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New Hampshire House Pushes the Energy Performance Envelope

THIS HOUSE MAY NOT WIN ANY architectural design awards—its boxy, utilitarian design echoes the Yankee values personified by its designer—but the "Hanover House" is indeed ground-breaking. Designed for a middle-aged couple without children by mechanical engineer Marc Rosenbaum, P.E., of Meriden, New Hampshire, this residence has about the lowest energy consumption of any house in the United States. Fortunately for us, very careful energy consumption records for the all-electric home have been kept since it was occupied in 1994.

We'll get to those performance numbers. First some specifics on the house:

• **Configuration.** It is a wood-framed, two-story, 1,887-square-foot (175 m^2) house (exclusive of basement) with attached garage in Hanover, New Hampshire. Three-quarters of the window area is on the south side for passive solar gain.

• **Superinsulation.** Double 2x4 walls are insulated with 11½" (290 mm) of dense-pack cellulose providing R-40 (RSI-7), the ceiling is insulated with R-60 (RSI-10.6) blown cellulose, band joists are insulated to R-40 (RSI-7) with rigid foam and fiberglass, and basement walls are insulated on the interior with R-11 (RSI-1.9) fiberglass.

• **High-performance windows and doors.** Center-of-glass R-values for insulated-fiberglass-frame windows range from R-6.7 to R-9 (RSI-1.2 to RSI-1.6). Windows were site-glazed with the top-performing Southwall glazing to save money and because the manufactured windows Rosenbaum wanted were not available.

• **Airtight construction.** Air sealing was a high priority. Foam-in-place polyurethane was used at all penetrations, and Tremco sealant was used at framing connections. Neoprene boots sealed plumbing stacks, and a layer of polyethylene served as both air barrier and vapor retarder on walls and ceilings. All this resulted in a measured airtightness of 137 cubic feet per minute (cfm) at 50 pascals, or 0.37 air changes per hour at 50 pascals. At atmospheric pressure and without mechanical ventilation, this translates to just 0.03 air changes per hour, or less than 10 cfm of air leakage!

• **Mechanical ventilation.** A central heat-

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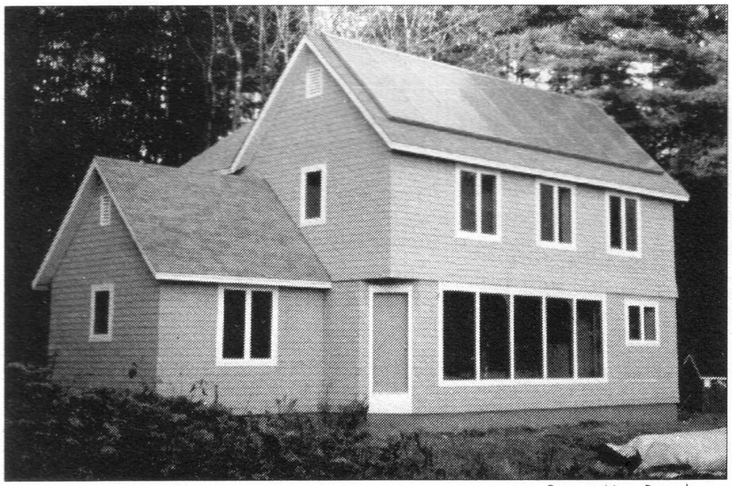

Source: Marc Rosenbaum

While many of the most advanced, low-energy solar homes look as if they just landed from outer space, Rosenbaum's Hanover House fits very comfortably into its northern New England surroundings.

In This Issue:

Quote of the month:

"By putting in the waterless urinals, the Bureau of Reclamation was able to avoid a planned $600,000 expansion of its sewage treatment system."

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H-axis market. Also, Frigidaire's Gallery is now being sold by Sears Contract Sales. For more on H-axis washers, see *EBN* Vol. 6, No. 4.

Also in Dallas we learned about two other **open-cell polyurethane** insulation products. North Carolina Foam Industries (NCFI) offers SEALITE™, a 0.5 lb/ft^3 (8 kg/m^3) density foam that insulates to R-3.6 per inch (RSI-0.63). And Polyfoam Products, Inc. in Spring, Texas, has just introduced Insul-Seal™ FR1070, a higher-density, 0.9 lb/ft^3 (14.4 kg/m^3) foam that insulates to R-3.8/inch (RSI-0.67). Like the open-cell polyurethanes from Icynene and Demilec that have been reviewed in *EBN* (see Vol. 4, No. 5, page 8, and Vol. 6, No. 5, page 4, respectively), these two are blown with water instead of HCFCs, so do not deplete ozone. For information on SEALITE, call 910/789-9161; and for Insul-Seal, call 281/350-8888.

