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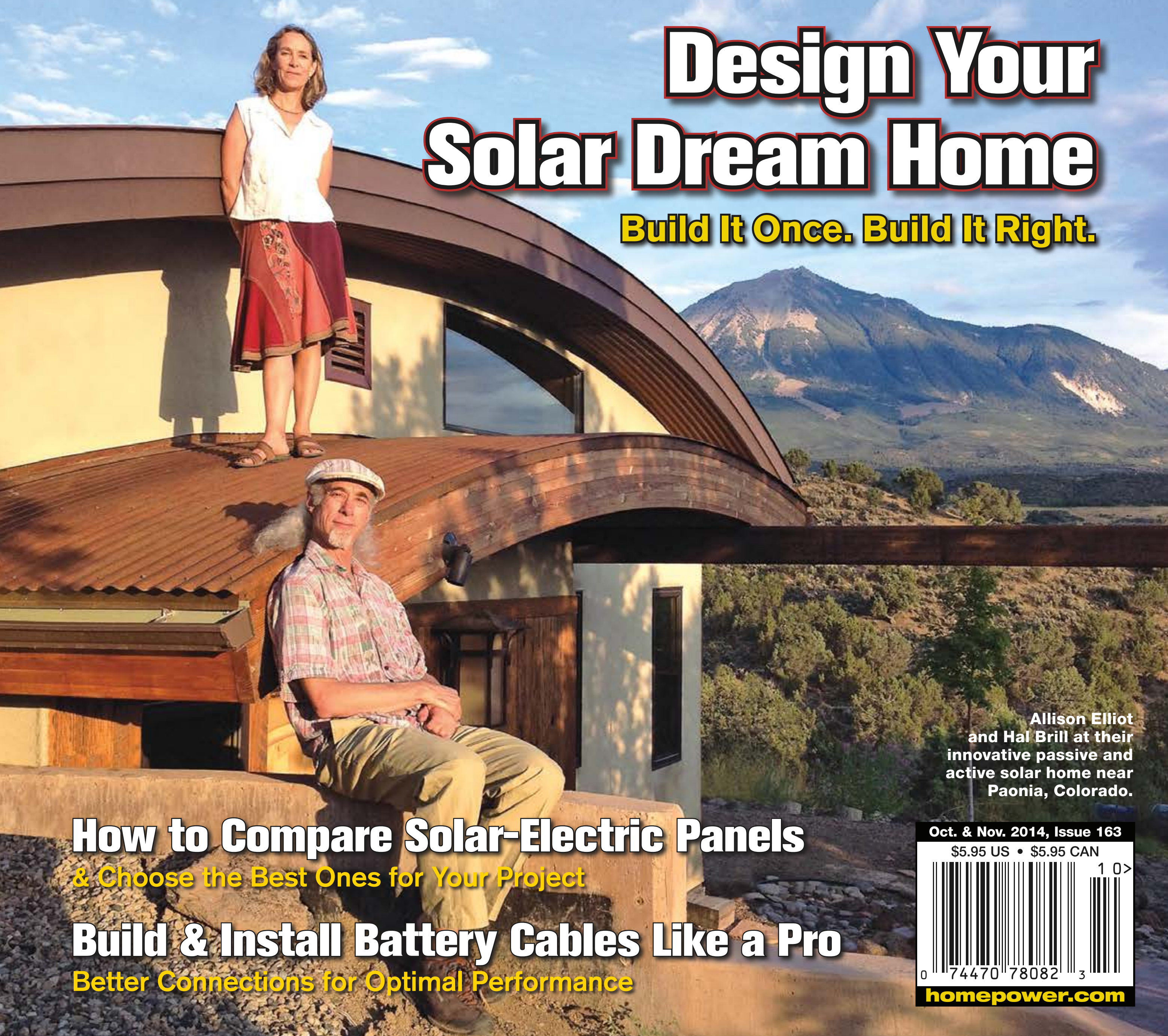

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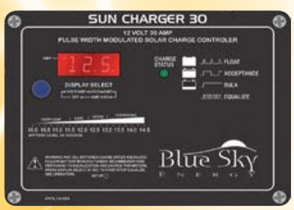



