Low-tech Solar

Before considering PV panels, integrate passive strategies into the core of your home's design to reap savings in heating and cooling costs

BY BRIAN KNIGHT

Building in harmony with nature has always made sense to me, but the consequences of not doing so hit home when I through-hiked the Appalachian Trail after high school. Along the way, I saw trees withering on ridgetops and tasted snow tinged with coal-stack pollution. In the middle of the woods, I could still hear the drone of combustion-generating traffic. The experience would never leave me.

As a biology major at Appalachian State University, I gravitated toward sustainable building and graduated with degrees in construction and appropriate technologies. After working for a time with a large national homebuilder, I set out on my own. I wanted to return to what I had learned in college about how a well-constructed building envelope could drastically reduce energy use and environmental costs. Passive-solar design, which employs a tight envelope along with various methods of solar control to heat and cool homes without mechanical means, was a natural next step.

My first experience building a passive-solar home, based on a design I purchased from architect Debra Coleman (sunplans.com) was unlike any project I'd worked on. Though I worked through the winter, the house had plenty of light, stayed comfortable during cold snaps, and allowed materials to dry faster. Seeking opportunities to build more passive-solar homes in my own town, I started designing an affordable, three-bedroom, two-bathroom plan that could fit a variety of site conditions.

A simple form

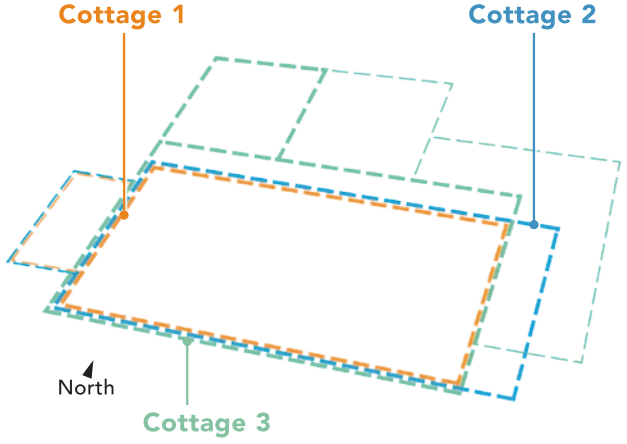
Asheville, N.C., is in climate zone 4, which has both heating and cooling needs. I wanted a design that would be efficient to heat and

Photos this page: courtesy of the author

A SIMPLE, APPEALING FORM

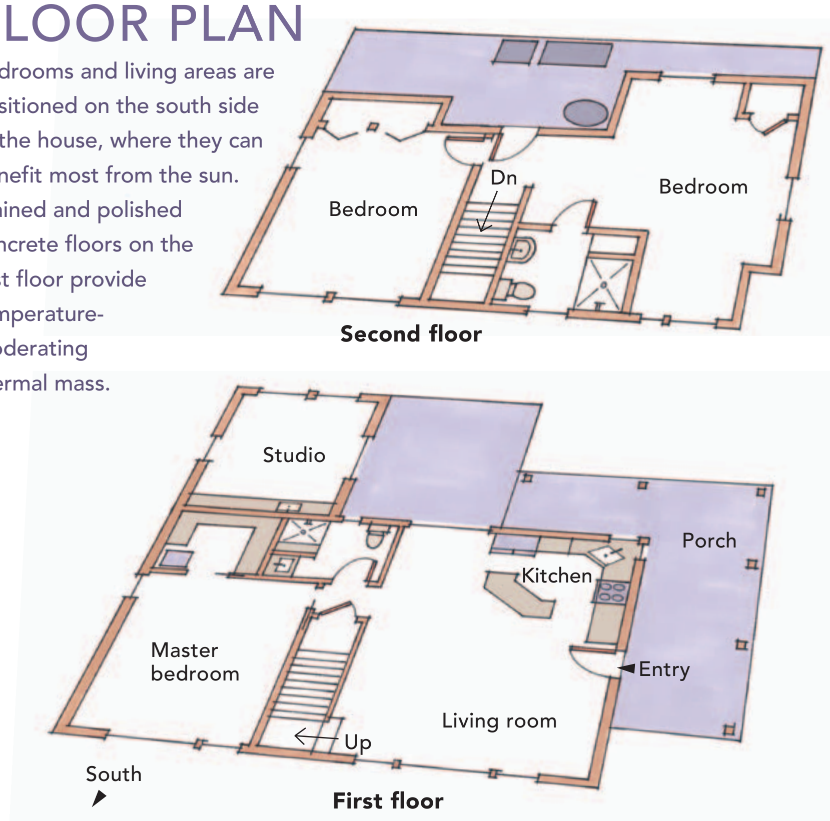
Based on a rectangular footprint stretched east to west, the Springtime Cottage plan minimizes glass on those sides and on the north (photo, cottage 3), and maximizes it on the south (photos, cottages 1 and 2). The kitchen, bathrooms, laundry, and closets are situated on the north side to keep the south elevations open for glazing. The floor plan is easily flipped to adjust to lot demands—for example, the entrance to cottage 3 was moved from the east to the west side—and it can be expanded to meet clients' wishes, as cottages 2 and 3 demonstrate. Each time, the sun-facing window area was increased to maintain an optimal glass-to-floor-area ratio.