Soy-based adhesives are here. Adhesives made from soybean oil have been approved by the Western Wood Products Association for use in finger-jointing operations at the Willamina Lumber Company in Willamina, Oregon. In the Willamina finger-jointing process, hydrolyzed soy protein is applied to one side of the joint and conventional phenol resorcinol formaldehyde (PRF) resin to the other. According to the United Soybean Board, which funded development of the adhesive, when the fingers are pressed together, a chemical reaction occurs bonding the joint very rapidly. The adhesive works with wet wood (even in excess of 150% moisture content), and the cured joint is generally stronger than the wood. The soy adhesive is made by Hopton Technologies, Inc. (HTI) in Portland, Oregon. For information, contact HTI at 503/977-2379.

As anyone who has tried to procure it recently knows, **Greenwood Cotton insulation has been unavailable** for several months. Users may have been further frustrated by the fact that the company's widely publicized toll-free number was changed due to a move. Product Manager Kirk Villar reports that Greenwood found the insulation more costly to produce than they had anticipated, so they are reevaluating the potential market. Meanwhile, they are pursuing other markets for their recycled cotton batting, including automotive panels and mattresses. One such deal currently in the works has the potential to consume the company's entire output for the time being. According to Villar, if they do decide to continue selling the recycled cotton insulation, it will be as a specialty item rather than as a commodity competing directly with fiberglass batts. "But other fiberglass alternatives are also expensive," Villar notes, adding: "I still believe there's going to be a market for the product but can't say at what price point." Villar can be reached at 770/998-6888, or 800/847-5929 x2151.

New Hampshire House *(continued from page 1)*

recovery ventilator supplies fresh air into the return ductwork.

• **Active solar space heating.** The house has a drain-back active solar system with 360 square feet (33 m^2) of site-built collector and a 1,200-gallon (4,500 l) storage tank that uses a 52-gallon storage-type electric water heater for back-up heat and domestic hot water (see schematic). Heat from the large tank is delivered to the house using a water-to-air heat exchanger in the forced-warm-air delivery system. When there isn't enough heat in the large storage tank, the electric water heater (with 5 kW element) takes over. The electric water heater has been separately metered, so we have data on the thermal energy component of the home's total energy consumption.

• **Lighting and appliance efficiency.** Electric loads in the house were minimized with compact fluorescent lighting, halogen lighting on dimmers, and careful attention to appliance selection—though super-efficient products were not used. Energy Star computer equipment is used in the home office.

The deep window wells are splayed for better light distribution into the house. This casement window has an insulated fiberglass frame from Owens Corning and super-high-performance Heat Mirror® glazing from Southwall. Source: Marc Rosenbaum

• **Graywater separation.** Though separate graywater treatment is not permitted in Hanover at present, Rosenbaum decided that it made sense to plumb the house so that graywater (wastewater from showers, bathroom sink, and washing machine) could be collected separately if regulations change.

• **Resource efficient.** Very little lumber from large-diameter trees was used. Most framing members larger than 2x4s were trusses, I-joists, or Parallams®. Oriented-strand board was used for sheathing and subfloors.

- **Built for durability.** Through careful selection of materials and attention to moisture and air flow in the home, the home should be very durable.

- **Safe indoor environment.** Low- or zero-formaldehyde wood composites were used. Instead of carpeting or vinyl, floors were hardwood, tile, or natural linoleum. Counters were made from granite rather than laminate. Only water-based finishes were used. There is no combustion of wood or fossil fuels on the site. Fresh air is provided continuously. And a passive radon stack was installed—an in-line fan can be added should high radon levels ever be found.

Cost

The Hanover House was built for a total project cost of $200,000, or $111/ft^2 ($1,195/m^2), based on 1,800 square feet (167 m^2) of finished space. This paid for high-end finishing details, such as custom cherry cabinets and stairs, hardwood and tile floors, etc. On a per-area basis, this worked out to about $90/ft^2 ($969/m^2) if the porch, garage, and some site work were excluded. Because the owner served as the general contractor, costs were kept down. Jay Waldner of Weewaw Construction in Plainfield, New Hampshire was hired as the builder. Costs were typical of custom homes in the area in the early 1990s, according to Rosenbaum.

