Low-Tech Building Techniques for Energy-Efficient Housing

Saving energy doesn't have to be complicated—or expensive.

by Marc Rosenbaum

Does it still make sense to conserve energy in these days of plummeting oil prices and vanishing solar tax credits? I think that it does—provided that you don't go overboard and spend more on energy-saving features than what is likely to be recouped in lower energy costs.

Wall Construction

The homes that I design and consult on range between 1,500 and 2,400 square feet and cost $50 to $60 a square foot. In homes such as this, the budget can raise hell with the client's (and the designer's) wish list.

In most cases, I've backed off from the double-stud-wall superinsulation levels I was using five or six years ago. In a typical custom house, the heat lost through the walls and roof represents only 20 to 25 percent of the total heat loss. I like to see R-values of at least 25 in the walls and 40 in the roof. To achieve these values, the insulation typically must be layered, which gives a much tighter construction and eliminates the thermal short circuits through the insulation that occur in the typical fiberglass-insulated stud wall.

My favorite wall system for low-budget houses is a 2x6 stud wall (24 inches on center and filled with unfaced fiberglass batts) with a "Tu-Tuff' vapor barrier and plastic, vapor-barrier, electrical-box shells, crosshatched horizontally on the outside with 2x3s on edge filled with 2½-inch beadboard.

The 2x3s are installed 25½ inches o.c., enabling the builder to start with the bottom 2x3, put a 24-inch-wide piece of beadboard on top of it, then the next 2x3, and so on, thereby proceeding rapidly with minimal cutting of the beadboard. The beadboard can be slightly compressed to create a very tight wall assembly.

In the lowest-cost houses that I design, Tyvek is installed next, and then the exterior finish (vertical shiplap pine) is put in place. (A nail base and clapboards could replace the shiplap at a substantial increase in cost.) There is no sheathing such as plywood or chipboard, so the 2x6 stud wall must be braced diagonally. I use Troy T-bracing (a galvanized-steel, let-in bracing), and I brace major interior walls as well.

This wall assembly has a true R-value of about 27 (compared to R-18 for a typical 2x6 wall). It is very tight, but at the same time it is quite permeable to vapor flow outside of the vapor barrier. I find that builders easily understand this wall system, and they like the fact that there is solid wood to nail into when installing trim.

Ceilings

Over a flat ceiling, I like to see either 15 inches of fiberglass batts laid in two layers (the second at right angles to the first) or, in trussed construction, 18 inches of blown-in fiberglass.

Sloped ceilings are a problem; I don't like the foam-behind-the-drywall detail, so typically I spec 2x12s filled with unfaced fiberglass, Tyvek over that, then 2x2s nailed right over the rafters to create a 1½-inch air space from soffit to ridge vent. Builders occasionally may moan about the Tyvek, but if they begin at the bottom and deck it as they go, it works out fine. Thoughtful detailing can ensure that the Tyvek along the roof and the walls overlaps so that it is continuous, creating a very tight house.

Foundations

If the foundation is only basement space, use one inch of extruded polystyrene foam on the exterior for a minimum-cost job, and two inches if the budget can tolerate it.

If the basement is to be used as living space, I use four inches for the first four feet down and then two inches the rest of the way to the footing.

Insulating below the basement slab generally is not cost-effective, but if the basement is for living space, I spec one inch of foam below the slab for comfort. Some people advocate placing one inch of foam under the slab at the perimeter only. This may be fine from a theoretical standpoint, but remember that filling the uninsulated center portion with an extra inch of concrete instead of sand is more expensive: at $100 a cubic yard, concrete costs 31 cents per board foot, which is more than the foam. (Perhaps we should build foundations out of styrofoam instead of concrete!)

Doors & Windows

Steel doors are the way to go both thermally and economically, although I favor them more because of their dimensional stability and magnetic weatherstripping *(tight)* than because of their insulating value. They don't need a storm door or an air-lock entry to maintain low air infiltration. Sometimes my clients shudder at the thought of a steel door from an aesthetic point of view, but when they are pressed, most admit that they never have seen one (and this usually is after they've visited my house, which has three steel doors, including the one they entered by).