	Cottage 1	Cottage 2	Cottage 3
Size:	1433 sq. ft.	1544 sq. ft.	1908 sq. ft.
HERS:	51	47	47
Airtightness:	0.9 ACH50 (0.062 cfm50 per sq. ft.)	0.85 ACH50 (0.054 cfm50 per sq. ft.)	0.75 ACH50 (0.05 cfm50 per sq. ft.)
Slab:	R-10	R-13	R-13
Foundation:	R-10	R-15	R-15
Walls:	R-25	R-25	R-26.4
Roof:	R-38	R-38	R-38
Certifications:	Energy Star, Green Built NC Gold	Energy Star, Green Built NC Platinum	Energy Star, Green Built NC Platinum



A SOUTH-FACING FLOOR PLAN

Bedrooms and living areas are positioned on the south side of the house, where they can benefit most from the sun. Stained and polished concrete floors on the first floor provide temperature-moderating thermal mass.



cool with an air-source heat pump, the most common appliance for space conditioning in the area.

The plan I came up with, which I call the Springtime Cottage, not only fills this need but has become a valuable tool for educating prospective clients on the basics of good passive-solar design. Since 2010, I've built three Springtime Cottages, adjusting them each time for client and site.

Knowing that passive-solar design must account for the seasonal path of the sun, I started my cottage plan with a rectangular footprint stretched from east to west, with most of the windows facing south. A rectangle works particularly well for mixed and warm climates like this one because it reduces the wall area and windows exposed to extreme sun angles in the east and west. In fact, I'd argue that in cooling-dominated climates, minimizing western sun exposure may be more important than designing for the winter sun to the south.

In terms of passive-solar design, there are only so many ways to design a small, open floor plan when you put a master bedroom on the main floor, as I wanted to do. I arranged the kitchen and bathrooms on the north side to keep the south elevations open for glazing, but I included enough solid wall on the south side to resist shear forces and to create opportunities for furniture placement. The plan also allowed for modest alterations in room arrangement and square footage based on clients' needs.

It's all about the envelope

Free heat is better when it sticks around for a while, so in my opinion, designing for passive solar is almost worthless without a good thermal envelope backing you up. In fact, I would say that a tight envelope trumps orientation and the amount of sun-facing glass—two topics that get a lot of attention in passive-solar circles.

This makes air changes per hour (ACH) possibly the most significant factor in passive-solar performance. My crew's airtightness goal for the cottages was a blower-door reading of 1.5 ACH50 or less. We surpassed that goal with readings ranging from 0.9 ACH50 on the first cottage, to 0.85 ACH50 on the second, to 0.75 ACH50 on the third. We did this by targeting specific areas of concern, including the masonry-to-framing transition, the windows, and the wall-to-roof transition (see "Harvesting heat and making it last," facing page).

