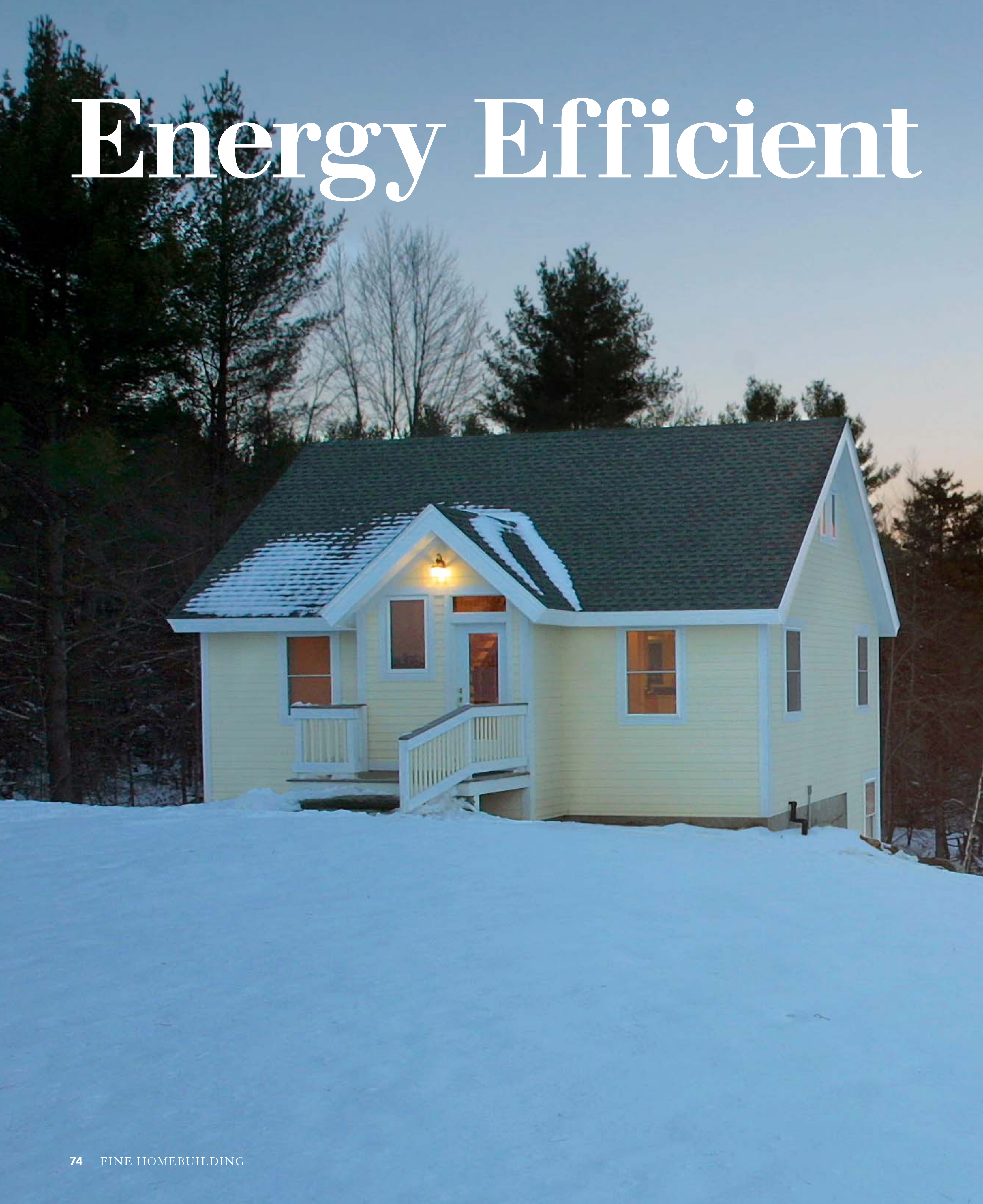
Energy Efficient



from the Ground Up

One builder's proven formula yields Vermont's most energy-efficient house

BY AL ROSSETTO

After witnessing a steady parade of problematic houses in my early years as a remodeler, I concluded that there's something wrong with the way that we're building today. I saw new homes with leaky basements, siding and plywood sheathing that rotted from the inside, and winter heating bills that were out of control. In addition, high levels of moisture within the new, tighter houses not only smelled musty but also sometimes made people sick. Not satisfied with any of this, I began my search for a better way to build.

