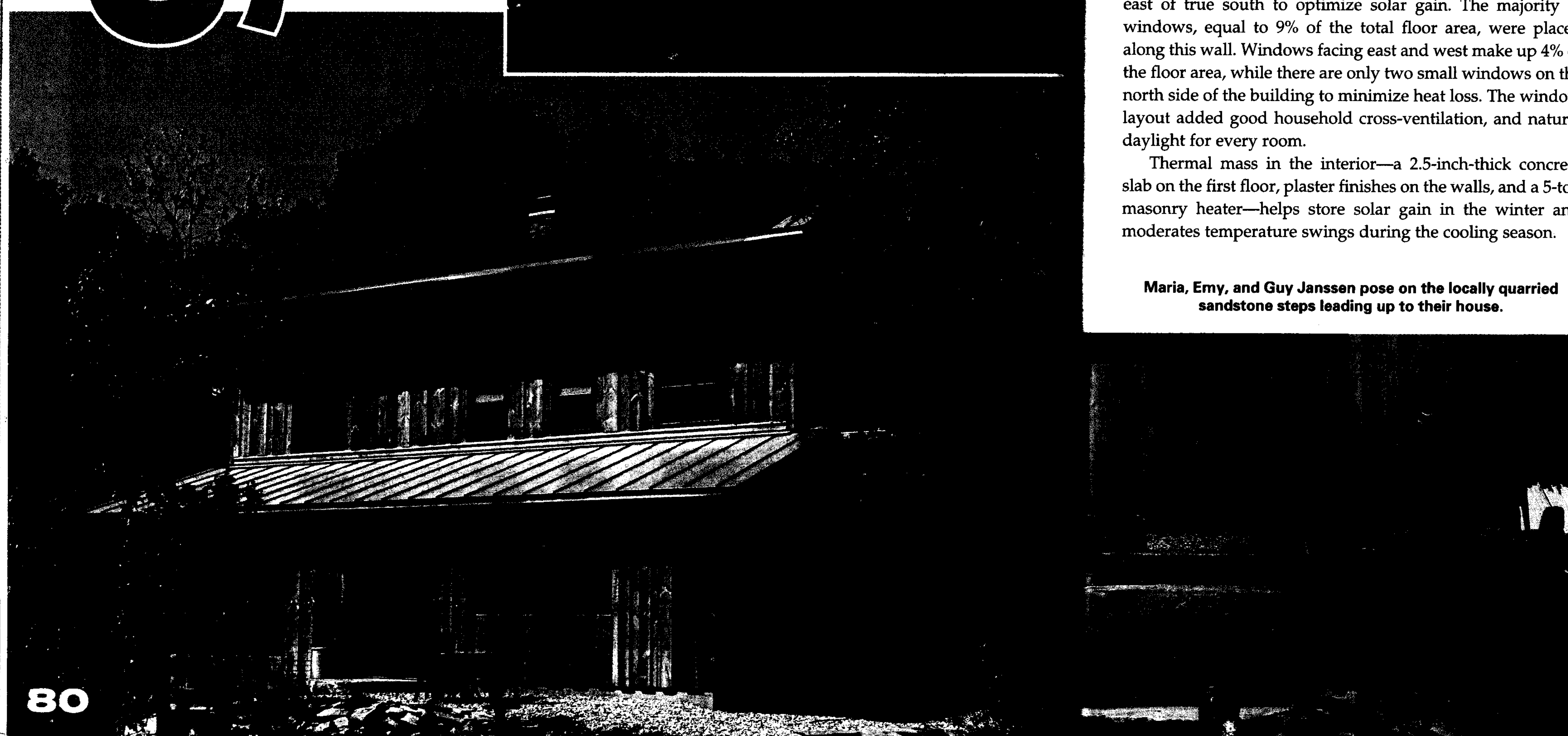
green FROM THE GROUND UP

by Jim McKnight, Mark Klein & Laura Lee



Maria, Emy, and Guy Janssen pose on the locally quarried sandstone steps leading up to their house.

