Energy Design Update
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Industry News: *Solar in the City*

Solar in the City

For custom homes, three parties usually collaborate on the design and specifications: the client, the architect, and the builder. When Pat Hanson of Burlington, Vermont, was ready to build her house, she was fortunate to connect with architect William Maclay and builder Chuck Reiss. All three share an interest in energy efficiency and green construction, and the convergence of their common interests produced an elegant result. Hanson's three-bedroom, 2,018-square-foot house, built in 2000 on an infill lot in a residential neighborhood of Burlington, Vermont, includes both active and passive solar features (see Figure 1).

Figure 1 - The Hanson House includes two roof-mounted solar thermal panel and 12 photovolatic modules with a peak rating of 1,440 watts.

A Client Committed to Solar

Hanson wanted Maclay to design an energy-efficient house equipped with solar hot water and photovoltaic (PV) panels. "I just believe strongly that it's important to do what we can to reduce our fossil fuel use," said Hanson. "Even if photovoltaic panels aren't quite cost effective yet, the more people are willing to install them, the more likely they will be cost effective in the future."

Maclay's design is rooted in standard passive solar principles, with careful attention to orientation and window placement. Maclay and Reiss both have extensive experience building energy-efficient homes, and Hanson readily accepted most of their recommendations. She did, however, resist their advice to use pultruded fiberglass casement windows from Accurate Dorwin. "In other houses I've lived in, I've had some bad experiences with the wind blowing against open casement windows," said Hanson. "I wanted to have the double-hungs, so I ended up going with Marvin windows."

Framing and Air Sealing

Many of Maclay's buildings are framed with double 2x4 walls with a total thickness of 11 1/2 inches. However, after Maclay consulted with Reiss, they settled on 2x6 walls with interior horizontal strapping for the Hanson house (see Figure 2). "There is a significant expense to go to double- wall framing," explains Reiss. "The cost is lower for interior strapping, which works well to cut thermal bridging through the studs. For strapping we use up all the 2x4s that aren't straight enough for plates or studs. It goes up pretty quick, compared to building the wall twice."

Figure 2 - Horizontal 2x4 strapping was used to reduce thermal bridging through the 2x6 studs.
[Photo credit: Pat Hanson]

Reiss's close attention to air sealing paid off at the Hansen house. The blower-door results showed 480 cfm @ 50 pascals (Pa), equivalent to about 0.10 cfm per square foot of building envelope surface area @ 50 Pa -less than half the EEBA standard of 0.25. "We're real careful with any penetration," says Reiss. "We foam everything in -pipes, wires, and windows. We're also careful with the poly on the walls. We don't go to the level of taping the seams, but we overlap each seam by a foot." Reiss uses ordinary electrical boxes. "Since we have 5 1/2 inches of cellulose behind all of our electrical boxes, hardly any air gets though," he says.

Insulation

The Hanson house has a slab foundation, since site conditions did not permit a full basement. "I usually put 2 inches of rigid foam under a slab," says Reiss. "But on this house, the architect called for 4 inches." The vertical edge of the slab perimeter is insulated with two inches of rigid foam.

The 7-inch thick wall cavities were insulated with damp- spray cellulose. Reiss usually allows about a week for the cellulose to dry before putting up the wall poly. "The cellulose installers complained a lot about the horizontal strapping, since it's hard for them to run their rollers over it," said Reiss. On his next house, Reiss modified the wall details to accommodate his cellulose contractor. He installed 2 inch wide by 1 1/2 inch thick strips of rigid foam insulation on top of each stud, between the courses of horizontal strapping. This created a coplanar checkerboard-like grid, making it easier for the insulators to trim the cellulose flush (see Figure 3). Reiss was pleased that he was able to cut almost all of these rigid foam strips from scraps left over from insulating the foundation.

Although the attic of the Hanson house is unfinished, the rafters are insulated, creating a partially conditioned space that is available for future remodeling into living space. The 2x12 rafters were packed solid with dry cellulose, installed behind cross-linked polyethylene held in place by lx3 strapping. Although a ridge vent was installed, Reiss did not install any vent channels in the rafter bays.

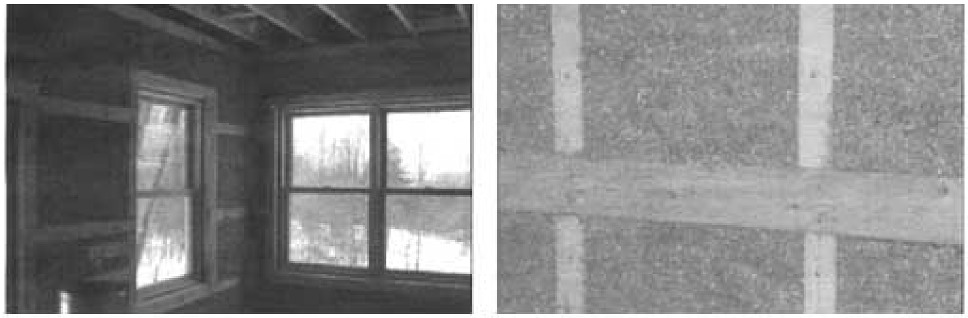

Figure 3 - The cellulose installers complained that the horizontal strapping interfered with the use of their rollers, making it hard to trim the cullulose flush (left). On his next house, builder Chuck Reiss packed out the studs with strips of rigid foam insulation, providing a surface to guide the trimming of the cellulose flush with the strapping. [Photo credit, both photos: Vermont Energy Star Homes]

Conventional framing usually dictates that rafters receive a bird's-mouth cut for installation on the top plate of the wall. In order to provide more room for insulation at the eaves, energy-conscious framers usually install the rafters above the attic rim joist, bearing on a 2x6 plate. Maclay provided a detail that goes one better: he specified the installation of four stacked 2x6 flat plates above the attic sub floor (see Figure 4 **Note:** opens in a new window, large file size). This raises the heel of the rafter an additional six inches. "We prefer to install R-50 insulation at the eaves, where ice damming can be a problem," says Maclay. "If possible, we try to get more than that."