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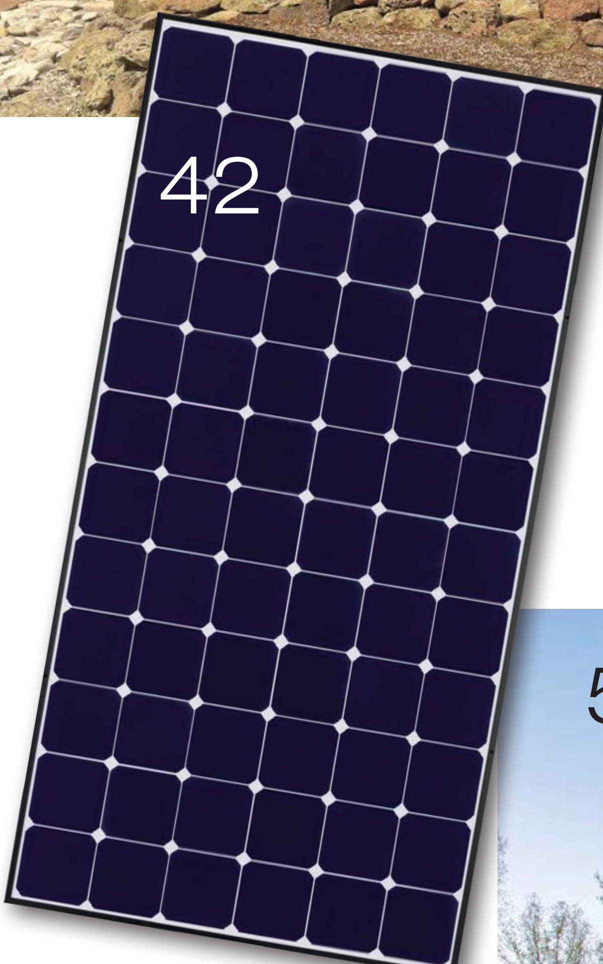
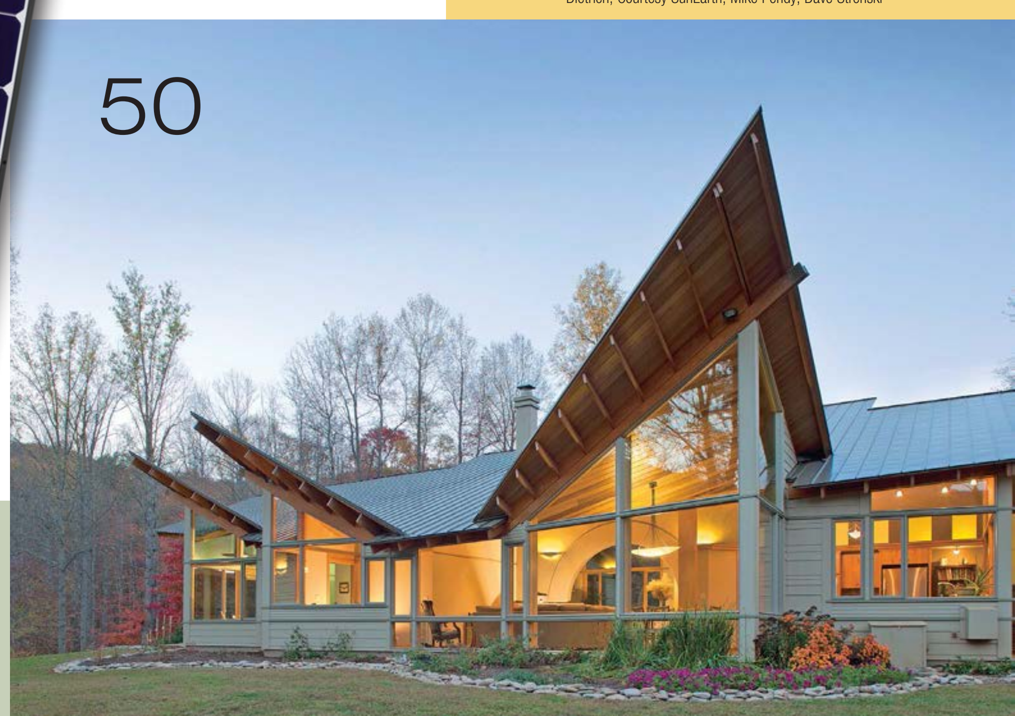


DIY Efficiency

Switch your linear tube fluorescents to LEDs—see "Methods" on page 16.



On the Cover

Allison Elliot and Hal Brill at their innovative passive solar, net-zero energy home in Colorado.

Photo by Mike Pendy

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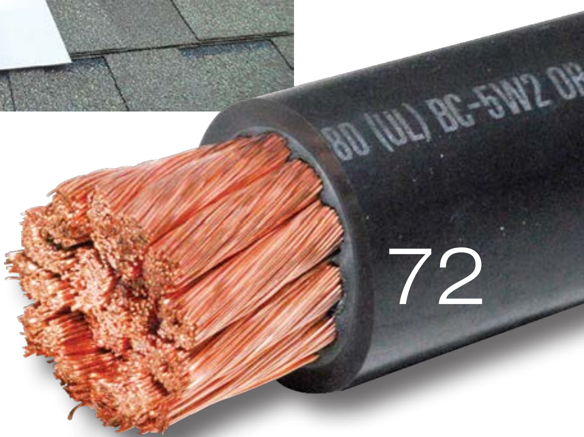

