Energy Efficient
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.
ARE GREATER THAN THE SUM OF THEIR PARTS

- R-50 structural insulated roof panels
- Low-E, argon-filled, triple-glazed windows with frames sealed with expanding foam
- Solar panels assist the domestic hot water and heat the 16-in. layer of sand beneath the house. For more on this, see "The Solar Flywheel," p. 78.
- Soil-gas vent
- Chase from the solar panels to the house is sealed and insulated with R-10 rigid foam.
- Radiant tubes from solar panels
- 120-gal. water storage tank with integral heat exchanger
- I-joist floor system
- High-efficiency gas water heater
- #30 felt building paper overlapped 6 in.
- Thermal insulation extends to roof at corners and surrounds windows.
- Expanding foam seals outside corners and butt joints.
- Panel adhesive seals at bottom plate.
- Self-adhesive bituminous membrane
- High-temperature radiant heat from water heater
- Low-temperature radiant heat from water heater
- R-22 insulated concrete form (ICF)
- Waterproofing paint
- Perforated PVC footing form
- An 8-in. by 24-in. footing lies on 4 in. to 6 in. of level, compacted gravel over undisturbed soil.
- Frost-protected shallow footing insulates ground at grade to eliminate need for deep frost footings.
- Drain to daylight
- Concrete slab
- Radiant tubes from water heater
- 16 in. of sand
- Self-adhesive bituminous membrane
- Drain to daylight
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.

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.

A 120-gal. water-storage tank with integral heat exchanger sends preheated water to the water heater.

To domestic hot water

From domestic hot water

Household radiant tubing

A 16-in. layer of sand is preheated by fluid coming directly from solar panels.
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.

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 consider-ably 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