Guy and Maria Janssen own a popular coffee shop in Stevens Point, Wisconsin, named Emy J's after their 12-year-old daughter. The business shows off their environmental values—like serving fair-trade organic coffee, using a high-efficiency coffee roaster, using biodegradable cups and plates, and purchasing renewable utility power and carbon offsets.

In 2005, they invested in a solar hot water (SHW) system for their coffee shop and other building tenants. "We do these things because we believe that in doing so we give back to the community, the environment, and to the world at large," says Guy. From that philosophy, and with the positive solar experience fresh in their minds, the Janssens contacted our sustainable building company, Gimme Shelter Construction, to incorporate renewable energy (RE) and sustainable building techniques into the new home they were planning.

The building site, which sits west of town on a bank above the Wisconsin River, is populated with oaks, maples, and pines that are reclaiming the farm fields of Wisconsin's early pioneers. We identified a south-facing rise which provided an open, unshaded site—perfect for a passive solar home and the planned SHW and solar-electric systems.

Solar Tenets for Solar Tenants

The 2,600-square-foot Janssen home is based on the tenets of passive solar design, including proper building orientation, optimum window placement, natural daylighting, and thermal mass within an efficient building envelope.

The longest wall of the home was oriented to 2 degrees east of true south to optimize solar gain. The majority of windows, equal to 9% of the total floor area, were placed along this wall. Windows facing east and west make up 4% of the floor area, while there are only two small windows on the north side of the building to minimize heat loss. The window layout added good household cross-ventilation, and natural daylight for every room.

Thermal mass in the interior—a 2.5-inch-thick concrete slab on the first floor, plaster finishes on the walls, and a 5-ton masonry heater—helps store solar gain in the winter and moderates temperature swings during the cooling season.

ECO-EFFICIENT BUILDING STRATEGIES

Passive solar design—Reduces heating and cooling loads by 10% to 15% through proper solar orientation, window placement, and interior mass.

High-performance building envelope—Reduces heating loads an additional 40% to 50% through higher insulation values, high-efficiency windows, using a continuous vapor barrier, and sealing penetrations.

Masonry heater for space heating—Uses local biomass as fuel.

PV system and solar thermal system—Use a free, renewable energy source (sunshine) to provide electricity for the house and space and water heating. Can be sized smaller as a result of efficient building design and construction. Heater and solar hydronic systems are locally made, reducing their embodied energy.

Heat recovery ventilation system—Brings in fresh air to the home and controls indoor humidity while minimizing heat lost to indoor/outdoor air exchanges.

Interior choices: cabinets, subfloors, paints, and finishes—Formaldehyde-free sheathing, and low-VOC paints and finishes don't compromise indoor air quality.

Sustainably harvested wood—Supports local milling operations and foresters, and healthier ecosystems.

Acid-etched concrete—High embodied energy of concrete is offset by its durability and low maintenance requirements, plus its improvement of the home's thermal performance.

Steel roof—More durable and better value than asphalt shingles; recyclable at end of life span.

We used a continuous vapor barrier with careful sealing, spray-on cellulose insulation (R-32 in the walls; R-60 in the ceiling), dropped sidewall framing (where the wall insulation extends below the floor level), and triple-pane windows. Combining a superinsulated shell with passive solar design reduced the heating and cooling needs to about 40% of a standard Wisconsin Energy Star-rated home. But having such a tight building envelope necessitates bringing in fresh air during the heating season, so a heat recovery ventilator was included (see Fresh Air sidebar).

For the Janssen home, the combination of having a high-efficiency building envelope and passive and active solar technologies will result in utility bills for the heating season being about 60% less than a typical home of the same size, and reduce carbon dioxide (CO_2) emissions by nearly 7 tons annually. The Janssens, who are also committed to using the sun to provide electricity, hot water, and space heating for their home, the carbon reduction is even greater—nearly 12 tons per year.

Left: Laying the masonry heater's refractory brick. Right: The final product in action!

