RENEWABLE ENERGY

Comfort and Savings from Clean Energy

CASE STUDY

BIOMASS

GEOTHERMAL

HYDROPOWER

SOLAR

WIND

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The Bircher home combines conventional curb appeal with superior energy performance, setting an exciting example for mainstream homebuilders and their customers.

Bircher home demonstrates energy efficiency and solar energy for mainstream builders

Since 1999, the Bircher family of DePere, Wisconsin, has been living in a mainstream solar demonstration home they built using readily available, off-the-shelf equipment and contractors from the local area. They wanted to show that solar energy technologies can be attractive, reliable, user-friendly and easily integrated into the design. They also wanted to minimize energy use through efficiency and conservation, and use healthy and natural materials to maintain indoor air quality and minimize environmental impacts. Finally, they wanted to integrate the home with nature on all levels.

More than three years later, the Birchers are still very happy with the home. They have been tracking their energy use on utility bills, in addition to monitoring performance with a data acquisition system. They have found that the home uses 40 percent less energy than homes of similar size, age and number of occupants. Based on 2004 prices, the savings are $811 annually—$458 in natural gas and $353 in electricity.

FIRST THINGS FIRST: ENERGY EFFICIENCY

Using the sun's clean, renewable energy is good for the environment, but the greatest earth-friendly savings can be achieved by first increasing a home's energy efficiency. The Bircher home uses a full range of strategies and equipment to cut energy use while maintaining high indoor air quality.

BUILDING ENVELOPE

The walls, constructed with 2" x 6" studs, are insulated with blown-in cellulose to R-20; the attic has R-44. The exterior sheath, made with oriented strand board (OSB) structural panels, is covered by an infiltration barrier with taped seams, while a continuous vapor barrier covers the interior. All seams and envelope penetrations are sealed with urethane foam or caulk. Blower door testing conducted shortly after occupancy revealed that the infiltration rate is 765 cfm, which is half of the typical value for new construction in the area.

Double-pane casement and fixed windows are used throughout the home to reduce both infiltration and conduction. These windows have an overall U-value of 0.38 (corresponding to a R-value of about 3). The window design includes low-e plastic film suspended between two panes of glass, creating two air spaces in the window.

MECHANICAL EQUIPMENT

The 93 percent efficient forced air furnace has a two-stage burner and a multi-speed fan to provide the amount of heat needed for a more continuous and

Double-pane low-e windows reduce both infiltration and heat loss while admitting both light and heat from the sun. Ceramic floor tile provides some of the home's thermal mass by absorbing and radiating solar heat.

efficient operation. A set-back thermostat regulates the indoor temperature. The auxiliary water heater is a natural gas power-vent water heater with an energy factor of 0.63 (the higher the better; the range for gas water heaters is typically 0.5–0.7). Also, an efficient central air conditioner was installed in the home.

RENEWABLE ENERGY SYSTEMS

SOLAR HEATING

The passive solar design optimizes the relationship among south glazing, shading and thermal mass to assure year-round comfort.

- The window area on the south side was sized based on the footprint of the building and the available wall area. With the total area of south facing windows equal to 6 percent of the home's square footage, the Bircher house can be categorized as "sun-tempered."
- Overhangs on southern windows are used to shade the windows from direct sun from mid-May through early August, while allowing direct sunlight during winter months.
- Extra thermal mass was included in the design. Ceramic floor tile was chosen for the south side of the first floor, and ⅝-inch dry wall was installed throughout the home. A masonry fireplace safely retains flue gases so that heat continues to radiate long after the fire is out.

Results: In the first year, the Bircher's home used 55 percent less heating energy than similar homes, and it continues to perform well. On sunny days in January and February, the indoor temperature never drops below 65˚F. Regardless of the outdoor temperature, the furnace never needs to run during daylight hours on sunny days.

SOLAR WATER HEATING

The solar water heater was sized for a family of four. The system includes 64 square feet of collectors and an 80-gallon solar storage tank. It has a pre-assembled "balance of system" module that includes two small AC-powered pumps, controller, heat exchanger and expansion tank.

Results: Based on monitoring, the solar water heater provided 62 percent of the annual hot water needs. The system provided nearly all of the water heating during the period May through September.

VENTILATION AND INDOOR AIR QUALITY

A combination of fans provides fresh air to the home. To cool the house in the summer, the Birchers open the upstairs windows at night and run the 1,000 cfm whole-house fan, which draws cool, dry air into the house. They close the windows in the morning, and the house is usually cool for the rest of the day. A 220 cfm ventilation unit using a humidistat is used to dehumidify basement air. In the winter, this unit draws in outdoor air, which is filtered twice before being supplied to the furnace. Air leaves the house through the bathroom and range hood fans. In addition, carefully chosen paints, floor coverings and cabinetry minimize indoor air pollutants.

ELECTRIC LIGHTING AND APPLIANCES

Sunlight is the main source of daytime lighting. For electric lighting, the home has a mixture of fluorescent and incandescent fixtures. ENERGY STAR® appliances were chosen for energy efficiency and low noise levels. Their horizontal-axis clothes washer uses less than 4 gallons per wash load.

Overhangs were installed on south-facing windows on the first floor to keep out direct sun between May and September.

The refrigerator is expected to use 594 kWh per year, 25 percent better than federal standards. The dishwasher is rated at 4.4 gallons per normal load. As required by code, all toilets use 1.6 gallons per flush. Also, low-flow showerheads and faucet aerators save water and energy.

PASSIVE COOLING

The Bircher home employs passive cooling from shading, and natural and forced ventilation to keep the house comfortable while minimizing energy use.