Performance

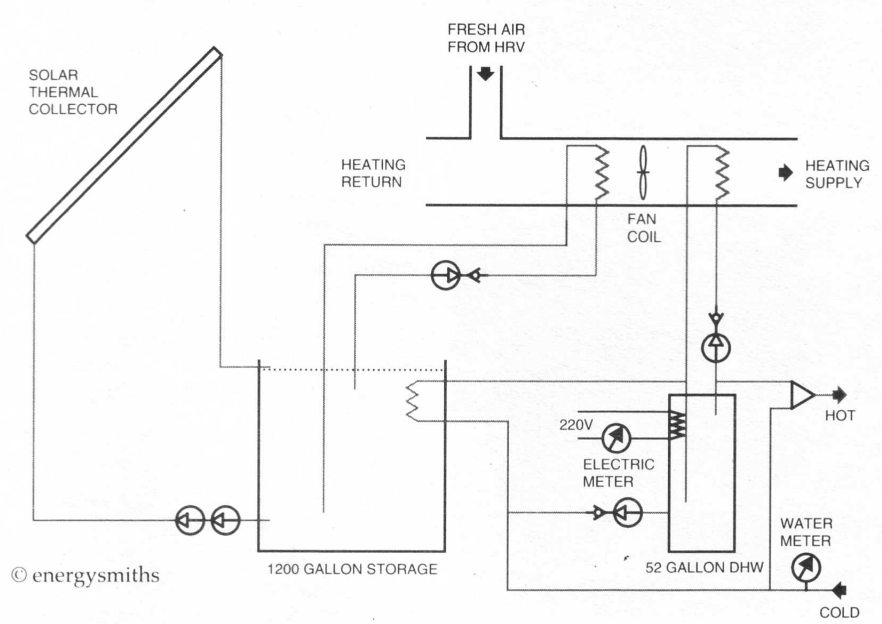
Where the Hanover House really shines is in its energy performance. During the first three years of operation, total annual energy consumption for the house ranged from 4,250 to 5,560 kWh, and the total annual thermal energy consumption—back-up heating and water heating—ranged from 1,200 to 2,240 kWh (see table above). Rosenbaum believes that the high fluctuation in thermal energy consumption—electrical consumption the second year was double what it was the first—is due almost entirely to variability in the weather. "We're within the statistical variability of the weather," he told *EBN*. After a three- to four-day cold, cloudy period the thermal storage is used up, and each day can add

Measured annual energy performance

	1994-95 Heating Season	1995-96 Heating Season	1996-97 Heating Season
Heating degree-days (°F based on 65°)	7,029	7,826	7,344
Heating degree-days (°C based on 18.3°)	3,905	4,348	4,080
Electricity use—back-up heat & DHW (kWh)	1,197	2,243	2,178
Total electric consumption (kWh)	4,255	5,541	5,556

Note: Degree-day information for September through April heating season.

HANOVER HOUSE - SOLAR/MECHANICAL SCHEMATIC



While sophisticated, the active solar system on the Hanover House has been performing very well since the house was completed in October 1994.

Source: Marc Rosenbaum

The Hanover House offers more than outstanding energy performance. A custom cherry staircase and tile flooring, shown above, are among its architectural details.

Jim Serdy, who helped design and build the active solar heating system, at work on the rooftop collectors.
Source: Marc Rosenbaum

as much as 100 kWh to the annual energy consumption. (For weekly energy consumption, degree-day, and solar radiation data, go to the *EBN* website (www.ebuild.com).)