Five elements of a five-star home

After a few years of experimenting on my own houses, I gradually moved away from board-by-board, 2x4 building as usual. Five elements emerged as the simplest way to build highly energy-efficient houses.

In short, a tightly sealed ICF foundation (insulated concrete forms) and a shell made of SIPs (structural insulated panels) combine to create a high-strength version of a polystyrene picnic cooler. Because most of us probably would enjoy viewing the landscape and sky from our cooler, it needs high-performance windows. The cooler also needs to be ventilated because it's so tightly sealed, and to be heated using low-temperature radiant heat because it is so well insulated.

In Vermont, if these five elements are included in the construction, the house likely will receive five-star status in the Energy Star Homes program (sidebar p. 78), which makes it eligible for rebates. The Environmental Protection Agency (EPA) defines an Energy Star home as being at least 30% more energy-efficient for heating, cooling, and water heating than a conventionally built home.

Indoor-air quality begins at the footing

In northern Vermont, it's a little more of a challenge to build one of these houses because it gets cold and because the soil is rocky. A shallow frost-protected foundation works well here and is less expensive—up to 30% less—than a traditional footing and foundation. Frost-protected footings have been done with success in Scandinavian countries since World War II. The footing sits more or less on top of the ground, and R-10 rigid foam extends out from the foundation a distance equal to the frost depth. Often, we add 1 ft. or more of earth on top of the insulation for added protection.

The footing is formed by two parallel (one inner and one outer) pieces of perforated PVC plastic (Form-A-Drain Footing; www.certainteed.com; 800-782-8777), which serve two purposes. The first is that water reaching the outer drain is channeled away from the footing through a rectangular PVC pipe. Second, the inner drain vents soil gas out through a roof vent.

ICFs provide continuous R-22 foundation

On a conventional house, concrete-block or poured reinforced-concrete walls sit on top of the footing. These walls are tough to insulate well, and the area at the top where the masonry meets the framing is notorious for air infiltration and the heating (or cooling) loss that accompanies it.

Insulated concrete forms (ICFs) are the solution, and building the forms is like stacking adult-size Legos. For people with ordinary carpentry skills, ICFs are relatively easy to customize with hand tools; just about any shape is possible (for more, see *FHB* #128, "Insulated Concrete Forms," pp. 74-81).

ICFs come in many styles, but this much remains the same: The connectors that tie the two outer layers together lock the forms into the concrete as well as establish the width. Once the concrete is poured, the smooth, continuous, nearly airtight R-22 forms remain.

Strong SIP shell goes up fast

With conventional 2x4 plywood construction, the house shown here would have had 200 plywood seams and more than 500 studs, joists, cripples, and headers with each one needing to be measured, cut, and nailed in place. Instead, it took four people installing 26 SIPs eight days to frame and at the same time insulate the walls, ridge, and roof panels (which required a crane).

Energy-efficient and strong, SIPs are made of two layers of oriented strand board (OSB) surrounding a core of expanded polystyrene foam that on this project yielded R-26 walls

FIVE ELEMENTS COMBINED

1 Energy efficiency begins at the foundation

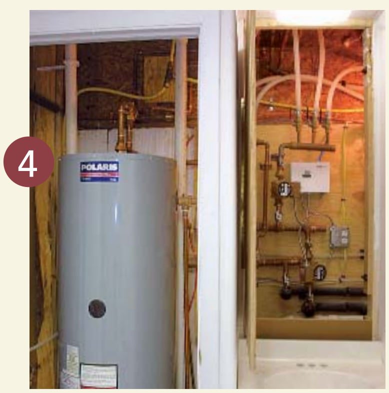
Any one of these five elements would increase the comfort and reduce the amount of energy a home uses, but the greatest benefits come from combining them. Resting on level, compacted stone, an insulated, frost-protected footing and ICF foundation work well in cold, rocky northern Vermont. Form-A-Drain footing forms drain water away from the foundation's exterior and at the same time vent soil gases and improve indoor-air quality.

2 SIPs for the walls and roof

Around since the 1940s, structural insulated panels (SIPs) are important to this system because their few seams (at panel edges) greatly reduce air infiltration. They're made of two outer layers of oriented strand board (OSB) surrounding an inner core of insulation, so the house is framed and insulated at the same time. SIPs are strong and stable. Because relatively few pieces are needed on each home, a SIP shell goes up quickly.

3 High-performance windows

Most houses lose heat through leaky windows. Even though the low-E, argon-filled, multipane windows initially cost more than ordinary windows (on this house, windows averaged $350 each), their energy savings are ongoing. Sealing the framed opening with expanding foam during installation is essential for peak performance.