Warming Systems

A 320-square-foot closed-loop glycol solar hot water system provides domestic hot water and primary space heating through hydronic tubes in the concrete floors, producing about 35 million Btu per year. A 50-watt PV module powers a DC pump, which circulates the glycol mixture through ground-mounted collectors in the garden, through insulated, buried lines, then to the storage tank. This system provides enough hot water for in-floor space heating for early spring and late fall, plus plenty of domestic hot water year-round. During the peak heating season in December and January, supplemental heat is needed.

A high-mass (masonry) wood heater provides extra space heating and supplemental water heating during the colder months. There is plenty of fuel from small woodlots in the area, so masonry heaters are becoming more common. They are one of the most efficient ways to heat with wood, and homeowners love the comfortable, radiant heat.

Guy and Maria prioritized integrating hot water capability into the masonry heater to assist the solar collector. A stainless steel exchanger within the secondary combustion chamber heats water that's routed to the storage tank in the basement. This stored heat is used both for domestic hot water and space heating.

Because they are designed for relatively quick burns at temperatures above 1,800°F, masonry heaters are convenient and efficient. Superheated flue gas circulates through a series of chambers and most of the heat is absorbed by the 5-ton mass of the heater before exiting the chimney. Masonry heaters are about 70% efficient, roughly equal to EPA-qualified wood heaters. The high combustion temperature produces very low emissions—about 2 grams of particulates per hour (typical wood heaters produce about 15 grams per hour; outdoor wood-burning boilers can produce about 40 grams). Because masonry heaters burn so cleanly, flues and chimneys need

FRESH AIR

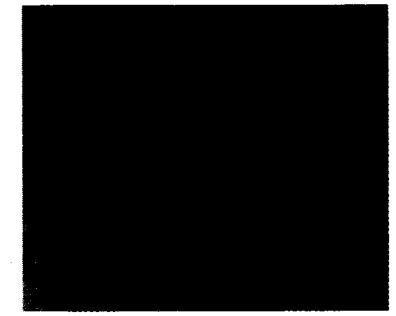
A heat recovery ventilator (HRV) helps maintain good indoor air quality by exhausting stale inside air while drawing in fresh outside air. HRVs help control relative humidity, preventing moisture buildup on windows and reducing the chances of mold (a HEPA filter can be added to remove dust and pollens). As the two airstreams—indoor and outdoor—pass through a heat-exchanging core, most of the inside air's heat is transferred to the incoming air. Even at an outdoor air temperature of 32°F, the Janssens' Bryant HRV can exchange 211 cubic feet per minute with 69% to 77% percent of the heat transferred back to the incoming air.

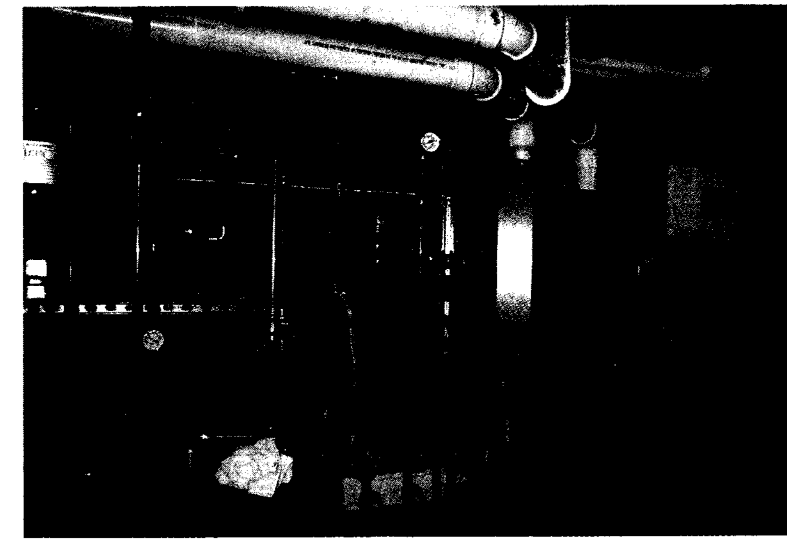
Typically, inside air to the exchanger is pulled out of high-moisture areas like baths and kitchens, while fresh air is supplied to bedrooms, assuring whole-house circulation. Although most HRVs are programmed to run intermittently at low speed, a high-speed override can provide on-demand venting when moisture levels are high.