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Up Front

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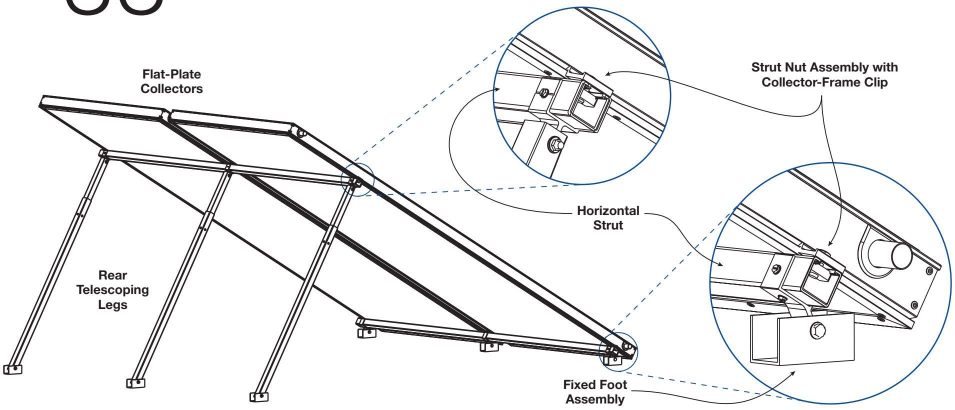

In Back

Home Power (ISSN 1050-2416) is published bimonthly from offices in Phoenix, OR 97535. Periodicals postage paid at Ashland, OR, and at additional mailing offices. POSTMASTER: Send address corrections to Home Power, PO Box 520, Ashland, OR 97520.

Solar Industry Hits High Notes

Courtesy David Brearley

A year has gone by since I attended Intersolar 2013 and wrote about the disappointment of solar marketing with "booth babes." I am happy to report about some notable industry conference trends in that department. Having attended Intersolar in San Francisco this July (held in partnership with the ASES national solar conference), I noticed a significant decline in "booth-babe" marketing stunts. Other positives were networking events, forums, and panel discussions specifically designed for promoting women working in the renewable energy industry.

When it comes to employment in the solar industry, men outnumber women five to one, so I think it is fantastic to see efforts made toward evening the gender gap. At the panel discussion, Anna Bautista from Grid Alternatives, Jan Hamrin of HMW International, Claudia Wentworth from Quick Mount PV, and Christie McCarthy of Vista Solar and Creotecc provided inspiration to women looking to enter or advance in the solar industry by sharing their personal stories of where they came from and how they have navigated their way to become key industry players.

Further displaying their creative and progressive nature, Claudia and Christie have helped establish another great conference event—the Solar Battle of the Bands (SBoB). SBoB showcases the musical prowess of solar industry insiders, and as a music-loving solar nerd, I consider this event "betta' than Christmas." Looking across the dancing crowd, all you can see are thousands of smiling eyes beaming at the stage in appreciation for all our shining solar brothers and sisters.

Founded in 2011 by Johan Alfsen and Meghan Vincent-Jones of Quick Mount PV, this event has grown from 500 attendees in 2011 to more than 1,200 this year. This event was born out of a desire to bring two passions together—music and solar—and has risen to become perhaps the best marketing and networking event solar conferences have to offer. This year, bands from five companies—Exosun, Inovateus Solar, RGS Energy, SolarCity, and Sungevity—competed for best band.

The 2014 SBoB started with Christie McCarthy—backed by Quick Mount PV's house band, Northerner and the Rafters—singing her original solar anthem, "Rise and Shine." This year's highlights included Exosun's Exoband from France (complete with striped shirts, berets, and a keytar), who offered up songs from the White Stripes and Daft Punk, and even added a fun French number—"Je Veux du Soleil" by Au P'tit Bonheur. Inovateus Solar's Reverend Ray and the Everlasting Incentives provided great stage antics and costumes (i.e., lots of sweat and sequins), classics from the Rolling Stones and an original song, "New Paradise," written for the industry and a clean-energy world. SolarCity's The SoulMetrics delivered an impressive performance including Mumford and Sons' dreamy "I Will Wait." RGS Energy's Public Energy #1 performed a fantastic guitar solo during "Magic Carpet Ride" by Steppenwolf. But it was the reigning champs, Sungevity's The Killa Watts!, who took the title again this year with their funky soul sound, including "Jungle Boogie" and "Leave My Kitten Alone."

At the end of the night, we are left marveling at how companies that compete every day for our solar business can come together in harmony to create a wonderfully fun event.

—Justine Sanchez, for the *Home Power* crew

web extra

Listen & watch the SBoB at **solarbattleofthebands.com**.

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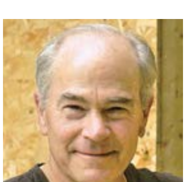
In 1977, **Windy Dankoff** started a business in New Mexico to supply wind power to off-grid homes. In 1980, he began to use photovoltaics for homes and well pumps. Eventually, his company, Dankoff Solar Pumps, became a worldwide supplier. Windy credits his success to taking a whole-system approach to energy efficiency. He retired in 2005 and continues to write, teach, and explore.

Kelly Davidson lives in Longmont, Colorado, where she and her husband are upgrading their 1970s trilevel home with insulation and new doors and windows, in preparation for a PV system in the coming years. The upgrades are being made possible by low-interest loans through the local Energy Smart program.