The new high-performance, or low-emissivity (low-E), glass is a real blessing for energy-efficient construction. Andersen offers three types of casement windows: a double-glazed model (with an R-value of 1.9), a low-E model (R-3.3), and a low-E model with an exterior storm window (R-4.5).

If we look at a specific unit—a CW14 casement window with a rough opening of 2'4"x4'—and compare it to the cost of the double-glazed model, the low-E window has a 6½-year payback, and the low-E-plus-storm combination has a nine-year payback. The marginal payback of adding the storm window to the low-E window is 16 years. (All of this is based on the cost of oil at $1.10 a gallon burned at 90 percent efficiency in a 7,500-degree-day climate.)

I spec low-E windows even in low-budget jobs. Not only are they more comfortable to sit near because our net radiant heat loss is reduced, but they are less likely to experience condensation, given their higher R-value and consequently their higher interior-surface temperature.

A tight house built with low-E windows, steel doors and well-insulated walls and roof can expect to have a net heating load of about 1.5 Btu per square foot per degree-day. This translates into about 1.75 cords of hardwood or 175 gallons of oil per year for an 1,800-square-foot house in an 8,000-degree-day climate.

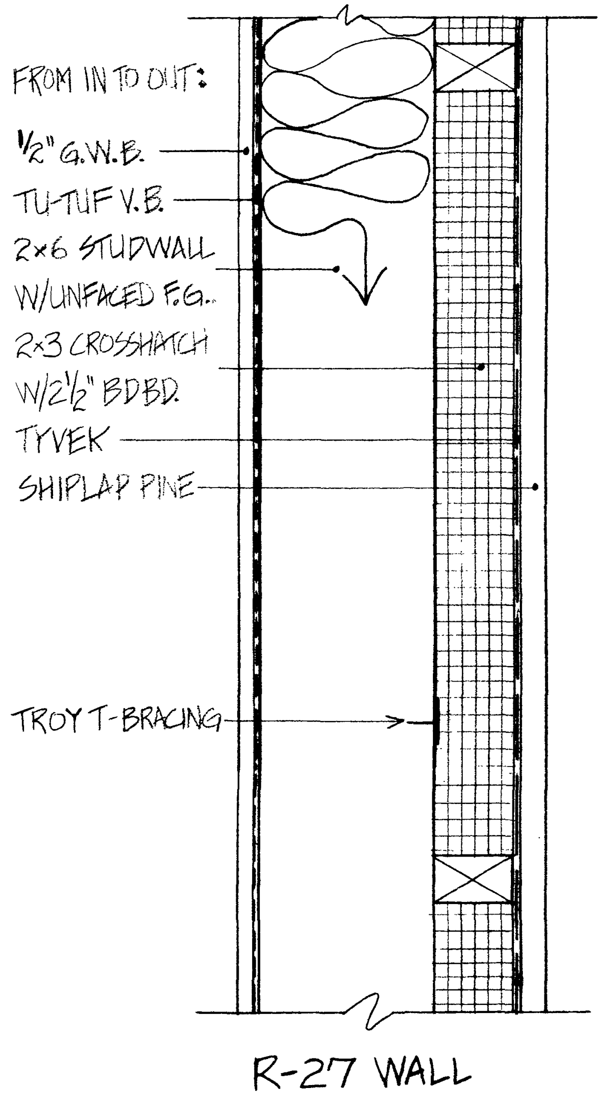
Such a house can use simple, inexpensive heating systems and remain comfortable and draft-free. As an added bonus, the house temperature will drop slowly if there is an interruption in the supply of heat. If the house is exposed to solar gain and reaches 72 degrees Fahrenheit after a typical sunny winter day, the temperature of the house still will be in the 60s the following morning if the overnight temperature drops to 10 degrees. This is a particularly nice feature for people who heat with wood, as they need not light an evening or overnight fire.

Active-solar systems, sunspaces, greenhouses, and even added mass for passive-solar heating are not cost-effective ways to reduce heating costs in climates such as that of northern New England. Most of the houses I have designed incorporate one or more of these elements, but the client and I are clear at the outset that they are amenities and not primarily energy investments.