A straightforward installation costs about $3,000, but the recovery of 70% or more of the heat otherwise lost through an exhaust-only system can offer significant savings, especially when extreme differences exist between indoor and outdoor temperatures.

Alternatives to HRVs include exhaust-only ventilation systems, which use standard exhaust fans and a dampered makeup air supply. They are less expensive and consume less energy, but require the homeowner to monitor conditions and adjust the system's timer accordingly. They also will not maintain a preset humidity and will not recover the heat lost when venting directly to the outside.

The concrete tank in the basement used for hot water storage.
Right: Heat exchanger coils inside the tank.
Below: The systems' mechanics wall, with the expansion tank, circulators, and boiler next to the PV system inverter and other electrical equipment.





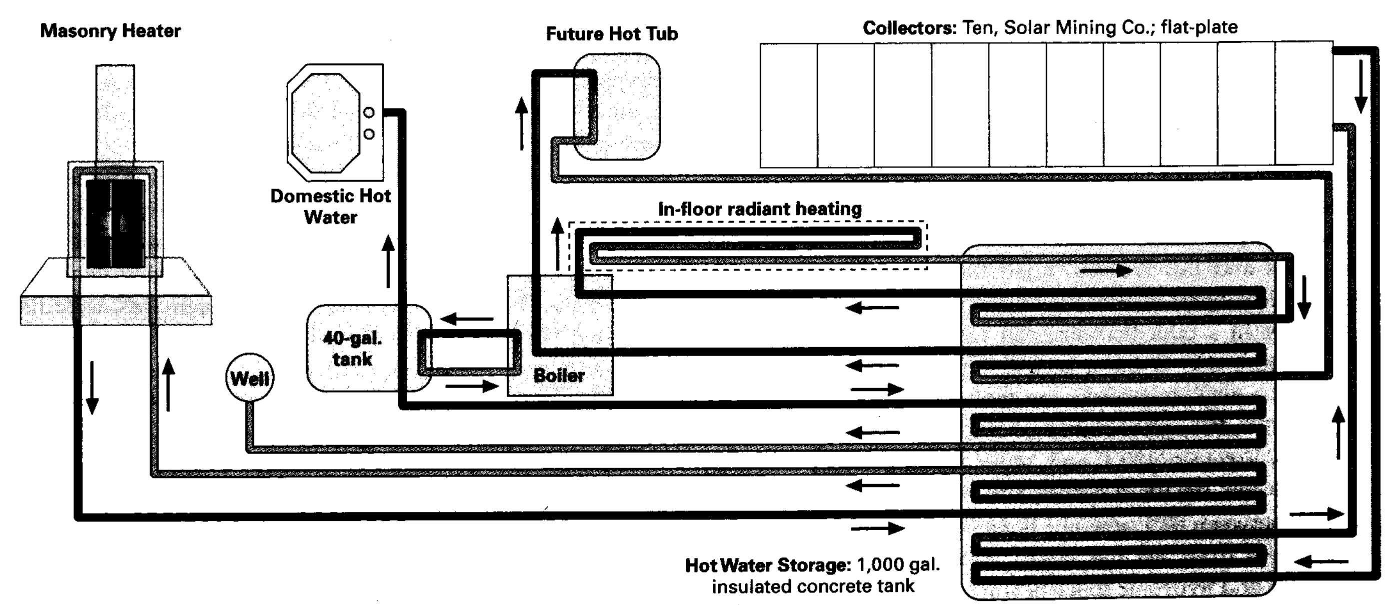
less frequent cleaning than for typical wood heaters, usually once every five years. Masonry heaters are about 70% efficient, roughly equal to EPA-qualified wood heaters.