Penny & David Eckert live on their 40-acre homestead in Orleans, California, where they enjoy experimenting with the latest in renewable energy technologies, including their grid-tied RE system. Penny still works from home part-time as an environmental permitter, but David is fully retired, which means he never gets a day off from doing chores and projects!

Christopher Freitas is an engineer and project manager for international RE projects around the world. He was a cofounder of OutBack Power Systems and director of engineering at Trace Engineering, both located in Arlington, Washington.



Scott Gibson writes mostly about energy-efficient and green residential design. His work has appeared in a number of magazines and websites, and he is a contributing writer to *Fine Homebuilding* magazine and Green Building Advisor. He and his wife live in southern Maine.

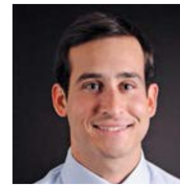
Thirty years ago, **Kathleen Jarschke-Schultze** answered a letter from a man named Bob-O who lived in the Salmon Mountains of California. She fell in love, and has been living off-grid with him ever since. *HP1* started a correspondence that led Kathleen and Bob-O to *Home Power* magazine in its formative years, and their histories have been intertwined ever since.

David Laino puts his aeronautical and mechanical engineering knowledge to use at work designing wind turbines for Endurance Wind Power, and for fun, sailing on the Chesapeake Bay in Maryland.

Ryan Mayfield is the principal at Renewable Energy Associates, a design, consulting, and educational firm in Corvallis, Oregon, with a focus on PV systems. He also teaches an online course in conjunction with *SolarPro* magazine and HeatSpring.

Gary Reysa is a retired aircraft engineer who now tries to keep up with his grandkids. In his spare time, he runs the Build It Solar website—a site for people who want to build their own renewable energy projects. Gary lives in Bozeman, Montana, amid a zoo of solar projects.

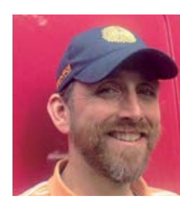
Justine Sanchez is *Home Power*'s principal technical editor. She's held NABCEP PV installer certification and is certified by ISPQ as an Affiliated Master Trainer in Photovoltaics. An instructor with Solar Energy International since 1998, Justine leads PV Design courses and develops and updates curriculum. She has her bachelor's degree in physics from the University of Colorado at Boulder and worked with the National Renewable Energy Laboratory (NREL) in the Solar Radiation Resource Assessment Division. After leaving NREL, Justine installed PV systems with EV Solar Products in Chino Valley, Arizona.



Martin Smith is an associate at Kaplan Clean Tech Education, formerly CleanEdison, where he researches and writes about clean energy industries. KCT delivers professional education for certifications and designations in the green design and renewable energy sectors.

Dave Strenski and his family have lived in Ypsilanti, Michigan, for more than 17 years. His full-time job is working as an application analyst for Cray Inc., a company that manufactures high-performance computers. Dave holds degrees in surveying, and civil and mechanical engineering, and has been playing with solar power since 2005.

Carol Weis is a NABCEP-certified PV installer and ISPQ Master PV Trainer. She writes curricula and teaches international PV classes to local technicians and end users. She has worked as a licensed electrician and solar installer in Colorado and worked as part of Solar Energy International's PV technical team for 15 years.



Vaughan Woodruff owns Insource Renewables, a solar contracting firm in Maine. Vaughan has developed curricula for and is currently teaching two online courses—Solar Approaches to Radiant Heating (through HeatSpring) and Solar Heating Design & Installation (through Solar Energy International).

Home Power senior editor **Ian Woofenden** has lived off-grid in Washington's San Juan Islands for more than 30 years, and enjoys messing with solar, wind, wood, and people power technologies. In addition to his work with the magazine, he spreads RE knowledge via workshops in Costa Rica, lecturing, teaching, and consulting with homeowners.

Contact Our Contributors

Home Power works with a wide array of subject-matter experts and contributors. To get a message to one of them, locate their profile page in our Experts Directory at homepower.com/experts, then click on the Contact link.