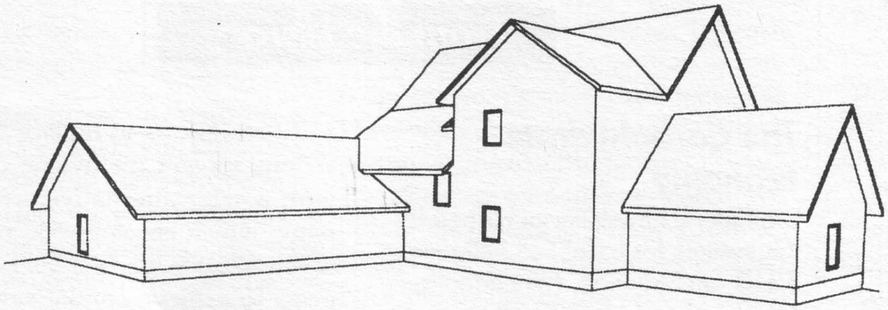
On a per-floor-area basis, a good, relatively energy-efficient house typically consumes about 5 Btu/ft²DD-F (28 Wh/m²DD-C) for heating. (Degree-days are computed here with 65°F and 18.3°C as a basis.) A 2,000-square-foot (186 m²) house in northern New England with this level of energy efficiency would cost about $700 to heat if natural gas, $650 with oil, $2,700 with electric resistance heat, and $900 with a geothermal heat pump.* A *really* energy-efficient house may use just 1.0 Btu/ft²DD-F (5.7 Wh/m²DD-C) for heating. By comparison, the Hanover House uses 1.1 Btu/ft²DD-F (6.2 Wh/m²DD-C) for *all* energy, and 0.40 Btu/ft²DD-F (2.3 Wh/m²DD-C) for combined heating and water heating. Although heating and water heating are not broken out (because both are done with the 5 kW water heater element), Rosenbaum estimates that heating accounts for no more than 75% of this, or 0.25 to 0.30 Btu/ft²DD-F (1.4 to 1.7 Wh/m²DD-C). During the three years for which we have energy consumption data, the space heating cost thus ranged from $100 to $190 per year—with electric resistance heat!

Room for Improvement?

While the Hanover House is highly impressive from an energy standpoint, Rosenbaum identified a number of opportunities for even greater savings. With more efficient motors in the solar system pumps and in the fan coil blower, he believes 250–300 kWh could be saved annually. More efficient lighting and a super-efficient refrigerator—especially one using outdoor "coolth"—might save another 300–400 kWh. Replacing the desktop computer with a laptop in the home office could save another 150-200 kWh. Graywater heat recovery would reduce back-up electricity use by about 200–300 kWh, but only during the three coldest months, according to Rosenbaum. Finally, he figures that standby electricity consumption ("phantom loads") of the TV, VCR, stereo, microwave oven, answering machine, and so forth comes to about 30 watts on a continual basis. If these were on separate switches, more than 250 kWh could be saved annually. In total, these changes could reduce energy use by as much as 25%, or 1,150–1,450 kWh, though some of these savings would not be additive. Also, less waste heat from more efficient equipment would increase heating loads somewhat, but this effect

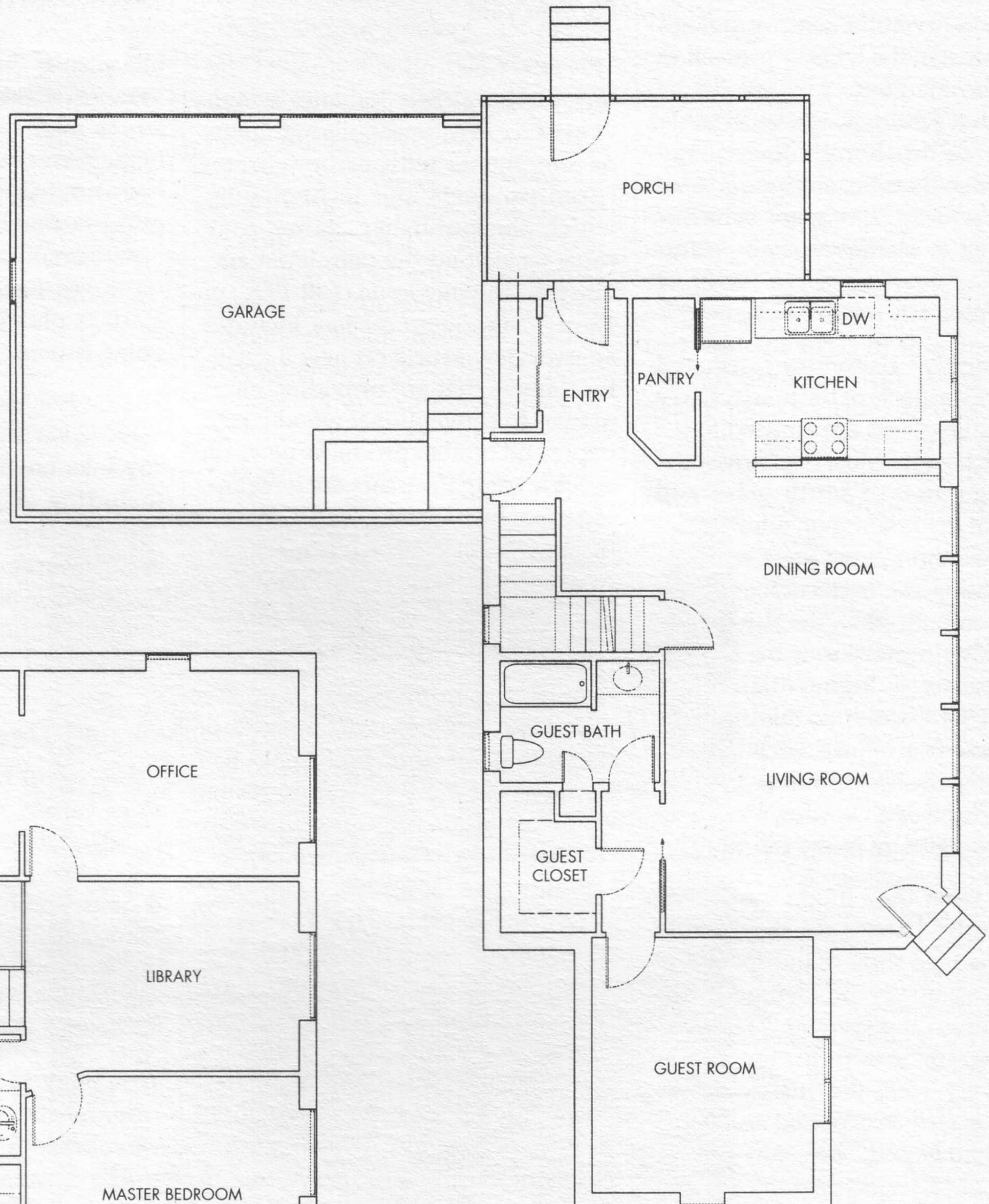
Source: Marc Rosenbaum
Walls were insulated with 11½" (290 mm) of dense-pack cellulose, and a carefully installed layer of polyethylene provides both air barrier and vapor retarder.