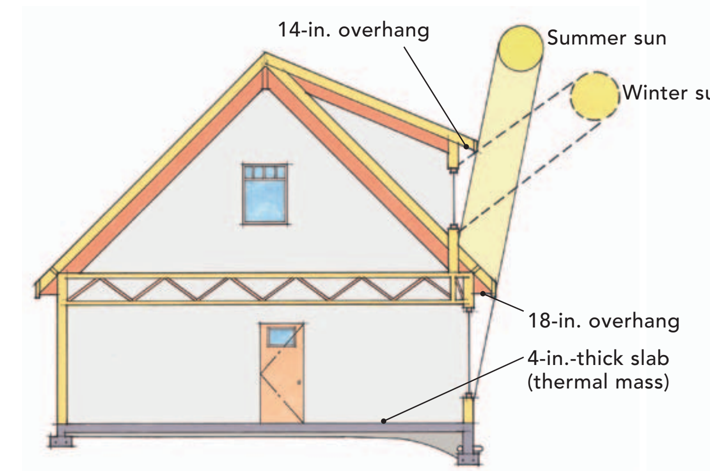
To avoid thermal bridging and performance problems resulting from gaps in traditional insulation, we turned to Eco-Panels, polyurethane-foam structural insulated panels (SIPs), from a local manufacturer. With space at a premium, it's tough to beat the support and the R-value (R-25) you can get out of a 4½-in.-thick SIP wall. The third cottage used open-cell spray foam combined with Zip System R-Sheathing for an R-26.6 wall. We also used R-40 Eco-Panels to eliminate thermal bridging and reduce air leakage through the roof. These panels are supported by rafter beams that have been left exposed to create a steeply vaulted ceiling.

Windows selected for solar gain

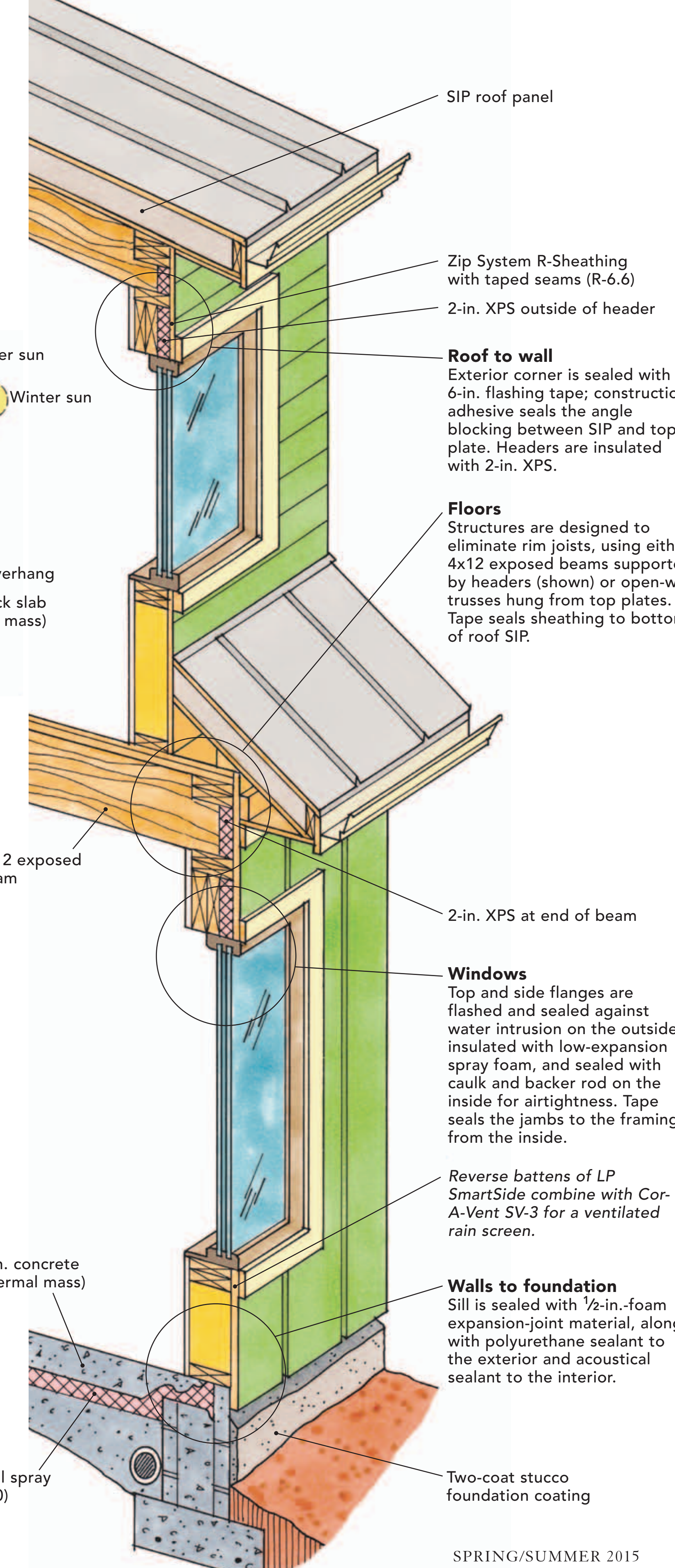
Windows play a critical role in passive-solar design, and getting the right windows in the right places can have a significant impact on a house's comfort and performance. The degree to which a house employs the sun's warmth for conditioning is often described by the ratio of sun-facing, high-solar-heat-gain glass to heated floor area. (In the northern hemisphere, *sun-facing* refers to the