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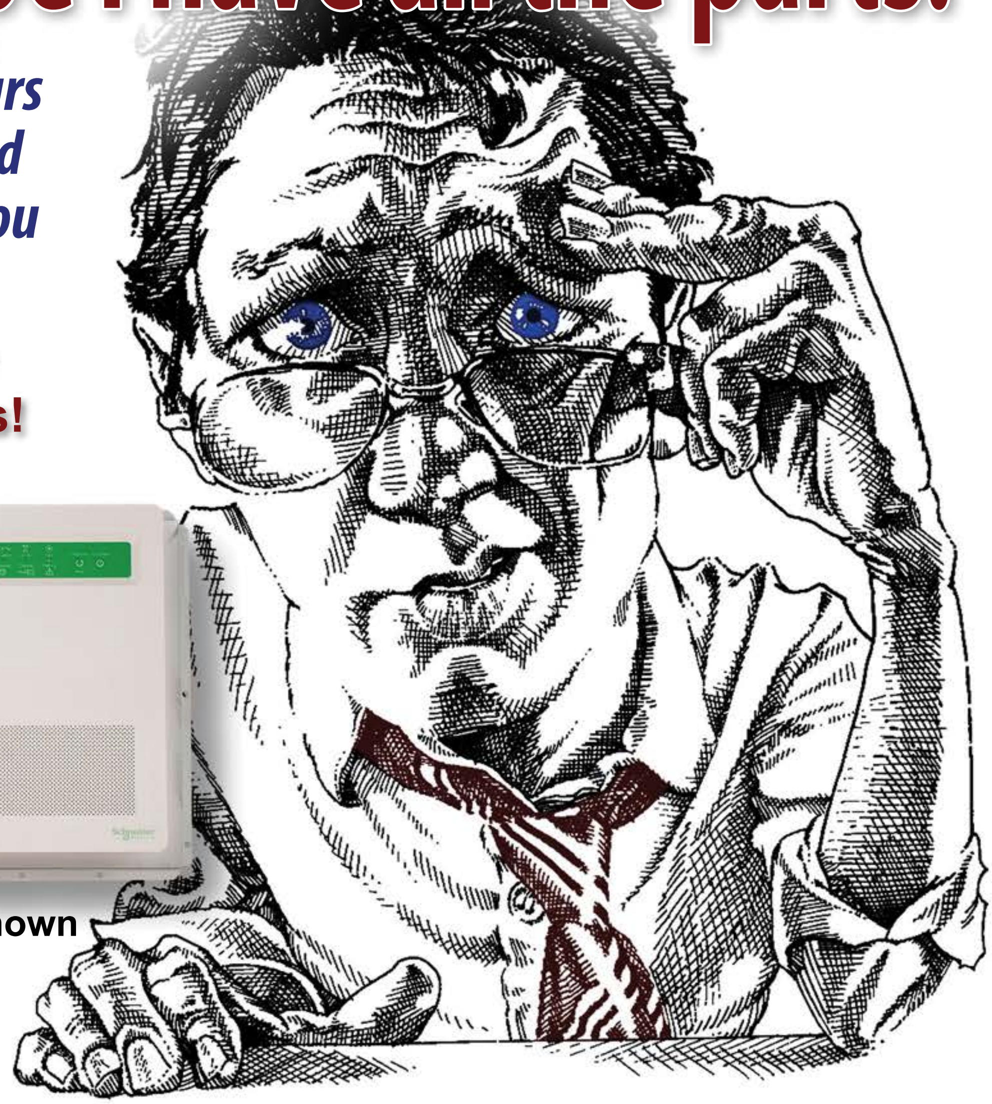

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Shawn Schreiner

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11/09/14	Fort Collins, CO	Intro to Off Grid Systems - Off Grid Reality
11/10/14	ONLINE	Grid-Direct Solar Electric Design & Installation
11/10/14	ONLINE	Renewable Energy for the Developing World
11/10/14	ONLINE	Battery-Based Solar Electric Design

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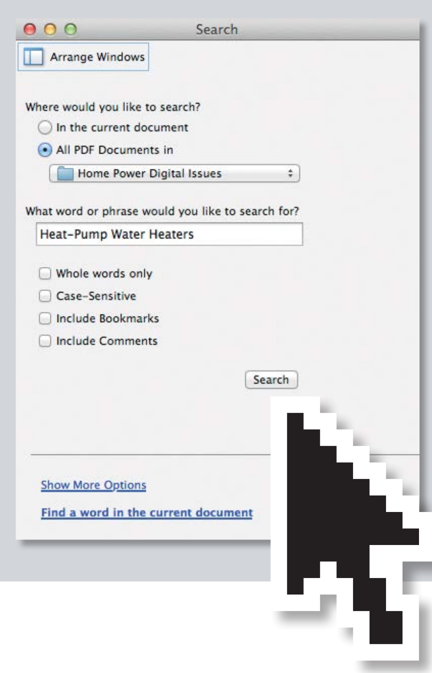

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Courtesy SolarEdge

SolarEdge

Rapid Shutdown Function

SolarEdge (solaredge.com) inverters now have the rapid shutdown functionality that the 2014 *NEC* Section 690.12 requires. The inverters' provider has completed Intertek Laboratories (ETL) testing to verify that its SafeDC technology meets the requirements.

Turning the inverter's safety switch to the off position de-energizes PV source circuits to less than 30 VDC in less than the *NEC*'s required 10 seconds. For equipment manufactured prior to built-in rapid shutdown functionality, SolarEdge offers kits for field-retrofitting inverters to meet the requirements.

—Justine Sanchez

Courtesy Stion

Stion

Thin-Film Solar Modules

Stion (stion.com) introduced its Elevation Series 3 copper indium gallium selenide (CIGS) thin-film PV modules, available in 140, 145, and 150 W models. Module efficiencies are listed at 13.1%, 13.5% and 14%, respectively. While thin-film modules have historically had low efficiency as a primary drawback, these efficiencies are comparable with crystalline modules that generally range from 12% to about 20%.

