Power House

21st-century technology and a classic look come together in a shingle-style house that produces more energy than it consumes

BY BILL HEIGIS AND HOBIE GUION

A cedar-shingled house with steep gabled roofs, shed dormers, and a nearby barn is a familiar image in the Vermont countryside. It's a low-tech look that has radiated the promises of shelter, warmth, and livability for centuries.

Our clients, Chip and Susan Stone, had a vision for a home that combined this timeless rural look with the most up-to-date building technologies. They wanted a house constructed of sustainable materials (preferably local), powered by the sun, and heated by the warmth of the earth.

We eventually developed a plan to create a house with a tight envelope around a lean space. It would be heavily insulated and mechanically ventilated to ensure good indoor-air quality. The heat would be supplied by a ground-source heat pump powered by a photovoltaic array (pp. 84-85). And all of this would be

Beautiful, and energy-smart, too. *Built with an eye toward traditional design, this hilltop house and barn (above) boast a tight, highly insulated shell and a renewable-energy system. Understated details in an open plan (left) create a warm, inviting interior. Photos taken at A (above) and B (left) on floor plan.*

WHAT MAKES IT ENERGY-SMART?

A TIGHT STRUCTURE

- Urethane-foam insulation sprayed onto the inside of the roof and walls creates an air and thermal barrier.
- Rigid foam installed beneath the sheathing, as well as around and under the foundation, prevents thermal bridging and improves the house's energy efficiency.
- Triple-pane double low-e coated windows greatly reduce heat loss and increase solar gain inside.
- A high-efficiency heat-recovery ventilation system maintains good air circulation while preventing heat loss.

CLEAN, RENEWABLE POWER

- Although tied to the local grid, the house's 7kw photovoltaic array still supplies all the electrical needs of the household, including heat, and produces a surplus of electricity.

NON-FOSSIL FUEL HEAT

- A geothermal heat pump, powered by photovoltaics, creates hot water for radiant heat and domestic use that's stored in two 100-gal. tanks.
- A wood-fired fireplace insert and cookstove provide occasional heat and ambience.

LOW POWER REQUIREMENTS

- Energy-efficient appliances (no clothes dryer), LED and compact-fluorescent lamps, a gray-water heat-recovery unit, and careful monitoring of electrical use keep the house within the energy budget.

SUSTAINABLE FEATURES

- The house was framed with locally harvested wood.
- Certified or local wood was used for exterior and interior finishes.
- A solar-heated outdoor shower is used in warm months.
- Single-coat, integral-color plaster replaces paint on interior walls, reducing VOC levels and maintenance.

3 strategies for a net-zero house

1. Photovoltaics

THE ENGINE THAT POWERS THIS HOUSE

Although connected to the grid, the Stones' house derives nearly all its electricity from thirty-six 190w photovoltaic modules by Sanyo (http://us.sanyo.com/solar), which feed into a Sunny Boy SB6000U inverter (www.sma-america.com). The array is installed on the south-facing barn roof

(photo right taken at C on floor plan) and is expected to provide an average of 8000 kilowatt hours (kwh) per year. According to the homeowners' data, the array is producing as much or more electricity annually than the house consumes. The local electric company, Green Mountain Power, has an innovative program that pays a 6¢ premium for solar-generated power. While this doesn't necessarily tip the payback scale in favor of solar electricity, it does provide a significant incentive for customers who want to invest in renewable, local energy production. Over 20 years, that 6¢ premium is worth about $9000.

From May 2008 to January 2009, the house produced 60kwh more than it used. However, that period includes a disproportionate number of summer months, when excess power is expected, so it's likely that the annual surplus is less.

Cost: $45,000 after rebates

wrapped in finely crafted woodwork, hand-troweled plaster walls, and native-stone details. Here's how we did it.

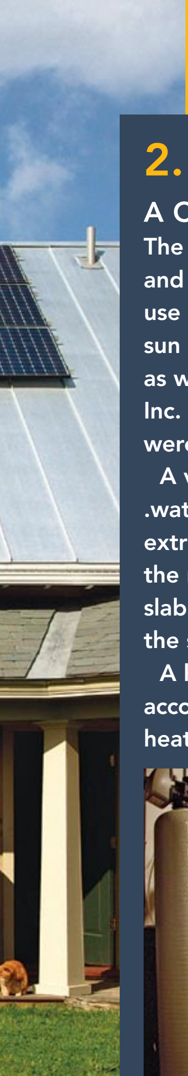
Find the sweet spot between comfort and conservation

From the start, the overarching concept was to make a net-zero house: one that uses renewable resources such as photovoltaics to create as much or more energy than it consumes. Our strategy was to build an airtight, highly insulated structure, minimize energy use with efficient appliances and lighting, and heat the house with a ground-source heat pump powered by photovoltaic panels.

