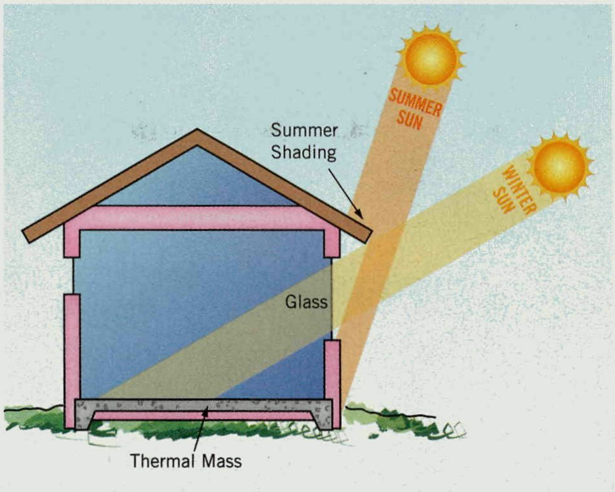
PASSIVE SOLAR Design Basics

Plan a comfortable, energy-efficient home that saves you money on heating and cooling.

By David Wright

Passive solar design begins with the simple idea that you can build a house that uses *natural* heating, cooling, ventilation and daylighting. These homes require much less fossil fuel energy to heat and cool than conventional homes do, which is better for the environment and saves passive solar homeowners money. Passive solar homes are comfortable to live in because they are designed to radiate heat in winter, maintain a comfortable year-round temperature, ventilate naturally, and let in plenty of natural light.

I became interested in sustainable design, specifically passive solar design, as a young architect — first while working in the Peace Corps in Africa, and later while working professionally in New Mexico. The details of any particular passive solar home design depend on the climate and the specifics of the site. Over the course of my 35-year career, I've designed a variety of passive solar houses throughout the country using different configurations of south-facing windows, sunrooms and other passive solar design features. (For specifics on one of them, see the sidebar below.) What follows are the principles used to design any passive solar home.



NATE SKOW; BELOW & PAGE 57: DAVID WRIGHT

The angle of the sun changes throughout the year, so a well-designed home can let in the sun in winter while blocking it in summer.

House Orientation and Window Placement

The first consideration for optimizing passive solar energy is to select a house site with adequate solar exposure. For solar heating in winter, a good measure of solar exposure is to have at least four hours of direct solar gain on the winter solstice. The best orientation is to have the "solar" side of the house face within 15 degrees of true south. In climates where summer heat is a major concern, it's a good idea to aim the solar windows a little east of south to get morning sun in winter and avoid the intense western sun in the warm season.

Typically, you would locate the day-use rooms, such as a living room or family room, on the south portion of the home's floor plan to allow the greatest amount of solar energy to penetrate these rooms on winter days. This layout also allows you to take advantage of the sunlight and view of the outdoors.

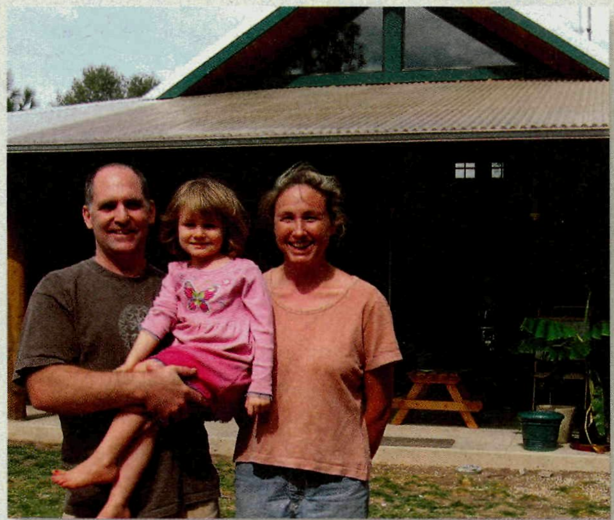
The "shell" of the house is composed of exterior insulated walls and "glazing," or windows. In a conventional home, the window area is equally distributed on all four sides of the home, or the majority of the window area may be focused on the direction

The Western Solar Farmhouse: A Passive Solar Design

Dick and Becky Myers wanted to do more than just add a few passive solar elements to their new home—they wanted to be energy independent. The first step toward meeting that goal was designing their home to take advantage of passive solar heating and cooling.

The house I designed for them is a three-bedroom, 1,850-square-foot home located in the foothills of the Sierra Nevada Mountains of California, a climate with hot summers and some snow in winter.

The basic form of this home is what I call the "Western Solar Farmhouse." The floor plan is arranged around a central great room with a high-vaulted gable roof. Around the sides of the central great room are grouped rooms or porches with a lower-pitched hipped roof. The porches can go around all sides as they do in the classic plantation house design that's built in tropical climates with shade cooling and "outdoor" rooms. The Western Solar Farmhouse's central living area is typically a rectangle, and the solar gain rooms would usually be located on the long solar side. The great room also hosts the family hearth—a fireplace or woodstove to provide heat and perhaps be used for cooking.