Water Heating

If a house is built to the standards specified here, it's quite likely that domestic water heating will cost as much as (or more than) space heating. Once again, conservation is the quickest payback strategy. Turning down storage-tank thermostats, adding insulation to an under-insulated tank, using low-flow shower heads, and using cold or warm water instead of hot in the washer will produce savings from virtually no investment.

If a woodstove is to be used as the primary source of heat, it should be set up to heat domestic water, too. The Vermont Castings stoves, which are popular with



drawing by Marc Rosenbaum

my clients, have an excellent stainless-steel water-heater option and come with a superb design and installation manual. The total cost of a pumped system is $500 to $600, or much less if it is a passive thermosiphon system.

I've used thermosiphon systems in several houses, including two of my own, and found that they work well if properly designed and installed. Make sure that the hot side of the loop goes upward immediately as it leaves the stove (or that the cold-side piping takes a quick dip downward) so that the circulation will occur in the direction you want. Storage tanks should have a capacity of at least 60 gallons, and relief valves *must* be installed properly and piped safely to drains.

When installing thermosiphon systems, make sure that the hot side of the piping loop goes up immediately as it leaves the stove (or that the cold-side piping takes a quick turn downward) so that the circulation will occur in the direction you want.

Vermont Castings has a good detail for a small, fintube baseboard loop used to dump excess heat in the event of consistently high stove output and low hot-water consumption. I used something like this in my new house to dump waste heat into the greenhouse at those times when it's very glad to get it.

I still think that solar water heating can make sense if it is properly integrated into the house design at the initial stages. I design thermosiphon systems using Thermafin absorbers (large-diameter risers, selective surfaces and custom sizes are available). If you place absorbers behind sloped glass in heated or buffered spaces such as greenhouses, sunspaces or large, fixed skylights, no antifreeze or heat exchangers are required: the building itself supplies the freeze protection. (As far as I know, this was first proposed by Steve Baer of Zomeworks.)

In the house I just built for myself, hot water is supplied by 50 square feet of Thermafin absorbers in the greenhouse and a Vermont Castings woodstove with an integral water heater. Both are direct thermosiphon systems. Storage is provided by two 35-gallon, stainless-steel tanks insulated with three inches of urethane foam. One sits atop the other, and they are connected by a short length of ¾-inch copper pipe. A 5.5-kilowatt electrical element for backup power sits near the bottom of the upper tank, but in the five months that our two-person household (with occasional guests) has had this system, we've had to turn it on only about 10 times.

Tall tanks are particularly desirable in thermosiphon systems. Due to the low water-flow rates, strong thermal stratification can result, which allows more useful heat to be extracted from the tank (especially after partially sunny days).

I find this system to be a substantial improvement over the batch heater in my first home, because hot water is available far longer after a sunny day. Total system costs were about $1,500 installed, and I figure that 95 percent of our water will be heated by solar and wood on an annual basis. A family of four or five would have a lower solar/wood percentage with this system due to their higher consumption, but the payback would be quicker because more hot water would be produced by the system.

Ventilation

I've specced air-to-air heat exchangers in virtually every house I've, designed; installed costs are in the range of $1,600 to $2,000. But heat recovery is an *option* based on economic considerations—ventilation can be provided by other means that are less expensive (and no less healthy).

What's important is not the type of ventilation—it's that some form of ventilation be provided. In lower-budget houses, I am starting to experiment with exhaust-only ventilation systems, as the Swedes are doing.

My house, for example, has a six-inch axial exhaust fan in the basement, and there is an exhaust register located in each of the two bathrooms and in the kitchen. All three spaces are ventilated simultaneously by the central exhaust fan. The register in the kitchen is placed high in the wall, but, to avoid grease contamination, not over the range.

The exhaust fan is controlled either by a 30-minute timer switch in each bathroom or by a manually operated, variable-speed, on-off switch. The timed controls in the bathrooms can be overridden by the manual switch, allowing me to select continuous or timed ventilation.

Fresh, untempered air is supplied at two locations: from an inlet in the hearth beneath the woodstove, and from a window opened a crack—how's that for low tech?—at the top of the upper stairwell. In both locations, the cold, incoming air mixes with air that is hotter than average house air, and at a location where a draft will not be felt by occupants. (The hearth inlet is 1½ inches wide. The next time I'll probably make it three inches wide, because there are times when the chimney draft is so weak that the fan reverses flow and pulls smoke into the room—a good argument for smoke detectors!) A simple forced-air system circulates hot air from either the greenhouse or from high above the woodstove, which in turn spreads the fresh, incoming air throughout the house.