After settling on the shell-construction methods (drawing facing page), we considered other ways to minimize energy loads and still meet the needs for heating, hot water, and other electrical consumption. Although the house is grid-connected, it has a solar array designed to generate as much electricity as the homeowners use in a typical year (sidebar left). We also installed a batch solar water heater by the outdoor shower and the barn sink for three-season use. This helps to reduce demand on the heat pump, which is more efficient at producing 100°F water for the heating system than 120°F domestic hot water.

In keeping with the net-zero goal, the house incorporates many energy-saving appliances and fixtures. For lighting, compact-fluorescent bulbs are the default, but near the end of the project, we found and installed seven LED recessed cans in the kitchen (www.creelighting.com). Energy Star appliances include an electric induction cooktop, a front-loading washer, a Bosch dishwasher, and a bottom-freezer Amana refrigerator. The Stones do not own a clothes dryer and instead have opted for a clothesline and, when the weather doesn't cooperate, an indoor drying rack.

Drawings: Martha Garstang Hill



2. Geothermal heating

A CLEAN, RELIABLE SOURCE OF HEAT AND HOT WATER

The Stones didn't want to use fossil fuels or electric resistance to heat the house, and they didn't want to rely on a combustion appliance. In the end, they chose to use a ground-source heat pump, which extracts heat from groundwater. When the sun is shining, the photovoltaics power the geothermal heat and hot-water system as well as the house's basic electrical requirements. Andy Shapiro of Energy Balance Inc. and energy consultant Tom Reilly from Salem Engineering in Shelburne, Vt., were responsible for designing the mechanical systems.

A variable-speed well pump delivers water to a Water Furnace heat pump (www.waterfurnace.com) that extracts heat before the water returns to the well. The extracted heat is stored in two 100-gal. Marathon electric hot-water tanks—one for the radiant-heat system, and one for domestic hot water. Tubing installed in a thin slab on the first floor and in radiant-heat panels (we used a Warmboard product) on the second floor provide a comfortable, quiet, even heat to the entire house.

A heat pump commonly has its own well, but here, a single well was dug deeper to accommodate both domestic-water needs and the heat-exchange surface area for the heat pump. This eliminated the need for a second well, which can be more efficient but is substantially more expensive.

The heart of the system. *A heat pump extracts heat from well water. The extracted heat is stored in two 100-gal. electric hot-water tanks—one for the radiant-heat system and one for domestic hot water.*

Cost: $32,000; includes geothermal heat and hot-water system, portion of well, all mechanicals including heat storage and distribution, and electrical work associated with the system.*

Other costs: Solar hot water (seasonal use), $4600; heat-recovery ventilation system, $4500

* For comparison, a high-efficiency propane boiler for heat and hot water with storage and distribution would be approximately $20,000.

Before you commit to a ground-source heat pump

How much will the system cost?
These systems are expensive. Design the house shell and mechanicals for lower heat and hot-water demands to keep the geothermal system as small as possible.

Water-to-water, water-to-air, or air-to-air system? As with many building decisions, it all depends. Each system has its place. Consult a professional designer to make this decision.

Who will install and maintain the system? Be sure you can find a local contractor with a proven track record of installing and servicing the entire system. Complex geothermal systems require maintenance over time.

What is the electricity source?
Ideally, these systems are coupled with renewable supplies (solar, wind, etc.), or there may be no real net-cost savings or environmental benefit.

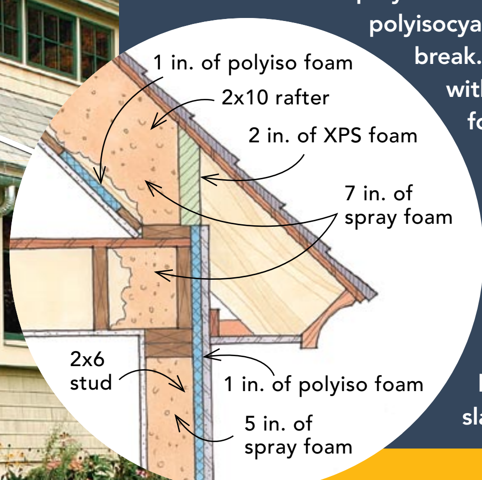
FineHomebuilding.com

Visit the Magazine Extras section of our home page for an audio slide show on this project. While you're there, you'll find an explanation of how a heat pump works.