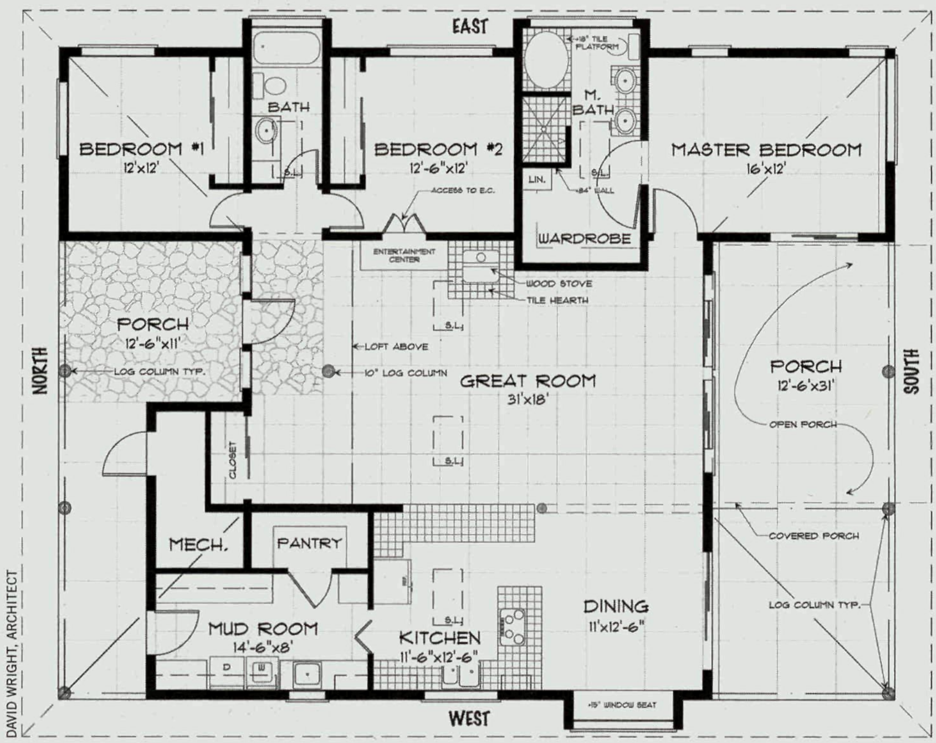
The Myers family lives in a passive solar home. See Page 57 for a look at the interior and Page 60 for the floor plan.

The south-facing porch can be glazed in as a sunroom, which can heat the house and add pleasant living space.

Adjustments often need to be made to fit the exact site. In the case of the Myers' house, the available house pad was narrow and long on a north-south axis, so I placed extra glass on the south-facing great room for more solar heat gain. The bedrooms are along the east side, a cooler part of the house where they also get morning sun. The kitchen, utility and mechanical rooms are on the west side.

Dick and Becky report that their house has performed extremely efficiently since it was completed in 2004. They have a radiant heating system but have not needed to use it, relying instead on passive solar heat and a woodstove. They are off the grid, have a solar water heater, and use solar electric panels with battery storage for all of their power needs (plus a small generator for backup). By working with the sun, the Myers family has met their goal of being as energy independent as possible.

Plans for this house and other passive solar houses are available at www.davidwrightarchitect.com.



Above and right: A sketch and floor plan of the Western Solar Farmhouse, an example of a passive solar home design. This home is described in more detail on Page 59.

with the best view. For a passive solar design, one would locate more of the window area on the south side, which has the best solar access. Some windows would be placed on the east and west sides of the house for daylighting and cross-ventilation with only a few windows to the north.

The glazing is important. Choose high-quality, tightly constructed windows to reduce air infiltration. At a minimum, use double-insulated glass. Some of my favorite high-quality windows are Loewen metal-clad wood windows, but all-vinyl windows are more economical and perform well. Double glazing is adequate for most climates, although in locations with severe winter conditions, triple glazing is advisable to reduce heat loss and condensation on the glass.

I usually recommend clear double glass for solar-oriented windows and "low-e" glazing on the other sides. Low-e glazing limits incoming heat in summer and reduces heat loss from the inside in winter. Using clear glass on the south wall windows allows more of the sun's energy to warm the house in winter, when the sun will be able to enter the house through the south-facing windows. In colder climates, using insulative window drapes or blinds at night helps reduce overnight heat loss and increase comfort.

Natural Ventilation and Cooling

In summer, you may want shade over the south-facing windows to avoid overheating. At this time of year, the sun will be at a higher angle in the sky, so with a well-designed roof overhang, you can let in the sun during winter while blocking it in summer. A porch outside these windows can also provide shading, or you can use open beams with solar shade cloth, lattice or any kind of sun filtering material added as needed for seasonal shading. It is a good idea for a solar facade to be somewhat flexible to adapt to variable weather conditions. Deciduous trees and vines can also be used to provide shade during summer.