Advantages over crystalline include better high-temperature performance (i.e. a lower power temperature coefficient of -0.26% per °C) and less output impact from shade since it is harder to shade the entire cell because it runs the length of the module. Stion modules are available framed (STO model) or frameless (STL model), with glass-on-glass architecture, and are U.S.-made—in California and Mississippi. They are low amperage, high voltage modules (open-circuit voltage (Voc) is around 80 volts), so fewer modules are allowed in series when using string inverters.

—Justine Sanchez

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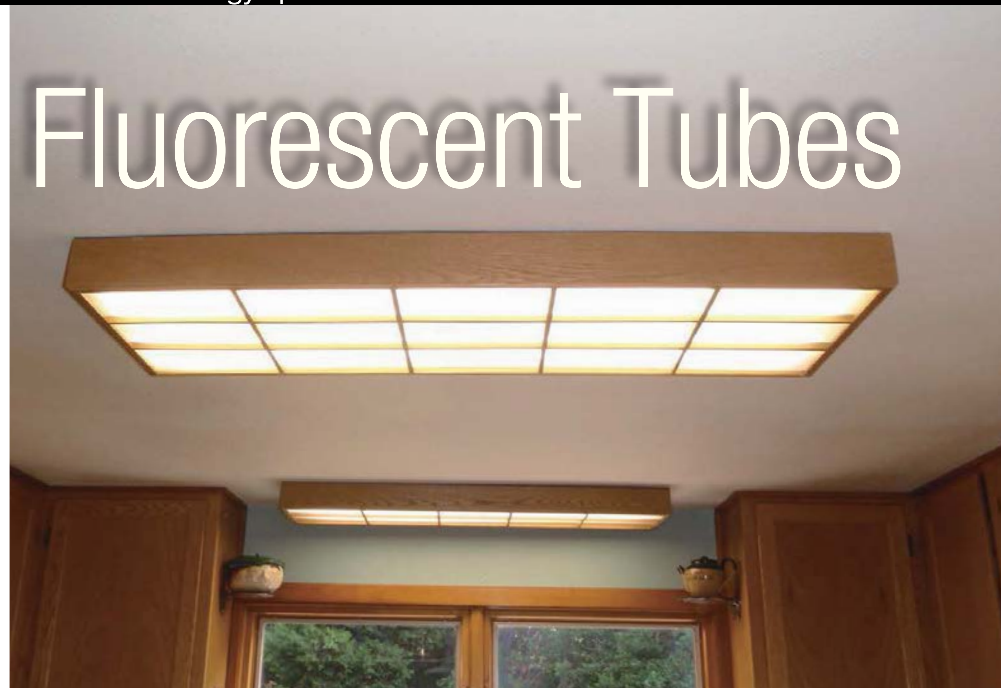
Changing Fluorescent Tubes to LEDs



All photos Penny Eckert

Comment & Discuss this article @ homepower.com/163.16

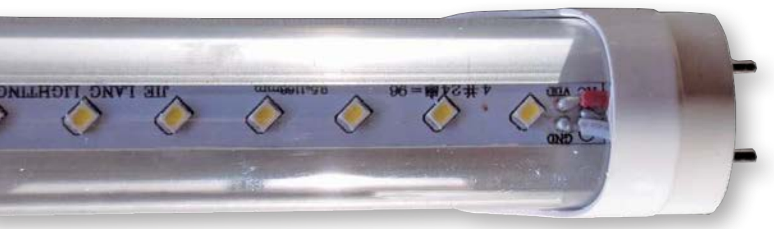
My husband David and I have been switching all of our home's lamps to LEDs. For lighting efficiency, you can't beat 'em. Most replacements were straightforward—unscrew the old compact fluorescent bulb from the light socket and screw in a new LED. But replacing our 32-watt T-8 linear fluorescent bulbs with 20-watt LEDs required some tinkering.

The LED bulbs will physically fit into the 4-foot-long fluorescent fixtures. However, the ballasts will ruin new straight-LED bulbs. Some LED bulb manufacturers offer bulbs that can work with the ballast in place, but they are less efficient and more expensive. (For more pros and cons on replacing fluorescent tubes with LEDs, see bit.ly/tubereplacement.)

Here are the steps we took to replace our old T-8 linear fluorescent bulbs in an older kitchen fixture:

Step 1: Be Safe

Turn off the electricity. The "lock-out, tag-out" approach is safest—turn off the breaker that supplies power to that fixture. Tape a note over the breaker that explains you are working on a fixture and to keep the breaker off. Inform other people in the house what you are doing. Also make sure you wear eye protection—this is especially important should an old fluorescent bulb shatter while you are removing it.



Step 2: Remove the Bulbs

You may need to remove a fixture cover to expose them. In some states, fluorescent bulbs are considered hazardous material. They contain mercury, and should not be thrown in the trash but must be taken to a disposal center (some hardware stores serve as drop-off points). See bit.ly/lamprecycle for regulations in your state.

continued on page 18

Step 2: Carefully remove the fluorescent bulbs.

Step 3: Remove the ballast wiring cover and ballast.