3. Rigid and spray-foam insulation

A WELL-INSULATED, AIRTIGHT BUILDING ENVELOPE

In Vermont, good construction has to start with a well-insulated, airtight shell. We built R-39 walls with local rough-cut 2x6s, then blew in 5 in. of closed-cell spray urethane foam, and applied a 1-in. layer of rigid polyisocyanurate foam to the exterior for a thermal break. The R-60 roof was constructed of 2x10s with 7 in. of spray foam and 1 in. of rigid foam on the interior. All framing joints were caulked, and all rigid foam joints were taped to reduce infiltration further. In the basement, we used a 6-in. layer of rigid expanded polystyrene (EPS) on the wall interiors, followed by an interior stud wall covered with fiberglass-faced drywall. We also used 4 in. of high-density 4-lb. rigid EPS beneath the slab. Photo left taken at D on floor plan.



MINIMIZE THE FOOTPRINT, MAXIMIZE THE EFFICIENCY

Making the best use of space is a key element in an energy-efficient house design. Here, we crafted a plan that is big enough to be comfortable, but small enough to be heated with a minimum of energy. Sited on a south-facing hilltop, the house and barn are oriented for the best solar gain for both the photovoltaic array and the house's triple-glazed windows. A small guest bedroom and bath upstairs provide the only additional space beyond what is needed for the homeowners' day-to-day life. Photo left taken at E on floor plan.

SPECS

Bedrooms: 2

Bathrooms: 3

Size: 2291 sq. ft., including a root cellar in the basement

Cost: $284 per sq. ft., excluding the barn

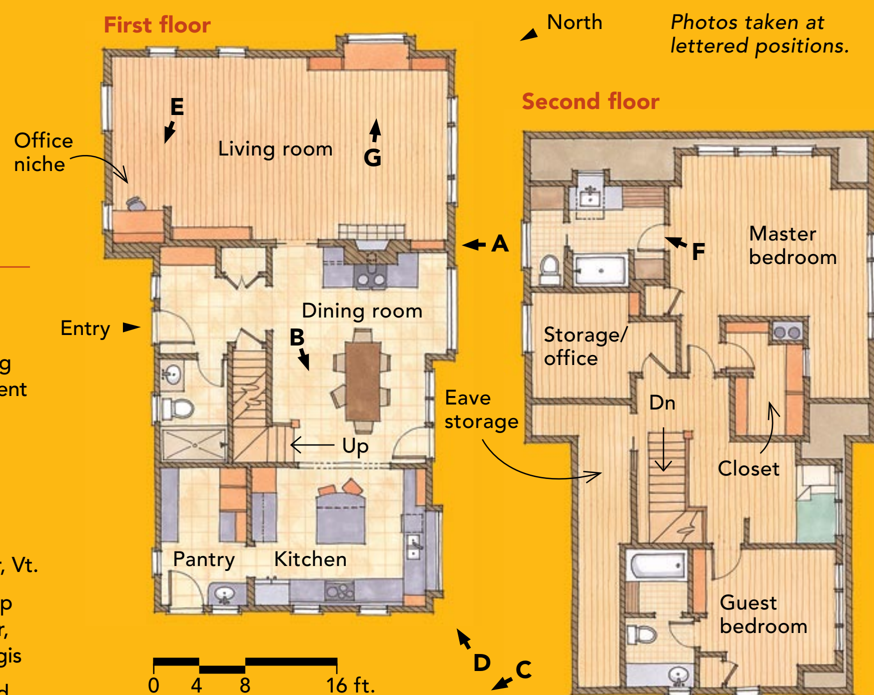
HERS rating: 18

Completed: 2008

Location: East Montpelier, Vt.

Designers: Susan and Chip Stone, with Steve Lowther, Hobie Guion, and Bill Heigis

Builders: Hobie Guion and Bill Heigis



Other mechanicals we specified to save energy include a GFX gray-water heat-recovery system (www.gfxtechnology.com) and a Metlund on-demand hot-water recirculating system (www.gothotwater.com) for the master bathroom. A high-efficiency Venmar HE-1.3 heat-recovery ventilation system (www.venmar.ca) provides balanced fresh air to this extremely tight house and exhausts stale, moist air from the showers, eliminating the need for bath fans that waste energy.

