Toward a ZERO ENERGY Home

A COMPLETE GUIDE TO ENERGY SELF-SUFFICIENCY AT HOME

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& Scott Gibson

Authors of Green from the Ground Up

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The Taunton Press

Case Study

The Good Life in Vermont

Simple forms, sophisticated systems, and net zero energy consumption

David Pill and Hillary Maharam's home just south of Burlington, Vermont, is an appealing blend of simple architectural forms and unpretentious materials that fits right into its rural setting. More to the point, the Leadership in Energy and Environmental Design (LEED) Platinum building won the couple a $10,000 prize from the Northeast Sustainable Energy Association in 2009 for documented net zero energy performance.

SPECIFICATIONS

House size: 2,800 sq. ft.

Average heating degree days at site: 7,900

Wall and roof construction: Stick-built 2×6 and 2×10, respectively

Insulation type: Above-grade walls and roof, closed-cell spray foam full thickness of cavity; basement, 4 in. EPS rigid foam under slab; foundation walls, 2 in. EPS on inside of foundation walls plus 2×4 framed wall with blown-in cellulose; basement ceiling, 6 in. denim batt

R-values: R-16 under slab; R-21 basement walls; R-21 basement ceiling; R-40 walls above grade; R-58 roof

Windows: Thermotech triple-glazed fiberglass; U-0.15 on north, east, and west elevations; U-0.17 on south elevation

Wind/photovoltaic capacity: 10kW net-metered Bergey wind turbine

Heating source: 3-ton ground-source heat pump

Air-conditioning: None

Cost per square foot: $200

Designer: David Pill, Pill–Maharam Architects

Energy consultant: Andy Shapiro, Energy Balance

General contractor: Jim Huntington, New England Housewrights

A house designed by architect David Pill for his family in Vermont blends traditional architectural elements with state-of-the-art energy performance. Documented net zero performance won Pill a $10,000 prize from the Northeast Sustainable Energy Association.

Pill, an architect, designed the house for the 44-acre site after he and Hillary decided to leave the Boston suburbs with their two children for life in the country. Their goal was an affordable house with low environmental impact and no carbon emissions.

The result is an all-electric house, completed in 2007, that uses no fossil fuels and produces all the electricity it needs with a net-metered 10kW Bergey wind generator. It keeps everyone warm and comfortable on sunny winter days even with the heat turned off. Construction costs were about $200 per square foot—not exactly cheap, but less than what many custom homes cost these days, zero energy or not.

Nothing Exotic in Building Design

The house uses advanced framing with 2×8 studs 24-in. o.c. and 2×10 roof rafters. Pill eliminated all unnecessary framing members, not only to reduce waste but also to leave as much room as possible for insulation. He used two-stud corners, for example, and headers over doors and windows only where they were needed structurally (unlike houses framed with optimum value engineering, this one has structural sheathing).

Closed-cell polyurethane foam (R-6.5 per inch) completely fills the wall cavities of this trimmed-down frame, and 1 in. of polyisocyanurate foam wrapped around the outside reduces thermal bridging through the frame (see chapter 1). The 2×10 roof frame also is filled to capacity with sprayed-in foam. The basement slab is insulated with rigid foam.

Insulating the concrete slab of the basement is another step in reducing energy losses in winter.

A layer of rigid foam insulation on the outside of the house reduces thermal bridging between wood framing and cold outside air. Advanced framing techniques also helped by eliminating unnecessary framing material and leaving more room for insulation in the walls.

House shape and orientation both proved crucial to energy performance. The 60-ft. by 20-ft. house runs on an east-west axis, which creates a wide southern exposure to gather light and heat in the winter. Because the house is narrow, sunlight can reach every room and reduce heat and light requirements during the day. On the second floor, roof overhangs nearly 2 ft. wide block intense summer sun but let it in when the weather is colder.

On the first floor, a ground and polished 4-in.-thick concrete slab poured over a frame of wood I-joists soaks up the sun's energy on winter days and releases it gently at night. Windows are triple-glazed with insulated fiberglass frames made by Thermotech, a Canadian manufacturer. Windows have very low U-values and solar transmittance designed for their particular orientation—higher on southern exposures, lower on the rest of the house.