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continued from page 16

Step 3: Remove the Ballast

Remove the cover(s) from the ballast and wires and unscrew the ballast from the unit. Remove the ballast from the fixture wires, leaving enough of the black (typically "hot" or energized) and white (typically neutral) wires from the center to reach the socket wires. We threw the old ballasts in the trash. There are no regulations regarding their disposal and no recycling programs available for them.

Step 4: Rewire

Next, connect the fixture and socket wires together, then replace the wiring cover. The most straightforward way to rewire the fixture is to twist the wires together with the properly sized wire nuts. In our case, there were two yellow wires on the left side; and two reds and two blues on the right side. Regardless of the colors, the important thing is to put all the wires from one side together securely with one of the leads from the center (i.e., the incoming circuit wires), and all of the wires from the other side together with the other lead.

Some replacement LED tubes are made with both the hot and neutral connection on one side. In that case, you'll need to rewire the sockets and follow the LED bulb manufacturer's instructions.

Step 5: Install LEDs

Take the LED bulbs out of their packaging, peel off the protective plastic, and remove the tip guards. Install the bulbs as you would a fluorescent T-8, inserting each end into the slots and twisting to lock each into the receptacle, with the LED string facing down. All bulbs should be tightly seated.

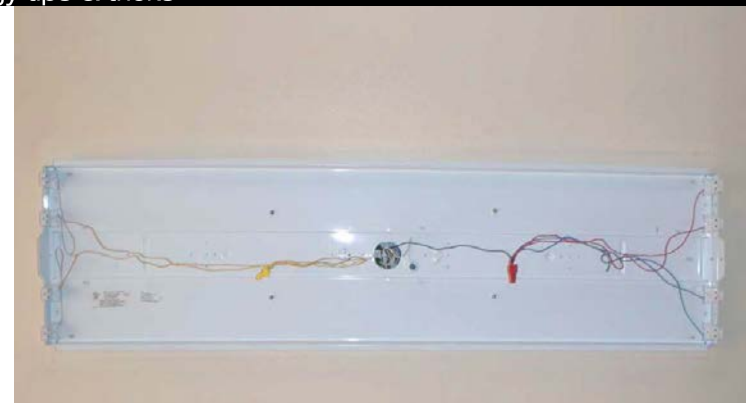
Step 6: Try It Out

Return to the breaker box, remove your note, and turn on the breaker. Test the light and replace the cover, if your fixture has one.

Let There Be Light

If in the future someone mistakenly installs fluorescent bulbs into the fixture, the bulbs won't work, but won't be harmed. It's a lot like what happens when the ballast dies on an old fluorescent fixture—no light. Just in case, consider placing a sticker on the wiring cover noting that the fixture is wired for LED only and has no ballast.

We tested a new two-bulb fixture fresh from the store with the old T-8 fluorescents and with the new LED bulbs. The fluorescents, despite being rated at 32 watts, drew 45 W each, while the LED bulbs (rated at 20 W) drew 19.9 W each. We typically run the lights four hours per day, 365 days a year, and our electricity costs us $0.17 per kilowatt-hour. In this case, our annual savings will be $6.23. Our LED bulbs cost $12 each, so it will take a couple of years to recover the cost of the replacement.



Step 4: Rewire electrical supply to opposite ends.

Step 5: Reassemble wiring cover and install LED bulbs.

Step 6: Close the breaker, hit the switch...ta da!

The light quality in the kitchen is very good—the bulbs provide the same amount of light as the old fluorescents, but with a nicer color cast and no flicker. The lights take about 1 second to come on fully.

—Penny & David Eckert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Future Renewable Energy Users

For those of us who have solar-electric systems on our rooftops, one of the best ways to promote renewable energy is to welcome tomorrow's science, technology, engineering, and math (STEM) leaders to tour our homes. Living in a university city has provided me with this opportunity for the past four years after installing a 5 kW PV system.

During July 2014, the College of Engineering and Engineering Technology at Northern Illinois University in DeKalb hosted a weeklong Engineering Summer Academy for high school students. Outreach coordinator Brian Long indicated that "this intensive summer camp challenges students to explore a specific area of engineering. Students perform several hands-on learning experiments in our state-of-the-art laboratories, working alongside engineering faculty, alumni, and current students."

While touring the PV system at my home, the students assembled into groups of four and cycled through several hands-on activities including:

- Investigating the effect of shadows on energy production
- Using a pyranometer and inverter output to determine the efficiency of the PV array
- Viewing sunspots and solar prominences through a telescope
- Investigating historical household production and consumption of electricity as well as calculating tons of carbon dioxide avoided
- Studying the concepts of kW and kWh in relation to computing the charging time for my 2011 Chevy Volt
- Viewing energy.gov's Energy 101 videos on concentrating solar and PV power.

These students asked thoughtful questions and proceeded through the hands-on activities with great enthusiasm. It was an honor for me to have the opportunity to host them on what turned out to be a beautiful, sunny, cool morning. I am confident that with students such as these throughout our great country, our energy future is in great hands.

Richard Born • DeKalb, Illinois

Courtesy Richard Born

Motion Sensors?