Drawings: Martha Garstang Hill

HARVESTING HEAT AND MAKING IT LAST



Combining a tight, well-insulated envelope with strategic sun-control measures yields a home that's comfortable year-round. The depth of overhangs and their distance above the window are calculated to address window size, the presence of thermal mass, and the latitude of the house (drawing above). Meanwhile, air leakage is kept at bay with meticulous air-sealing at critical points in the building envelope—including where the roof meets the walls, where the framing meets the foundation, and around windows. The thermal boundary is improved with SIPs on the roof; depending on the cottage, walls are made of either SIPs or 2x6s with Zip System R-Sheathing (drawing right).



Sunny side up. *Extensive glazing on the south side of the house captures winter sun on the bleakest days, and the thermal mass of the concrete floor harnesses it.*

windows on the south side of the house.) For most homes, the ideal window-to-floor-area ratio (WFR) for passive-solar design ranges from 9% to 12%, although houses with high-performance envelopes may be better served by holding that WFR at 5% to 7% to prevent overheating during warm periods of spring and especially fall. (This is known as *sun-tempered*.) In the cottages, I aimed for a WFR of about 10%.

For south-facing windows, it's extremely important to specify high-solar-heat-gain glazing, with a whole-window solar-heat-gain coefficient (SHGC) of at least 0.40 (a better target is 0.56). Be aware of the difference between glazing-only SHGC and whole-window SHGC, which tends to be a lower number because the frame and mullions are taken into account.

To balance costs and performance, the window area should be reduced on other sides of the house in order to include more glazing on the south side. Likewise, using more south-facing glass with a lower SHGC will yield results similar to using less glass with a higher SHGC, but this approach increases the materials cost and heat loss when the sun isn't out in cold weather. To be sure you get the energy performance you expect, check your glazing plan using energy-modeling software. Resfen 3.1 is an excellent resource that's very easy to use and can help you balance window performance and window costs.

Although they get less attention, window size and style affect performance as well. Compared to multiple windows, a big window of the same area has less air leakage and thermal bridging, better SHGC values, and simpler flashing and trim requirements. Upfront costs and potential maintenance are also dramatically lower with fixed windows, making it possible to upgrade to better windows without increasing costs simply by choosing fixed windows where operable ones are not needed. I found in building the cottages that one operative window per average-size room, large enough for egress, is sufficient for ventilation.

Divert what you don't need, capture what you do

Carefully placed porches, overhangs, and landscaping can contribute to blocking unwanted solar heat in warm weather while admitting it during the winter when it's needed. I've used all in my cottage design.

Overhangs are architecturally engaging and can be a cost-effective way to maximize passive-solar performance, particularly in cooling climates and on houses with higher percentages of south-facing glass. Overhangs work best when they're integral to a home's design, which is the approach I took for the cottages. Climate, deciduous shading, and angling of the house off true south can all influence effective placement of overhangs. There are a number of online tools to help calculate overhangs; I use one by Sustainable by Design (susdesign.com) out of Seattle.

While overhangs block the sun's energy, thermal mass embraces it. Thermal mass refers to a material's ability to store heat. The use of high-thermal-mass materials to moderate temperatures by holding and releasing that heat gets prominent play in many discussions of passive-solar design. I think its importance is overblown, however. While thermal mass can certainly improve performance and reduce overheating, in my experience, heavy reliance on thermal mass is expensive and has less of an impact than other variables.

In the Springtime Cottage design, our thermal-mass strategy is simply to avoid crawlspaces in favor of a slab. We build stemwalls, fill them with gravel, and pour a 4-in. slab, which provides good thermal mass while eliminating concerns about indoor-air quality associated with crawlspaces. In our last two cottages, we used 2 in. of closed-cell spray foam for an R-10 layer between the slab and the gravel. This decouples most of the slab from the ground and brings it inside the thermal envelope.

Not only does this concrete layer provide thermal mass at a very low cost, but once stained or polished, it makes an attractive finished floor that offers the best of both worlds: beauty and free heat. □

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