Be sure to consider cross-ventilation, too. Windows and doors should be placed carefully around the house to naturally ventilate and cool each room. I also use vent skylights (such as those from *www.velux.com*) high in the vaulted ceiling to allow daylighting and create natural "stack-effect cooling," which is what happens when the hot air rises up and out. Interior windows, doors and transoms can facilitate natural convective airflow throughout the house. To supplement, I use Casablanca-type ceiling fans (available at *www.casablancafanco.com*) to mix the warm air in winter and provide air movement in summer.

In cool or moderate climates, a passive solar house will not require any air conditioning and will be comfortable inside simply with natural nighttime ventilation cooling. When the outdoor temperature drops below the inside temperature, you just open up the house and let it breathe. By morning, it will be nice and cool inside. In designs with limited natural ventilation, a whole-house fan can be used. In hotter, drier climates, you might consider an evaporative cooler (such as those at *www.coolerado.com*) to supplement cooling.

In cold climates, I recommend heat-recovery ventilators (HRV). These units expel stale air and bring in fresh air through an air-to-air heat exchanger, recovering more than 60 percent of the heat from the exhaust air. These systems are important in snow country, where windows and doors are kept

Passive Solar Design Principles

- Areas for daytime use should have good solar exposure
- Solar shading for summer
- SIP walls (R-24+) and roof (R-31+), almost zero infiltration
- Nontoxic materials
- Perimeter slab insulation (R-10)
- Ceiling fans for ventilation and cooling
- Stone veneer and hard plaster walls for thermal mass
- Clear insulated glazing for south-facing windows
- High-quality windows with at least double panes

shut in winter and houses are thermally tight. Heat-recovery ventilators can be on a timer or indoor air-quality sensor to prevent over-ventilating, and with a little creative design, you can replace bathroom fans with this one central unit.

Corrugated metal roofing is a good choice for a passive solar house because it deflects much of the sun's radiant energy while also reducing the heat transferred to the roof surface below. Because of its undulating configuration, little of the material touches the roof, minimizing its heat conductivity. Additionally, if you install a vent ridge cap, air will circulate upward in the furrows, letting heat escape naturally while drawing cooler air under the roofing.

Adding Insulation and Thermal Mass

Insulation is a vital part of any energy-efficient home. I have been using structural insulated panels (SIPs) in most of my designs for many years. SIPs are sandwich panels with solid polystyrene (styrofoam) in the middle and oriented strand board structurally laminated to each side. One of the advantages of SIPs is that, if properly used, they are almost airtight, so a home will have minimal air infiltration. Keep in mind that you would also likely need to use mechanical ventilation, such as an energy recovery ventilator, for an airtight house to maintain indoor air quality while also maximizing energy efficiency.

Other options for wall and roof insulation include batts, granular loose-fill insulation and sprayed-on foam. The minimum R-factor in most climate zones should be R-19 walls and R-31 roofs. With SIPs, I like to use a minimum of 6-inch walls (R-24) and 8-inch roof panels (R-31). It's also important to use perimeter-edge insulation (available at *eeform.com*) if building with concrete slab on grade, particularly if you're using radiant floor heating.

Another key to making passive solar design work properly is thermal mass.

Think of thermal mass as a sponge that absorbs solar heat during the day and slowly releases it at night. In general, the more distributed the thermal mass, the better. I often use masonry interior walls, stone veneer and dense interior plaster to absorb heat throughout the house. Another good way to add thermal mass is with an exposed, dark-stained concrete floor. The thermal mass keeps a home from overheating during the day and stores heat for nighttime comfort. Concrete floors and other types of mass also help with summer cooling if you flush out the heat during the cooler nights.

Additional Home Heating Equipment

For heating, I prefer radiant-heated floors, which distribute heat by piping hot water through the flooring. This technique usually requires a natural gas or propane boiler instead of an electric one, or you could use solar thermal or wood systems to heat the water. Radiant floor heating costs more initially to install, but it's also more efficient and comfortable than forced-air heating, and in some situations, it can be more cost-effective.

Other heating options include a woodstove, a solar heater, a geothermal heating and cooling system, or a small conventional heating and cooling system.

Whichever option you choose, you'll use less energy than you would in a typical home, because the passive solar design of the house will minimize your need for additional heating, cooling and lighting.

David Wright is a solar environmental architect located in Grass Valley, Calif. In 2008, he was the winner of the Passive Pioneer Award from the American Solar Energy Society. His 1978 book, *Natural Solar Architecture: A Passive Primer*, recently has been updated and republished as *The Passive Solar Primer: Sustainable Architecture* (see Page 64 to order).