Heating andVentilation

Hanson chose to install a hydronic radiant floor heating system. " A radiant floor heating system costs thousands of dollars extra, just to deliver a few hundred dollars of heat," says Maclay. "It clearly is not an efficiency measure, it's a comfort measure." But after living with hydronic heat for a year, Hanson has second thoughts. "If I were to do it over, I don't think I would go for the radiant heat," says Hanson. "It turns out that I don't like warm feet, although I know that most people do. And the radiant heat complicated the choice of flooring material."

Although Hanson, Maclay, and Reiss would have all liked to include a heat-recovery ventilator (HRV), budget constraints forced Hanson to settle for an exhaust-only ventilation system. The system consists of two 17-watt Panasonic bath exhaust fans controlled by programmable timers, and several passive inlet vents. "I try to encourage all customers to go to an HRV but it's a cost thing," says Reiss. "For smaller houses, an exhaust system with the fans on timers is barely functional."

Photovoltaics and SolarThermal

During the summer months, two 4 ft by 8 ft roof-mounted solar thermal panels supply most of the home's domestic hot water needs. The solar panels are backed up by an indirect water heater operating off of the gas-fired boiler. The antifreeze solution in the panels is circulated by a DC pump powered by a dedicated PV panel. The solar-heated water is stored in a 70-gallon tank which acts as a pre-heater for the water flowing into the indirect water heater. Since the Burnham boiler features cold starting, the boiler water stays at room temperature until the controls sense a demand for heat. During the summer, as long as sunshine is adequate to meet the domestic hot water needs, there is no need for the boiler to fire.

The grid-connected solar electric system consists of 12 PV modules with a total peak output of 1.4 kW and a utility- tied 1,000-watt sine-wave inverter. There is no battery storage.

The installed cost of the solar thermal system was about $4,600, while the PV system cost about $11,500.

Utility Bills

The house received a HERS rating of 89.6, earning it a 5 star Energy Star label. In 2001, Hansen used only 622 ccf of natural gas (see Table 1 below). According to Michael Russom of Vermont Gas Systems, the home's gas usage was 42% less than that of a typical Vermont home (that is, the "base case" home in the demand-side management modeling program used by the gas utility). The modeling software assumes that a typical 2,OOO-square-foot Vermont home uses 1,080 ccf of nah1ral gas for heating and appliances.

From March 27, 2000 (when the electrical net metering equipment was installed), through August 15, 2000, the house used 613 kWh of electricity. The cost of the power was offset by the value of 313 kWh of solar electricity fed back to the grid, resulting in net electrical bills totaling 300 kWh (2.2 kWh/ day).

An energy-efficient house offers not only lower utility bills, but also less tangible benefits. "Living in a house with a lot of insulation is much more comfortable, because your body isn't radiating heat to the cooler walls," says Maclay. "You don't have hot and cold spots in your house, or drafts, or temperature stratification. And when the electricity goes off, your house doesn't immediately get cold."

Table 1 - Natural Gas Consumption, Hanson House

Month	Ccf of natural gas	Cost
Januray 2002	155	$153.59
February 2002	113	$114.61
March 2002	85	$88.63
April 2002	70	$74.71
May 2002	15	$23.67
June 2002	12	$20.89
July 2002	14	$22.74
August 2002	5	$14.39
September 2002	8	$17.17
October 2002	22	$30.17
November 2002	53	$58.93
December 2002	70	$74.71
Totals	662	$694.21
Monthly Averages	55.2	$57.85

Spec Sheet: Hanson House

Location: Burlington,Vermont

Size: 2,018 square feet (conditioned space)

Bedrooms: 3

Foundation: Slab on grade

Wall construction: 2x6 studs @ 16 in o.c., with interior horizontal 2x4 strapping @ 24 in o.c.

Sheathing: CDX plywood

Roof framing: 2x 12 common rafters

Siding: Fiber-cement installed over a rainscreen of vertical 1/2-in strapping @ 16 in o.c.

Wall insulation: R-26 damp-spray cellulose Flat ceiling insulation: R-6S cellulose

Sloped ceiling insulation: R-30 cellulose

Floor insulation: R-IO at slab edge; R-20 under slab

Windows: U-0.34 (NFRC rating) Marvin windows

Blower door test results: 480 dm @ 50 pascals. 0.06 ACHnat

Domestic hot water: Solar with natural gas backup

Gas hot water: Bradford White indirect water heater off of natural-gas boiler

Solar thermal panels: Two 4 ft x 8 ft Thermo Dynamic G series panels with 60% propylene glycol fluid

Solar thermal storage tank: Vaughn Top Performer 70-gallon storage tank with top-mounted heat exchanger

Cost of solar hot water system: $4,600

Photovoltaic panels: 12 AstroPower 120-watt PV modules (total I ,440 watts peak output)

Inverter: Advanced Energy GC-I 000 utility-interactive 1000-watt sine-wave inverter

House batteries: None

Cost of photovoltaic system: $1 1,500

Mechanical ventilation system: Two 17-watt Panasonic bath exhaust fans controlled by programmable timers

Heating system: 87,4 AFUE Burnham Revolution RV5 natural gas sealed-combustion cold-start boiler (I 30,000 Btu/h input)

Annual natural gas use: 66.2 Mbtu, including 7.9 Mbtu for domes-tic hot water

Annual electric bill for lights, appliances, etc.: $320

Annual electric utility service charges: $190