



BIOMASS



GEOTHERMAL



HYDROPOWER



SOLAR



WIND

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As part of their lifelong personal commitment to sustaining the environment, John and Sue Davenport wanted to build a home that both conserved and generated energy. To accomplish this, the Davenports' home in central Wisconsin is designed around renewable technologies so effective that the home is heated with renewable resources alone. Nine years of satisfied occupancy by the Davenports demonstrates how easily these technologies can be integrated into any lifestyle.

THE PROCESS

The Davenports planned to build a home that wouldn't tax the environment and could produce needed energy on-site. They wanted a home that would see them comfortably through retirement. It was also important to them that the home be free of the allergens often present in the dirt that collects in carpeting, glues used in wood products and additives found in paints and finishes.

To select the technologies and develop a house plan that fit their needs and their budget, they worked with Gimme Shelter, builders who are knowledgeable about energy efficient construction and solar energy. The house that resulted has 3,300 square feet of living space, including a walkout basement.

ENERGY EFFICIENCY

Many of the most effective energy savings measures must be installed during construction. For instance, the Davenport home is airtight and well insulated, using techniques that could only be implemented while the house was being built.

The builder used a durable vapor barrier with all seams overlapped and taped for a continuous barrier. They sealed all holes and taped and caulked all joints. High insulation levels were achieved by using a 2x6 frame with 2x2 horizontal strapping on the exterior to create more space for insulation and provide an almost continuous insulation layer outside of the studs. The basement walls are framed with 2x4s set in 1.5 inches from the concrete wall. The ceiling is insulated to R-60, and the first floor walls to R-28.



The Davenport home integrates energy efficiency and renewable energy from the ground up.

The Davenports report that it doesn't take much to keep the house warm because it holds heat so well. Similarly, their metal roof helps keep the home cool in the summer, but selecting such a roof is an opportunity that homeowners are only likely to have once—that is, before they build.

LIGHTING

Much of the house has ample light levels provided by natural daylighting. If additional lighting is needed, compact fluorescent lights or strip lights are used. Compact fluorescent lights use less than one-third of the energy required by incandescent lights for the same lighting levels.



(above left) Thirteen solar thermal panels heat water for space heating and domestic use. The photovoltaic panels that generate one-third of the Davenport's electricity are located at the west end of the roof (out of view). *(above right)* All windows in the Davenport home are triple glazed low-e units except those on the south side, which are low-e double-glazed to admit more sun.

HEAT RECOVERY VENTILATOR

A tight home can accumulate moisture, stale air and pollutants. To supply fresh air, a heat recovery ventilator balances the incoming air with outgoing air while recovering heating and cooling energy from the outgoing air.

WHOLE-HOUSE FAN

The house temperature can be lowered on summer nights by opening the windows and turning on the whole-house fan, which pulls cooler outside air up through the house and expels warmer, indoor air out the top of the house.

WINDOW QUILTS

All windows in the house are equipped with window quilts, a window covering that adds R-5 of insulation to the window area. In winter, the quilts are closed at night to reduce heat loss and opened during the day to let in energy from the sun. In summer, they are closed during the day to keep out the heat and opened at night to cool the house. The Davenports have noticed a considerable difference in heat retention when the quilts are in place.

LANDSCAPING

The Davenports were fortunate to find a wooded building site. The trees surrounding the house help keep the area cooler in the summer and protect it from the winter winds.

RENEWABLE ENERGY SYSTEMS

SOLAR HOT WATER

The original solar hot water system consisted of three solar collectors on the roof, two pumps, two tanks (standard water heaters—one with electric heating elements, one without), a heat exchanger, a controller, piping and other fittings. After a few years in the home, this system needed to be modified slightly, as described in the next section.

SOLAR SPACE HEATING

Most of the heat for the house is provided by the active solar hydronic heating system. A 12-volt photovoltaic electric panel powers two pumps that circulate antifreeze solution through ten

solar collectors mounted on the roof and into the in-floor tubes. Consequently, the pumps operate only when the sun is shining, directly heating the floor with hot fluid from the solar collectors. The floors incorporate 200 tons of sand and concrete with in-floor heat tubes running through the sand. This mass can store enough heat to keep the floor warm for an extended time without sunshine.

Unfortunately, the in-floor heating sometimes made the home too warm on summer days. The shunt included in the original design to address this was not large enough to sufficiently cool the solution. The Davenports had the piping from the solar panels redirected so that heated water would flow to the storage tank first before reaching the floor. In the new configuration, all 13 panels are piped on the same loop instead of being dedicated to either the floor or to domestic water. To provide the needed heat capacity, the Davenports had to increase the size of the storage tank from 60 gallons to 120 gallons. During the summer, this provides the Davenports with far more hot water than they need.

This photo shows the hot water piping in the Davenport's mechanical room. The home is divided into separately controlled heating zones, and each zone has its own loop of piping.



PASSIVE SOLAR HEATING

The home maximizes southern exposure with a walk-out basement and a façade that features 220 square feet of south-facing, double-paned, low-e windows. Thermal mass plays an important part in both the passive and active solar heating systems. In addition to the sand beneath the flooring, this mass includes the flooring, walls and masonry stove. Heat from the sun enters during sunny days and heats the concrete and plaster. This mass not only stores the heat for later, but also helps prevent the home from getting overheated on sunny days.