*These figures assume 85% efficient gas heat at $0.75/therm; 80% efficient oil heat at $0.90/gallon; 11.5¢/kWh; and a heat pump with a COP of 3.0.

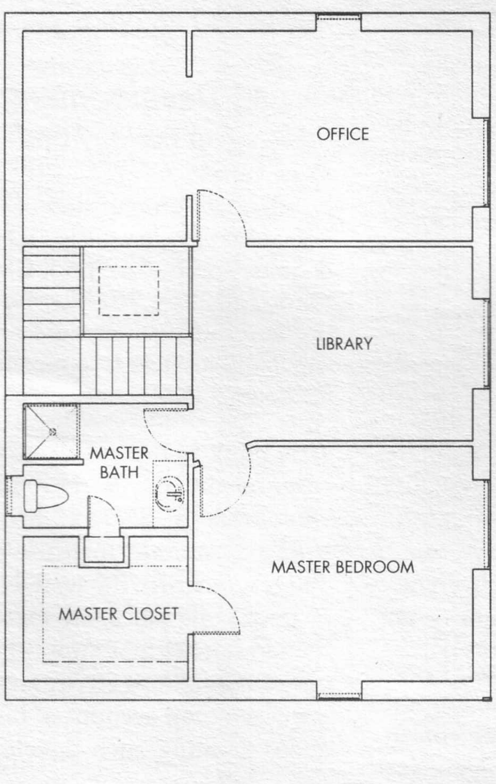


NORTHWEST VIEW

MAIN LEVEL



UPPER LEVEL



The floor plan of the Hanover House is simple and practical.

would be small because the effective heating season is only about three months.

When asked how they like the house, the owners, who wished to be identified only as Larry and Toni, told *EBN* that they were very satisfied. Larry noted very uniform temperatures throughout the house (even next to the windows), lots of daylight during the day, little maintenance required with mechanical equipment, and "overall a nice psychological comfort in the level of protection from the elements." It should be noted that while design is certainly the key to this home's low energy use, the owners' commitment may also be a factor. Occupant behavior is known to change energy performance—sometimes by a factor of two or more!

Their "nerdy" visitors are fascinated by energy aspects of the house, Larry said, while others are amused to see foot-thick walls. Most people assume the large area of south glass will overheat in the summer, which is not the case—though we were told that overheating can occur in late March or September (when the sun is relatively low in the sky) if the outside temperature is higher than about 70°F (21°C). To address this problem, Larry and Toni open a few windows. They keep the house cool in the summer by opening windows at night and closing them in the morning.

As for what they might have done differently, Larry said they would have changed some of the details but made essentially no change in the basic design and systems. "The overall program was right, the spaces work very well, the energy design works as well as expected and better than I had hoped," he said.