption will be a bigger part of the conversation about house design than location or square footage. "Right now, banks and appraisers only look at square footage and at the value of the house next door," he says. "They'll need to catch up." Biebel has chosen the route of building high-performance homes even though it has meant turning down clients who are interested only in getting the lowest cost per square foot. His reasoning includes equal parts altruism and genuine belief in offering his clients something with lasting value. "I want to put green back in the Crayola box where it belongs," he says. "The only way I see that happening is to make it a normal part of the conversation, not an upgrade." □

Martin Holladay is a senior editor at GreenBuildingAdvisor.com and at *Fine Homebuilding*. Justin Fink also contributed to this article. Photos courtesy of Prudent Living, except where noted.