The heat exchangers I specify cost from $1,600 to $2,000. But ventilation can be provided by other means that are less expensive and no less healthy.

In a house *without* forced-air circulation, I would opt for more air inlets. In addition to the potential problem of reversing draft in the woodstove chimney (and I should add that fossil-fuel heating systems in tight houses should be of the sealed-combustion type), there is the disadvantage of exhaust-only ventilation, because the house runs at a slight negative pressure. This is great from a vapor/condensation point of view, but it also has a tendency to raise radon levels—and I strongly recommend that all new houses be tested for radon. Adequately sized air inlets will reduce the negative pressure to nearly zero.

If I were to install an air inlet in each room, I would estimate that a two-inch-diameter inlet would be right for a bedroom, while a three-inch-diameter inlet would be better for a kitchen, living room, dining room or family room. They should be placed high on the wall and have back-draft dampers and a way of closing them off entirely. (You'd think that the Swedes already would have developed a product such as this, but I haven't seen one.)

Jenn-Air has a nice, six-inch wall cap for the exhaust air that has a simple and effective back-draft damper. If you duct untempered inlet air inside the house (to the hearth, for example), be sure to insulate the ductwork and wrap it with a vapor barrier to prevent condensation.

Windows can be used as air inlets, of course, but their placement often coincides with locations likely to cause uncomfortable drafts. Windows serving as air inlets need only be opened slightly, as the goal is merely a three- to eight-square-inch inlet per opening.

By using one central fan to collect the stale air, capital costs can be reduced and provisions can be made for heat recovery at a later date if it becomes economically feasible.

One final advantage of the exhaust-only system is its low power consumption. At peak operation, my fan uses only 32 watts of electricity, while some air-to-air heat exchangers use 150 to 200 watts—and it doesn't make sense to save three-quarters of a cord of wood per year if it costs $80 to do it. *Efficient* air-to-air heat exchangers (such as the "Air Changer," which uses only 64 watts) have a lot to recommend them.

Water Usage

Water conservation rarely is considered an area for conservation, but it should be. In a typical household, toilets alone account for about 40 percent of all water used.

A one-gallon toilet can save 20,000 gallons of water and 80 kilowatts of pump energy a year, not to mention wear and tear on the well, pump and leach field.

The new, code-approved "Ultra One" toilet by Eljer uses only one gallon per flush and looks like any other standard American model. It lists locally for $160 (about $75 more than Brand X), but it saves 2½ gallons per use over the typical water-saver types (which use 3½ gallons per flush)—or about 20,000 gallons a year. This translates into a savings of 80 to 100 kilowatts a year in pump energy for a house with a 200-foot-deep well. Looking at pump energy alone, then, the Ultra One can have a 10-year payback.

Other benefits include lower water charges for houses on municipal systems, less water usage in homes with marginal wells, less wear and tear on the pump, less

Product Caveats & Kudos

I suppose I'm the only one who finds that manufacturers' literature and salespeople occasionally are overly optimistic about their products' attributes. Here, then, are some personal, off-the-cuff reactions to products I used on my own new house:

Dow Foundation Coating: This stuff is supposed to produce a 1/8 "-thick, stucco-like coating for Dow Styrofoam where it is exposed to the elements. I tried to follow directions scrupulously and found the "one-step, brush-on" coating impossible to use. I finally capitulated and watered it down (despite the manufacturer's admonitions) at which point it *was* brushable—but it still required two coats to achieve an adequate thickness. I'm sticking to "Styro-Stucco" or "Insulgard" in the future.

Fibermesh: This product, a component of the relatively new ultra-thin slabs, was described in derail by Harris Hyman in the July 1985 issue, I used it in a floating garage slab. There are no cracks in the slab, and I think that Fibermesh has an advantage over wire mesh structurally. Be forewarned, however, that some of the fibers end up at the surface of the finished slab, giving it a somewhat "fuzzy" appearance.