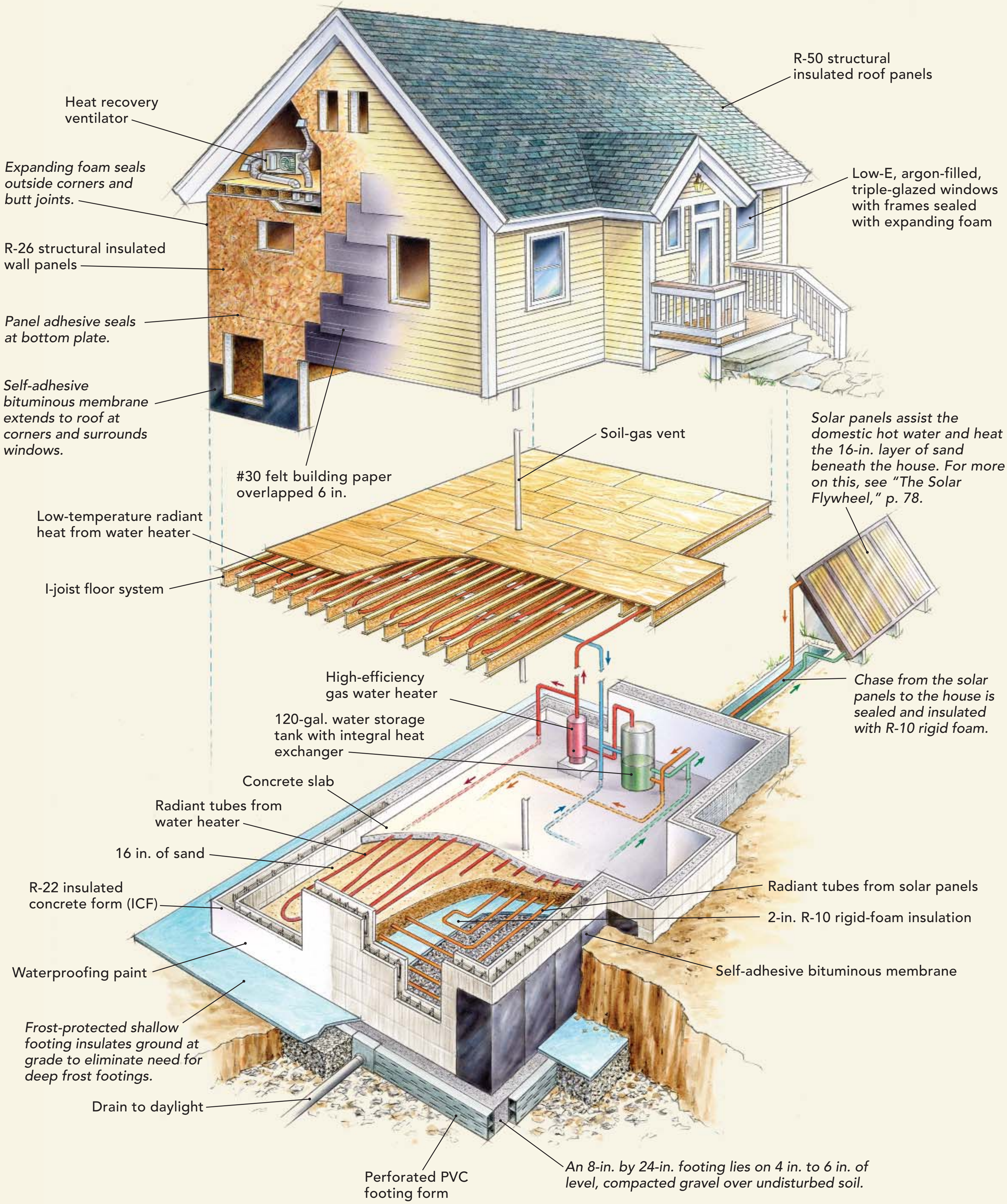
4 Low-temperature radiant heat

Because a home built using the above three elements is so well-sealed and insulated, its heat loss is low (this home's heat loss is half that of the same house built conventionally). So a second water heater provides enough hot water to run the radiant heating system. A boiler isn't necessary.

5 Balanced ventilation is essential

This house is so tightly sealed that it won't leak enough air to ventilate household moisture. A heat recovery ventilator (HRV) is needed. It removes moist air from the kitchen and bath through the hose outlet on the lower left and sends it outside through the upper right outlet. Fresh (but cooler in winter) incoming air entering from the upper left is tempered by warm outgoing air crossing its path and is sent to the bedrooms through the hose outlet on the lower right.