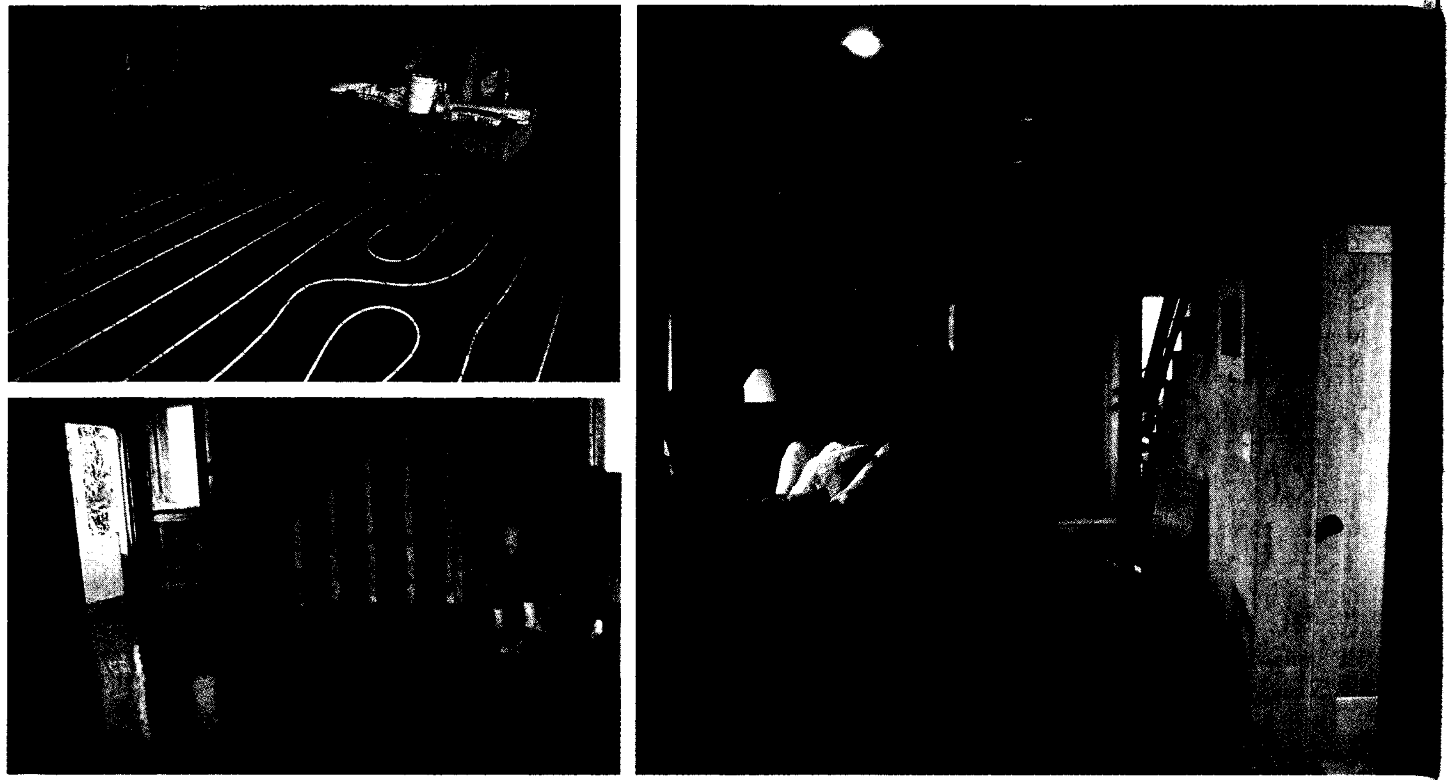
The heat-transfer efficiency and heat-storage capacity of the large mass keeps combustion time relatively short—three to four hours per day in midwinter—which translates into much less interaction required by the owner and a flexible firing schedule. When the days warm, firings can be spaced out even further because the rate at which heat radiates slows as room temperature rises. This phenomenon is true of all radiant heating systems, including in-floor hydronic systems.

A masonry heater is built with a core of cast refractory parts and firebrick, surrounded by a veneer of stone, brick, or block. The Janssens' heater has a solid 4-inch block veneer with a troweled plaster finish. The heated bench and the mantel are slabs of local sandstone.