WOOD-BURNING MASONRY STOVE

The three-ton masonry stove provides additional thermal mass and a heating source. The stove maintains very hot, efficient fires and forces the hot combustion gas back and forth through long passages in the stove's walls, heating the mass as it passes through. The draft damper is then shut and the stove releases heat gradually to the room.

SOLAR ELECTRIC

In 1999, the Davenports installed a photovoltaic system in their home. It was based to provide approximately one-half the amount of electricity used over the course of a year, sized on the power needed for a home unoccupied during business hours. They have since increased the PV system to 30 panels, providing 3,400 kWh annually. The Davenports estimate that this is roughly a third of their total energy usage, which has increased considerably because John now works out of his home.

ENERGY PERFORMANCE

According to analysis of the building shell, the energy required to heat the home annually is 60 million Btu per year for the original 2,400 square foot portion. With their additions, the load is roughly 65 million Btu. The Davenport's electric bill averages \$40 to \$50 per month. This includes electric stove, refrigerator, the pumps for their solar water heater, back-up heat for their hot

water, heat recovery ventilator, whole-house fan, air conditioner, lights and other appliances.

LIVING WITH THE TECHNOLOGIES

Like most owner/builders, the Davenports wish they had done some things differently (i.e. a larger basement and a different front façade) but they have almost no complaints about the renewable technologies in their home. The passive and active solar heating systems provide the bulk of their heat. They like the quiet hydronic heat and the warm floor surfaces. The solar heating works so well that it is late fall before they light the wood stove for heating. The only renewable system that has required significant attention is the in-floor solar heating, as described above.

Even though a masonry stove wasn't originally part of their plans, they are glad they had it installed. It uses little wood and provides heat over a long period. On average, they light one fire per day during the winter, usually at night. However, if the next day's weather forecast calls for sun, they don't need a fire that night.

During the summer, the Davenports rarely need the air conditioner. Even when the temperature was over 90 degrees for two weeks, they used the air conditioner only once. On cool nights they draw in outside air with the whole-house fan. During the day, they close up the house, including closing the window quilts. Using these methods, the indoor temperature can usually be lowered to about 70 degrees.

CONCLUSION

The Davenports live comfortably in a modern home powered mostly by renewable energy. They find being attentive to the weather, which is necessary for proper operation of the house, fits in with their philosophy of living closer to nature. If anything, they wish they could have done more, such as adding wind power to their generation mix to be able to take their home off the grid. But they are more than happy with the self-reliance and reduced environmental impact of their home.

(bottom left) The wood burning masonry stove is the prominent feature of the family great room. It's even and quiet operation creates a warm and peaceful atmosphere. *(bottom right)* Generously-sized windows on the south side of the home introduce the sun's warmth and light. Manually operated window quilts allow the Davenports to control heat losses at night.





Case Study Facts

Davenport Home Date Completed: 1994

Personnel

Owners: John and Sue Davenport
Design and Construction: Gimme Shelter
Renewable systems designers: PV designer: James Kerbel, Photovoltaic Systems Co., Amherst, WI; Solar thermal designer: SnowBelt Energy Center

Building and Site

Location: Central Wisconsin home
The Davenport home sits on a secluded 30-acre wooded lot in Central Wisconsin, with 220 square feet of windows facing SSE and overlooking their garden and greenhouse. The main floor is 2,460 square feet, and the walk-out basement is 972 square feet. Insulation levels: R-60 in the ceiling, R-28 in the walls, R-22 in the rim joist, R-20 in the basement walls, and R-10 in the basement floor.

Equipment

PHOTOVOLTAIC SYSTEM

Installed by James Kerbel of Photovoltaic Systems Company in Amherst, WI. This system consists of approximately 960 square feet of Solarex and Kyocera panels combined for a total of 2.9 kWh. The panels are stationary, and oriented SSE. The system employs an Outback controller, is grid intertied, and battery back-up is sized for three days off the grid.

SOLAR THERMAL SPACE AND WATER HEATING SYSTEMS (PRODUCE 43 MMBtu ANNUALLY)

Installed by SnowBelt Energy Center, the system includes 13 Snow King panels, and a 2 foot x 2 foot PV panel to power the DC pump.

MASONRY STOVE (PRODUCE 22 MILLION Btu ANNUALLY)

Designed by Envirotech, the stove came as a 4,000 pound modular kit of cast refractory components, enhanced by a locally provided masonry exterior.

System Costs and Benefits

ECONOMIC COSTS AND BENEFITS

Cost of solar water heating system was \$14,000. The space heating portion of the system cost about \$4,000 more than a conventional radiant floor system. The rebate received on the water heating system allowed for purchase of an extra panel. Heating fuel costs for the masonry stove average \$150/year for 1-1/2 cords of oak firewood. Electricity costs (for electric stove, refrigerator, system pumps, back-up hot water, air conditioner, lights and appliances) average \$40 to \$50 per month.

ENERGY AND ENVIRONMENTAL BENEFITS:

The combined solar thermal and wood stove systems save 65 million Btu (over gas-fired furnace) annually, and the photovoltaic panels offset 30 percent of the home's electrical load. The Davenport home therefore avoids pollution from 14,369 lbs. of CO₂; 14.1 lbs. Nox; and 27.2 lbs. SO₂ every year. (Calculations based on 1.988 lbs. CO₂/kWh; 4.16 lbs. Nox/MWh; 7.99 lbs. SO₂/MWh; and 117.08 lbs CO₂/MMBtu.)