ARE GREATER THAN THE SUM OF THEIR PARTS



Drawings: Don Mannes

Out of 1,400 or so homes tested for energy efficiency in Vermont, this house received the highest rating ever given.

If you're building a new home in Vermont, there's a free service available that can help you to make your home more energy efficient. Provided by Efficiency Vermont, a state-mandated utility (www.efficiencyvermont.com), the service is available

to builders as well as homeowners and is funded through a 0.02% energy-efficiency charge on your electric bill. Similar programs are available in other states, but not nationwide. Go to www.energystar.gov for more information.

Efficiency Vermont offers technical assistance including plan reviews, estimates of how much energy the house will use, and recommendations for improving its energy efficiency. Additional in-the-field help comes in the form of testing to make sure that buildings and ductwork are tight. Once testing is complete, Energy Star provides a document stating how well the house performed.

If your home does well enough (gets five stars), you'll receive money in the form of rebates, and best of all, your home will use at least 30% less energy than a comparable, conventionally built house for the rest of its useful life.

and R-50 ceilings. Because each wall and roof panel is sealed on all four sides at installation—this is an important step—their already high insulation values are boosted further by very low air infiltration.

The sandwich-like construction of these foam and engineered-wood panels creates a wall that's stable and inert. A conventional stud wall, which expands and contracts, vents both rain-driven and condensed moisture. If there's too much ventilation in a stud wall's cavity, the home is hard to heat; too little ventilation, and mold forms in the wall. With SIPs, there's no cavity, so there's no place for moisture to hang out.

Because the entire weight of the building is supported by the SIP shell, it's important to protect that shell. Using latex paint, we prime the bottom of the SIPs and the mudsills, then wrap the first 3 ft. with self-adhesive bituminous membrane. We attach the same material to the corners, the first- and second-floor seams, and the window and door openings. The remainder of the exterior is shingled with #30 felt paper. This heavy felt paper ensures that rainwater that gets past the shingles or siding stays out of the house.

High-performance windows preserve interior comfort

A home without windows may be energy efficient, but living inside would be bleak, to say the least. Because windows are responsible for up to 30% of a home's energy loss, buying good ones is important. Warm (or cool) air is lost in a number of ways: leakage, conduction, radiation, and convection. What's important to know, however, is that lower U-values mean better windows.

U-values are the inverse of R-values. So an R-value of 5 equals a U-value of $\frac{1}{5}$ or 0.2. In my opinion, high-performing windows have U-values of 0.2 or less. (See "Understanding Energy-Efficient Windows," *FHB* #114,

THE SOLAR FLYWHEEL

By supplementing an efficient gas water heater, the sun provides more than 75% of this home's total heat and domestic hot water. The combination of active solar collection and passive distribution (designed by Bob Starr of Radiantec; 800-451-7593; www.radiantec.com) provides all but exceptional hot-water needs in summer. The winter sun is too weak to heat the domestic hot water, but it supplies a boost to the heating system. Coming directly from the solar panels, warm fluid (antifreeze) circulates through radiant tubing to a water-storage tank (with integral heat exchanger) as well as to 16 in. of sand beneath the basement slab. That sand is heated to 75°F.