- The roof overhang shades the south-facing windows. Trees and an adjacent screen porch shade windows on the west side.
- Outdoor air provides cooling almost every night. To enhance natural cooling, the window plan maximizes cross-ventilation. Almost every room has operable windows on two sides, and two ventilating skylights were installed on the second floor to allow hot air to escape.
- The whole-house fan supplements natural air flows and minimizes air conditioner use. This fan draws outdoor air into the house to cool the house during the summer. It has an operable insulating cover (R-22) to minimize heat loss in winter.

DAYLIGHTING

Window placement and an open floor plan allow light into the interior of the home from multiple directions. Most rooms have windows on two walls, providing balanced, even light.

Results: Rooms are uniformly lit with daylight, and artificial lighting is seldom needed during the day, regardless of sky conditions. On sunny winter days, light levels range from 500 foot-candles (direct sunlight immediately behind the south-facing windows) to 50 foot-candles against the north wall. On overcast days, light levels drop to less than 20 foot-candles, which is still adequate for many tasks.

PHOTOVOLTAICS

The Bircher home has a grid-connected photovoltaic (PV) system mounted on the garage roof, facing true south. The system includes two 275-watt PV modules. On the back of each panel is a small DC/AC inverter. Electricity from this PV system serves the home or can flow back into the electric utility lines. Analysis shows that this small PV system should supply 843 kWh annually, roughly 14 percent of the home's projected electricity needs.

Results: In the first four years, the PV system produced 2,460 kWh, which is 10 percent of the home's total electricity use.

AFTER THE HONEYMOON

After three years of occupancy, the Birchers say they are very pleased with the home in every respect, from aesthetics and comfort to cost and energy use. No maintenance has been required for any of the energy features since they moved in, including the solar systems. While the active solar elements reduce the monthly energy costs, the home's remarkable energy performance is primarily due to its passive design. The Birchers are particularly happy that including passive elements—south-facing windows, thermal mass, window overhangs and additional insulation—made the house no more expensive to build, per square foot, than other new construction in the neighborhood.

Unlike photovoltaics and solar water heating, however, these passive elements are much harder to retrofit, underscoring the importance of considering energy performance at the very beginning of the planning process. Equally important is finding builders who are willing to implement the new features. The Birchers had to bring in separate technicians for the unconventional electrical, plumbing and HVAC demands of the home. While none of the work was difficult, many of the products and processes have yet to be mainstreamed, requiring builders with specialized knowledge or a willingness to learn.

Of all the home's features, only the whole-house fan has worked less well than desired—on humid summer nights it brings in too much moisture. The Birchers have found that the easiest way to get fresh air into the house on these nights is to open the windows to permit cross-ventilation. Other than that, the Birchers have no complaints—particularly about their lower electricity bills.

This skylight in the upstairs hall augments the home's daylighting strategy and draws visual attention to the elegant staircase.

CONCLUSION

The Birchers have shown it is possible to build a mainstream house that is comfortable and environmentally friendly, while using 40 percent less energy than a typical house in their area. By making wise energy decisions at the beginning of the home designing and building process, both the building occupants and the environment will benefit over the life of the structure. Through home tours, the Birchers hope to provide a taste of holistic comfort and inspire the local building community to use these technologies in their own work.

Case Study Facts

Bircher Home

Date Completed: December 1999

Personnel

Owners: Chip and Karen Bircher

Home design and construction: Gryboski Builders, Green Bay, WI

Solar consultant: Solar Design Associates, Harvard, MA

Renewable systems installers: PV system: Stiegler Electric, Green Bay, WI and Wisconsin Public Service Corporation; Solar hot water system: Jindra Plumbing & Heating, Manitowoc, WI.

Building and Site

Location: De Pere, WI

Building square feet: 2,700

Building cost per square foot: ~$100

Lot size: 2.8 acres

The home is situated on a neighborhood lot, and the solar panels are the only thing that visibly distinguishes the home, on the interior or exterior, from any other in the neighborhood.

Equipment

PHOTOVOLTAIC SYSTEM

- Two ASE Americas SunShine 300 AC modules, 275 watts each (0.55 kW total), mounted on garage roof
- DC/AC inverter mounted on back of each panel
- Capacity factor: 843 kWh per year
- Grid intertied

SOLAR WATER HEATING SYSTEM

- Two 4-foot x 8-foot Heliodyne, Helio-Pak 16 AC panels
- 80-gallon solar tank
- 40-gallon power vent gas water heater
- The solar system supplies 62 percent of the annual water heating load

MONITORING EQUIPMENT AND PARAMETERS

Campbell Scientific data logger for: sunlight in plane of PV panels; wind speed; outdoor air temperature; hot water use, including inlet and outlet temperatures

System Costs and Benefits

ECONOMIC COSTS AND BENEFITS

- Cost of PV system: ~$6,000
- Cost of solar thermal system: $3,900
- Grants, loans, tax benefits: Focus on Energy demonstration grant; Wisconsin Public Service/US Department of Energy solar water heating pilot program; Wisconsin Public Service PV research project
- Electricity costs/yr: ~$1,800
- Natural gas cost/yr: ~$375

ENERGY AND ENVIRONMENTAL BENEFITS

- Projected electricity production: 620 kWh
- Electricity load offset: 10 percent
- Heating costs offset: 55 percent (compared to similar house in area)

Annual Pollution avoided: 7067.0 lbs CO_2; 2.58 lbs NOx; 4.95 lbs SO_2

(Calculations based on: 1.988 lbs CO2/kWh; 4.16 lbs NOx/MWh; 7.99 lbs SO2/MWh; 117.08 lbs CO2/MMBtu)

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