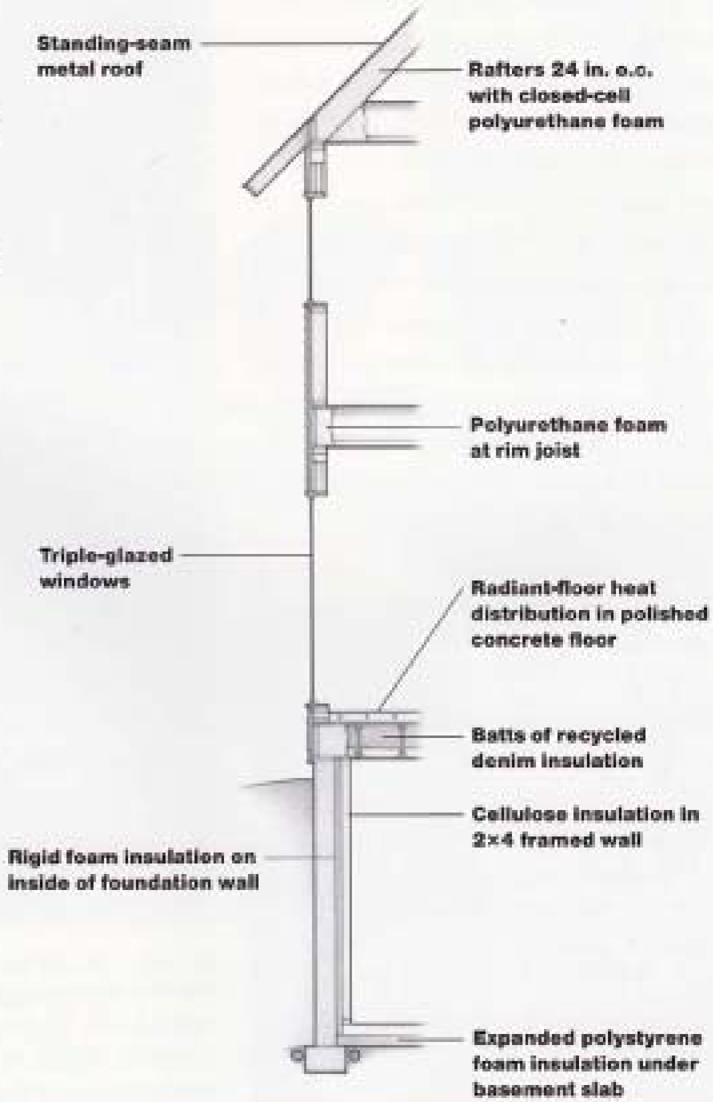
All of these features were fine-tuned by Pill's energy consultant, Andy Shapiro, who used Energy-10 software developed by the National Renewable Energy Laboratory's Center for Building and Thermal Systems.

Taking Advantage of Great Wind Potential

Pill and Maharam had decided early on that the house would consume no fossil fuels, and that made an all-electric design more or less a given. "The more we looked at it, the more we looked at the loads of the house, it looked

SUPER INSULATION YIELDS NET ZERO PERFORMANCE

David Pill's design for his family's Vermont net zero home includes a variety of building materials that sharply reduce energy consumption: polyisocyanurate sheathing, sprayed-in polyurethane foam, high-performance windows, and a thick layer of rigid foam insulation under the basement slab.



very possible to meet all our demands with a ground-source heat pump without using solar hot water," Pill says. "We wanted to stick to one simple system, either all [photovoltaic] or a wind turbine and consolidate the systems."

They caught a break on the site. Pill had noticed trees were "flagged," or distorted, from prevailing winds, possibly the result of unusual topography in the area. As it turned out, a neighbor worked for a company that makes wind assessment systems. He told Pill that wind on the site was obviously so good that it would be a waste of money to install monitors to verify suitability for a wind generator. A local turbine installer agreed.

The 10kW system cost $40,000 but it was also eligible for a $12,500 rebate from Vermont and a $3,000 federal tax credit, reducing its overall cost by nearly 40 percent.

From June 4, 2008, to June 4, 2009, the house used 5,999kWh of energy, plus the equivalent of 200kWh of firewood, while the generator produced 6,622kWh. With vigilance on the family's part, it was a net producer of electricity, by 423kWh.

The Pills' building site was breezy enough to make the wind turbine a good bet without extensive monitoring. On a lot with more marginal wind potential, testing is a prudent step before investing in a turbine.

A radiant-floor system provides heat. The thermal mass of the polished concrete slab is an energy bank that stores heat and helps even out sudden changes in indoor temperature.