Tremco Acoustical Sealant: Black death! If there was a milligram of the stuff somewhere on site, my co-worker and builder extraordinaire, Jay Waldner, would get it on himself or his tools. It's great for sticking poly to anything, but I hope that 3M's new contractor's tape will supersede it in this application, I used a huge bead of it instead of a fiberglass strip as a sill sealer, and it seems to be working well m this application.

Thermafin Solar Absorbers: These all-copper fintubes are 4½ inches wide and can be manifolded together to create solar absorbers of any size. They are available with a black chrome surface to enhance solar collection, and the large-diameter riser tubes are perfect for thermosiphon systems.

Polyurethane Foam: I injected this stuff into my house after it was constructed. It's very expensive, but it produces an extremely tight house with little care or expertise on the part of the builder. If you inject it as I did, be very careful you must have a way to verify that all the cavities are filled, or you can end up with substantial voids. Were I to use this material again, I would spray it in at the bare-shell stage instead of injecting it; this also would avoid the risk of bowing the sheetrock or plywood sheathing due to the expansion and contraction of the foam.

Aluminum Glazing Systems: My greenhouse glass is battened by a system of aluminum battens with synthetic-rubber (EPDM) inserts, attached with stainless-steel screws and washers with gaskets. After trying it a number of ways, I feel that this is the best way to go: no leaks, no repainting, no warping.

Flat Trusses with Steel Webs: Some portions of my 2x 12 flooring are framed with flat trusses with galvanized steel webs. ("Spacejoist" *is* the trade name.) The subfloor is ¾-inch tongue-and-groove fir plywood that is nailed and glued, and all spans are relatively short (11'8" is the maximum). The trussed section of the floor squeaks, while the solid-wood-joist section does not. Has anyone else noticed this phenomenon? ■

—Marc Rosenbaum

condensation on the toilet tank, and a greater life span for the septic leach field (less water flow means more time in the septic tank, which allows more solids to settle before the effluent runs out to the leach field).

Electrical Usage

Many appliances (refrigerators, freezers, air conditioners and water heaters, to name a few) are available in energy-saver models that cost a little more but virtually always provide a swift payback. Two similar appliances can consume vastly different amounts of energy. Even the power required to run various personal computers varied threefold the last time I investigated them.

Lighting offers a major, cost-effective opportunity to cut electrical usage. The recent advances in fluorescent lighting have brought fluorescents into the residential mainstream. In my house, I use the compact twin-tube PL-series lamps in fixtures in the bathrooms, pantry, hallways and stairways.

The Seagull 4911-15 fixture mounts two PL-13 lamps and is ideal for bathrooms, providing light equal to two 60-watt incandescent lamps. The Seagull 7908-15 is an inexpensive, attractive fixture with a six-inch white glass globe and a PL-7 lamp, providing the light level of a 40-watt incandescent.

Even people who hate fluorescent lighting will not notice that PL lights are fluorescent. There is no buzz or flicker, and the color match is comparable to that of incandescents. PL lamps cost about $7.50 each, but they will pay back with both lower electricity costs and average lifetimes of 10,000 hours.

Another version, the SL-18, is a self-ballasted fluorescent lamp that, unlike a PL lamp, screws into a standard fixture without any adapter. It replaces a 75-watt incandescent lamp-and, in a table lamp or a fixture where it cannot be seen directly, is indistinguishable from the incandescent lamp it replaces. It costs about $20, but the electricity it saves over its 7,500-hour lifetime costs $34 at eight cents per kilowatt-hour. So even with its substantially higher initial cost, the user should realize about $21 over its lifetime.

Tried-&-True Savings

My own 1,700-square-foot home incorporates most of these measures, even down to the water-saving toilet. Our annual energy budget is about one cord of wood, 1,500 to 2,000 kilowatts of electricity, and 25 gallons of propane (for cooking), for a total annual cost of about $265.

The house is comfortable, draft-free and easy to operate. As one advantage of the house's integrated design, the HVAC/DHW system is quite simple and low-tech; three small fans are the only moving parts. The house was not designed principally as an "energy machine," however, so it has some non-energy-conserving features, such as high ceilings and skylights that don't face south.

I still have not devised what one skeptical friend keeps bugging me for, however: the solar-powered mortgage payment. ■

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