Ideally, heaters should occupy a central location on the main living floor to take advantage of the radiant surfaces on all four sides. The heater can bear ceiling and roof loads, so designing homes with a central heater can open up areas that would have been obstructed by posts or bearing walls. Radiant heaters help prevent temperature stratification common with forced-air heating systems. We've had success heating two-story homes up to 3,500 square feet with a single masonry heater. Although they can be expensive—the Janssens' heater cost about $20,000—the benefits of a hearth experience and supplying heat with a renewable, local resource make the choice easier. Standard wood heaters are much cheaper, but they can't supply the quality of heat, ease of operation, decreased use of firewood, and longevity of a masonry heater.

Janssen Hot Water Plumbing





Left: The hydronically heated first floor, before and after the thin-slab concrete was poured.
Right: The finished floor and the earth-clay plastered walls help create an elegant, but earthy, atmosphere.

For backup when the wood heater is not being fired or when weather prevents solar heating, a Trinity 150 on-demand propane boiler helps out. The boiler monitors the incoming water temperature from the storage tank and modulates its flame to match flow rate and needed temperature gain. When incoming water from the storage tank reaches the boiler's temperature setpoint, the gas burner does not fire at all.

Heat Storage & Distribution

The same hot-water storage tank is used for both the solar and wood-fired heat sources. Typically, a 1,000-gallon concrete septic tank, buried under the basement floor slab, is a preferred alternative because it doesn't take up floor space. But at Guy and Maria's house, a thick layer of granite, just inches under the foundation depth, made that impossible. We set the tank in a corner of the basement, reinforced its perimeter with a poured concrete wall, and insulated the sides and lid. We also lined the tank with an EPDM (synthetic rubber) membrane to prevent leakage.

Water in a tank that size can absorb 8,060 Btu per 1°F temperature rise. Using a typical temperature rise of about 50°F on a peak solar day, the tank is able to store about 400,000 Btu. For most months of the year, water in the tank will stay between 120°F and 140°F. During colder months with less sun, the SHW system and masonry heater together keep it between 80°F and 110°F. At the top of the tank, heat exchangers draw off the stored water's heat for domestic purposes and hydronic space heating.

Radiant Heating

When space heating is needed, warm water from the storage tank is routed through polyethylene tubing ($^5/_8$-inch PEX) embedded in the thin slab of concrete that was poured over a wood-joist frame on the first floor. Radiant heat works more efficiently with a large mass, which also helps retain direct solar radiation and tempers the building's temperature in the summer, reducing cooling loads.

Upstairs, a thin-slab floor in the bathroom also has hydronic tubing installed. Less temperature stratification occurs with radiant heating systems, so minimal heating is required for upstairs rooms. "The system has worked well and has made a great impact on our comfort and peace of mind," says Guy.

Power From the Sun

Besides relying on renewable resources for space and water heating, Guy and Maria also wanted renewably generated electricity. Their decision to install a PV system was, according to Guy, "in part due to the rebates from Focus on Energy and because we felt it was a start to a self-sufficient home." The roof overhang provides summer shading for upper windows and accommodates a 2,400-watt array of Kyocera PV modules. The overhang's 45-degree angle is close to ideal for this location, maximizing year-round PV production and providing an inconspicuous mounting surface.

Originally, the PV system was expected to cover about 50% of the Janssens' predicted annual electricity usage,

producing an average of 3,120 KWH per year. But with high efficiency appliances, exclusive use of compact fluorescent lighting, an excellent daylighting strategy, and—most importantly—a family that pays adamant attention to energy conservation, the Janssens are consuming much less electricity than predicted. According to Guy, "Over a six-month span during the fall and winter, we used a total of 630 KWH [of utility power]. Our expectations are that we will break even with our system's annual production of electricity compared to our annual usage."

The Janssens' ultimate goal is to become a net zero-energy household, but they still have some improvements to make before they can wean themselves from fossil fuel. Their boiler, range, and clothes dryer use propane gas. Although propane use decreased their electricity use, they still use about 300 gallons annually. Guy says that they plan to "bring this usage down by living with and knowing the system better in the future."