The heat pump is complemented by two woodburning appliances: an Esse woodburning cookstove (www.esse.com) and a Scan woodburning fireplace insert (www.scan.dk). Because the house is so efficient, the homeowners have found that with only a small fire in the morning, the cookstove serves as both a primary heat source and an effective cooking appliance. Because of the house's tight construction, fresh air is ducted directly to these appliances from outside and is mechanically dampered when they're not in use. A blower-door test revealed, however, that the cookstove is a substantial source of air infiltration because it isn't designed like an airtight woodstove; we could not find an effective way to damper the stainless insulated chimney.

Elements of home

The shell and mechanicals in place, we turned our attention to finishing the exterior and interior spaces that honor the Stones' vision of simplicity, durability, and craftsmanship. Outside, the house is sided with Canadian white-cedar shingles that blend beautifully with a surrounding maple grove. The roof is slate, quar-

Take advantage of the light. *In the master bath, a skylight floods the room with natural light, accentuating the built-ins. Photo taken at F on floor plan.*

Craftsmanship didn't take a back seat. *Throughout the house, clear-finished trim and built-ins warm the interior. In the living room, a comfortable window seat with storage below is surrounded by floor-to-ceiling bookshelves, all made of cherry. Photo taken at G on floor plan.*

ried from southeastern New York. This extremely durable product should last at least 100 years; very few other roofing products can match that. Rock walls, stone patios, and edible landscaping complete the exterior and connect the house to its surroundings, giving it a sense of timelessness.

Inside, the materials and finishes invite you to slow down just a little to appreciate the solid feel and warmth of the home. The wood paneling, most of the window and door trim, and much of the built-in cabinetry are Douglas fir and northeastern cherry. The wood floors are red birch finished with a low-VOC Waterlox tung-oil varnish (www.waterlox.com). Wherever possible, we used wood certified by the Forest Stewardship Council (www.fscus.org). Durable materials like slate, soapstone, limestone, ceramic tile, concrete, and stainless steel were used for floors and countertops. Finally, the walls are finished with a tinted veneer plaster that adds warmth and softness to the rooms in a way that painted drywall cannot match. Applied over a special drywall, veneer plaster can be a cost-effective, one-subcontractor wall covering, compared with taping and painting.

This project is an excellent example of collaborative design and construction, with the homeowners intimately involved in every step of the process. The result is a beautiful, efficient place to call home that will also tread lightly on the earth for decades to come. □

Bill Heigis and Hobie Guion are builder/designers in central Vermont. Photos by Charles Bickford.

Feedback by Susan Atwood-Stone

Kenmore induction cooktop

This unit (www.kenmore.com) cooks wonderfully, and can saute for hours at low settings or boil water in less than a minute. According to various Web sites (and *FHB* #191), induction cooktops are 84% efficient, versus 40% for gas and 74% for a radiant cooktop.

In a tight house, we do not have to worry about fumes. Because the burner doesn't heat up, food doesn't burn onto the glass top, and the cooktop is easy to clean. The downside is that we had to buy new clad-stainless steel or cast-iron pots and pans that are magnetic. Another bother is that the stovetop makes a buzzing sound when turned on higher settings. It retails for about $1500.

Metlund D'Mand System

This is an efficient way to bring hot water to our master bath, the farthest point from the hot-water tank. When we push a button in the bathroom to circulate hot water up from the tank, the Metlund D'Mand System (www.gothotwater.com) runs only until it detects that the water is hot enough; after about 20 seconds, it shuts off, and hot water flows from the tap without our having wasted any water waiting for it to warm up. It takes only a few seconds more for hot water to come through the showerhead. Water that circulates through our bathroom returns to the tank. We figure that we save up to a gallon of hot water a day. (Note: If you are trying to calculate cost savings, remember, we shower indoors only from October through mid-May.) The big difference between this and other hot-water recirculation systems is that the Metlund is on-demand instead of a continuous or timer-controlled circulation loop. The price is about $400, uninstalled.

Esse Ironheart wood cookstove

Although not an integral part of the efficiency plan, our favorite appliance is the wood cookstove (www.esse.com). Geothermal heat tends to be mild, and the woodstove adds a coziness that is hard to replicate (except for a sunny winter day). We have used our electric oven only three times in the past four months, but have used the Ironheart constantly to cook everything from roast chickens to custard. Its only weak point is that it's responsible for a significant portion of air infiltration in what is deemed an ultratight house. That's a small price to pay for the pure pleasure it gives us to use it. The stove retails for about $4000.