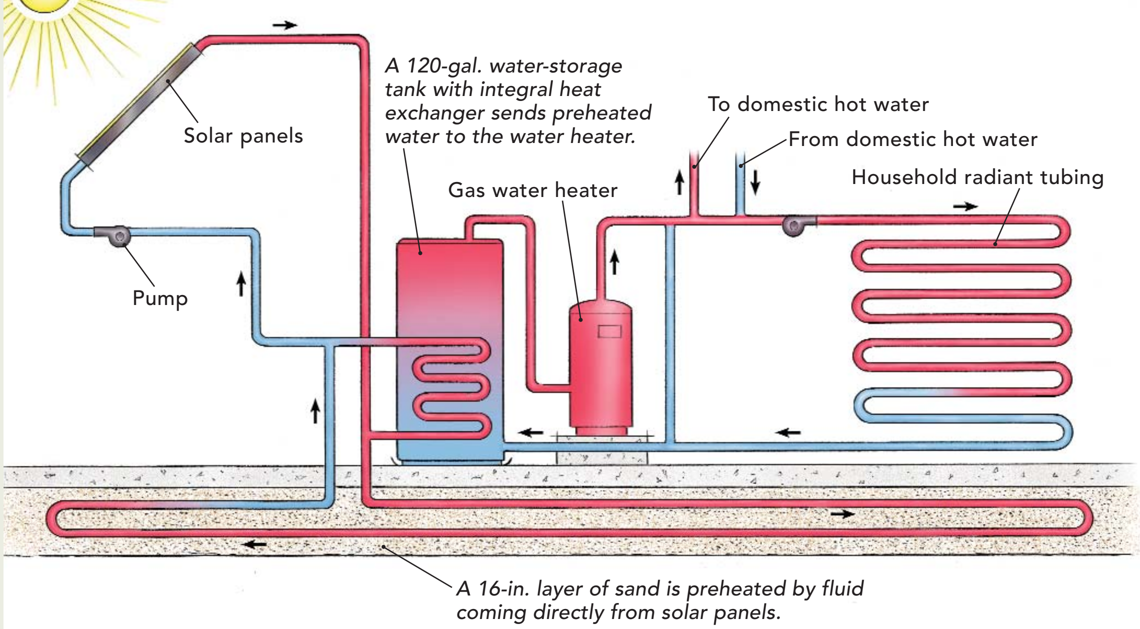


Photo this page: Courtesy of Efficiency Vermont

An energy-efficient home doesn't have to look strange. A lot of effort went into making this home inexpensive to operate. It costs about $80 per month, including heat, lighting, and appliances. Its openness, however, along with solid-maple floors and cabinets, modern appliances, and proper ventilation creates a healthful, inviting interior.

pp. 68-73.) Window features that improve energy efficiency include argon-filled double- or triple-pane glass and low-E coatings. Although these windows cost more, they are worth the money. They'll make your home more comfortable and pay you back in energy (and dollars) saved for the rest of their useful lives.

Heat the house with a water heater

If you build a house like this one, your heating system can consist of an efficient gas water heater, two small pumps, and a few rolls of plastic pipe. A boiler isn't necessary. The maximum temperature of the system will be that of a hot shower.

Radiant heat works well partly because the house is tight and well insulated. Another reason is that because hot air rises, the floors heated with radiant tubes will heat the room more evenly so that there's less stratification of warm air at the ceiling and cold air at the floor. Comfortable temperatures are 6°F to 8°F lower than with forced-air or baseboard systems.

Even though the radiant-heating needs of this house were designed to be met by an efficient gas water heater (Polaris; 423-283-8000; www.americanwaterheater.com), the entire system gets an extra boost from the sun. The solar flywheel (drawing, facing page) will furnish most of the domestic hot water and heat for the radiant system.

Balanced ventilation is the key

SIP houses are so tight they won't leak enough air to ventilate the building properly, so they have to be actively ventilated. For $1,000, you can hang a heat-recovery ventilator (HRV) in an out-of-the-way corner of your home and make the whole system work. Without it, you'll be living in a rain forest. An HRV doesn't cost much to operate because it's just a fan.

The idea is to remove air from the bathrooms and kitchens (air that's usually more moist), and to supply an equal amount of fresh air to the bedroom and living area. It's important that equal amounts of air are exchanged so that the interior and exterior air pressure are the same. Equal pressure means less air infiltration through leakage, or air being sucked in because of lower pressure inside. □

Al Rossetto builds energy-efficient houses in Waitsfield, Vt. Photos by Chris Green.

Super-efficient homes
How much do they cost?

According to Al Rossetto, the highly-efficient home featured in this article would have cost only a little less if it had been built conventionally. "The difference in cost is somewhere around 5%, so we're in the ballpark," says Rossetto. "Because the house is so efficient, however, it will cost less to operate." An important measure of the house's efficiency is the blower-door test (photo facing page), which uses an exhaust fan to check the house for air leaks. This house's air-infiltration rate was an all-time-low 0.04 air changes per hour.

So given the energy-efficiency of this $200,000 house, how long would it take to recoup your investment? With annual fuel and electricity bills of about $960, it would take about eight years to get your money back. If energy costs rise, however, which they're likely to do, you'll be repaid sooner. But there is another not-so-obvious benefit to the environment, says Rossetto. Because this house will use considerably less fuel than most, it will dump considerably less carbon dioxide into the environment.

Because we know how to build in ways that are better for the planet and everyone on it, "we have a responsibility to do so," says Rossetto. We can no longer pretend that we don't know how. What are the long-term costs if we don't?

—Chris Green, assistant editor