A BALLPARK ESTIMATE FOR WIND-GENERATED POWER

Estimating how much electricity a small wind turbine will produce gets complicated. The amount of power varies dramatically with small ups and downs in wind speed, and wind isn't entirely predictable. Nor do turbines always produce as much power as manufacturers say they will. But there are ways to make a good guess.

Start with the "capacity factor," which is the actual electrical output as a percentage of what it would be if the turbine ran at 100 percent of its capacity 100 percent of the time. For small turbines, such as the one at this house, the capacity factor would typically be between 10 percent and 20 percent.

Now multiply the rated power of the turbine by the number of hours in a year (8,760) by the capacity factor. In this case, annual production should be at least 8,760kWh.

This turbine produced somewhat less than that, but even a minor bump in average wind speed on the site would change the result.

Geothermal Heat Shares a Deep Well

The house is heated by a radiant floor system connected to a 3-ton (36,000 Btu) ground-source heat pump. It draws water from the same well that supplies the family with drinking water. Water is normally returned to the well after it circulates through the heat pump. A variable frequency drive on the water pump can sense whether water is being drawn for domestic water (higher resistance) or the heat pump (lower resistance) and adjust flow accordingly.

The heat pump also produces domestic hot water, with an assist from a gray water heat-recovery system, a 5-ft. section of copper-wrapped waste line that picks up residual heat in shower water going down the drain. Pill says the equipment appears to be reducing the cost of heating water by about 30 percent.

Using the same well for domestic water and the heat pump reduced the cost of the heating system considerably, but it required a well that produced a lot of water. And here again, the couple got lucky. At 300 ft., the well was producing only about 2 gal. a minute—not enough, even, for domestic supplies.

Only the bathrooms on the second floor of the house were equipped with radiant-floor heat distribution. But the house's passive solar design has been enough to keep bathrooms warm enough without it.

They kept going, and at 480 ft., the well was producing 4 gal. a minute. Still not nearly enough.

A dowser had looked over the site and predicted that well drillers would tap into a vein producing at least 12 gal. a minute. "I was thinking, 'Oh, boy, now what?' " Pill says. "We were going to have to change our whole concept with the ground-source heat pump because 4 gal. a minute is not enough flow."

The dowser returned, and insisted the water was there. Well drillers had stopped drilling but left their pumps running to clear drilling debris from the bore. Suddenly an apparent blockage gave way, allowing water to flow at its full potential. When they measured the output it was 12 gal. a minute.

GRAY WATER HEAT RECOVERY

Gray water heat recovery is a way of capturing heat that usually goes down the drain. The hardware is fairly simple, consisting of a length of copper drain line wrapped in copper tubing. Savings can be significant.

There are two basic approaches. In the simplest version, drain water heats incoming cold water before it goes to the water heater or to where it's being used. This system works only when hot water is being drawn at the same time it's being discarded, when someone is taking a shower, for example. Although these systems are less expensive, they can't capture heat lost in drain water from a tub, dishwasher, or washing machine because water is not being drawn at the same time.

A more complicated system includes a dedicated storage tank. Drain water flows through a heat exchanger inside the tank and warms up the water. Another heat exchanger at the top of the tank preheats water before it goes to the regular water heater or to where it will be used. Heat-recovery systems without storage tanks are much more common because of their lower cost.

A drain-water heat-recovery system is a simple but effective way of capturing latent heat that would otherwise disappear with the hot water from a shower or washing machine.

HOUSE & HOME

Toward a ZERO ENERGY Home

A "zero energy" home—a home that produces as much energy as it consumes—is an idea whose time has come. By reducing or eliminating utility bills, zero energy homes offer a new direction for housing in America. It is a win for the homeowner, for the planet, and for a new generation of builders who are building houses that better meet the energy challenges ahead of us all.

With unequaled knowledge and a passion for the subject, authors David Johnston and Scott Gibson explore the design and construction of energy self-sufficient houses from start to finish and feature 12 houses that were built for zero energy living.

About the authors: A leader in the green building movement, **David Johnston** is the author of *Green from the Ground Up* and founder of greenbuilding.com and whatsworking.com. His approach to green building has been embraced by building professionals, municipalities, homeowners, and sustainability advocates nationwide. **Scott Gibson,** coauthor of *Green from the Ground Up,* is a freelance writer and longtime contributing editor to *Fine Homebuilding* magazine.

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