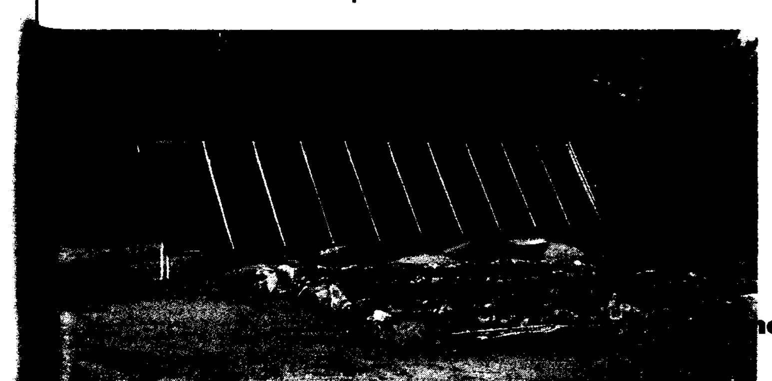
Green-Built

In keeping with their quest to build a resource- and energy-efficient home, the Janssens wanted to use as many local, long-lasting, and high-performance building materials as possible. They were aware of sustainably harvested, rough-sawn white pine exterior siding and shiplap sheathing available from the Menominee tribal forest in Wisconsin, and wanted to use this for their home. Lumber sheathing on the exterior is less susceptible to water damage than particleboard or plywood, and all construction scraps can be safely burned in the masonry heater. Vertical pine siding, with proper flashing and overhangs, can last a century or so with minimal maintenance. It also can be installed unstained, saving money and avoiding the environmental hazards of wood preservatives and stains.

Wood siding was used in the interior to avoid the off-gassing issues that plywood and particleboard have. Inside the home's walls, spray-on and free-blown cellulose insulation containing recycled material was an appropriate and effective insulation choice. Spray cellulose is more effective than fiberglass or other batt insulation because it consistently fills all the voids in a wall cavity. The disadvantage is that it takes a fairly sophisticated machine to apply correctly, costing about 50% more per square foot than fiberglass batts.

We chose steel roofing for its durability and longevity. Compared to petroleum-based shingles, standing-seam metal roofs have four times the life span at less than twice the cost. And when shingles are replaced, the debris is usually sent to the landfill, while steel can be recycled at the end of its useful life.

Solar collectors provide hot water for the house.



The house's framing is standard 2-by-6 stick-type with interior strapping added to create 7-inch-thick walls. The dropped sidewall framing technique addresses the typically poorly insulated area in conventional framing where exterior walls meet the floor.

Our framing materials are not yet certified "green," but we are working with local mills to eventually provide native red pine as a sustainable alternative. Building codes in Wisconsin require that framing lumber be graded, and the small local mills cannot yet absorb the cost of an on-site grader.

Interior walls were finished with naturally tinted earth clay, adding about 2 tons more thermal mass than standard drywall to help moderate heating and cooling swings. Earth-clay plaster also provides a breathable wall surface, which tempers humidity in the house. These wall finishes and the acid-etched concrete floors have high aesthetic value, and pay off because they are more durable and require less maintenance.

Enjoying the Process

The Janssens say they are very pleased with how everything turned out. "There were no major surprises, and we have no regrets," says Guy. "We would do it the same if we had to do it all over again, although I would devote more time to enjoy the building process, and take many more coffee breaks and listen to the birds sing." Now he has the perfect home in which to do just that.

Access

Jim McKnight (jim@gimmeshelteronline.com) and partner **Mark Klein** have designed and built homes as Gimme Shelter since 1987. They are nationally recognized by the National Association of Home Builders for innovative, cold-climate construction methods, and by the Wisconsin Energy Star program for having performance ratings in the top 1% of builders. They are charter members of the Wisconsin Green Building Association and present workshops on sustainable building for the Midwest Renewable Energy Association and other organizations. **Laura Lee** was office manager at Gimme Shelter until the summer of 2007 and continues to write and edit Gimme's Web site. She has a graduate degree in construction management.

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