Jeff Siegel's letter on "Automatic Energy Savings" ("Mailbox" in *HP159*) raises expectations too high for room-occupancy sensor switches. To do their job, these switches must have heat or motion and light sensors, plus a decision-making circuit. Parasitic energy consumption for various switches runs between 0.9 and 5.2 watts—just for the switch. That's as much as 3.7 kWh a month wasted on having a sensor acting as your electricity nanny. It's cheaper just to use LED lights and hope you remember to turn them off more than half the time.

Worse, most light switches are wired to the AC "hot" leg only, with no "neutral" present in the switch-box. That means the switch must be designed to either pass a nonstop small current to the load, or else to allow a "load" current in the equipment ground wire, which used to be a safety violation.

Jeff wrote a letter, not a full article, so there was no space to distinguish between switches that are "manual, on/auto, off" and the "auto on/auto off" type. There was no room to discuss the value of prime-time energy savings versus off-peak consumption. The whole question is way too complicated to allow a simple answer. My preference is to skip the sensor switches: "It's better manually!"

Joel Chinkes • Photon Harvest Company

Utility Policy

I would like to see an article comparing the major utilities' policies toward renewable energy (RE). I am motivated out of disgust about the attitude of my own provider (Mississippi Power), which requires paying fees for a net usage meter of $0.53 per day! I find this outrageous—some simple arithmetic will show that about 1 kW of additional PV capacity would be required to offset that cost. For example, to install a grid-connected PV system on my home, I would have to size it first to my anticipated usage, and then add another 1 kW of capacity just to offset the cost of meter rental!

My state has absolutely *no* incentives for RE installations, and although Mississippi Power is a member of the TVA Network, they choose not to participate in any of TVA's incentive programs. A particular kicker is that I live in southwest Mississippi, only about 5 miles from the Louisiana border, and Louisiana has some of the nation's *best* incentives. I guess I'm curious whether other utilities around the nation have similar policies, and if they do, what might be done about it. I realize that there are hundreds of power suppliers and an article encompassing all of them would be enormous, but a study of the major providers and their policies would certainly be well-received, particularly by those of us who are adversely affected by their utilities' greedy policies.

Frederick Smallwood • via email

Energy Star

I love the buckets of information you folks share, but for shame! Your glossary at homepower.com/glossary says that Energy Star identifies "the most energy-efficient products on the market." My understanding is that Energy Star products meet the *minimum* recommended efficiencies. This in no way means they are the *most* efficient. Consumers need to be educated to look deeper than a sticker, and not be led to believe all is equal.

Consumers generally don't think enough about efficiency and the cost of using a product over its full lifetime. They put too much focus on purchase price. When multiple products all have an Energy Star sticker, the most expensive product may

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have the least cost of ownership due to the lower energy use, yet the misled masses tend to go with the lower purchase price. After all, the products all are Energy Star-certified, right? As global warming makes news regularly, energy costs are going to climb, and energy conservation will blossom in North America. Please watch how the message is presented. I am sure your use of "the most" did not mean the absolute most, but not everyone receiving the message understands this. Keep up the great work.

Dwayne Jones • via e-mail

Thanks, Dwayne—we have edited the listing appropriately. For more practical energy efficiency and life-cost information, we like the Enervee website (enervee.com).

Traveling Highlights RE Options

I am a retired psychology professor who taught cross-cultural psychology, and used anthropological methods to design contextually valid school curricula in a number of developing countries. On recreational trips to Uzbekistan and Nepal, my wife and I saw solar-electric systems that your readers might be interested in.

In the Himalayas, most of the tea/guest houses rely greatly on solar power, both for the usual residential requirements and for recharging the computers, tablets, phones, and other devices used by trekkers and climbers. Many visitors bring their own portable solar chargers. In 2011, the world's highest webcam—solar-powered—started broadcasting images of Everest from the top of an adjacent peak, Kala Patthar (see bit.ly/EverestWebCam). This project was started with Italy's National Research Council in conjunction with the Nepal Academy of Science and Technology.

Recently, we stayed at a small desert encampment in Uzbekistan. We depended upon solar-electric modules to fulfill most of our electricity needs. We were also impressed with the announcement that Uzbekistan, with its 320 days per year of sunshine, will be the first central Asian country to build one of the world's largest solar power plants (100 megawatts) with the assistance of the Asian Development Bank. In 2012, Uzbekistan opened an international solar energy research facility in Tashkent, and hopes it will eventually become a solar energy exporter.

I have also observed the use of solar-electric modules for power generation in rural areas of India and parts of Africa. Solar power is also sometimes captured with parabolic mirrors for use in cooking. In addition, energy is occasionally generated from methane derived from human and animal waste. We've seen lots of creative and innovative renewable energy options in our travels!

David Baine • Edmonton, Alberta

Errata

In "Gear" (*HP162*, page 19), the Schneider inverter model number should have been listed as XW+ 6848 NA instead of 6648.

In "Mountain Solar" (*HP162*, page 39), the price for the Empire Masonry Heaters Phoenix kit, including the core, doors, cleanouts, damper, and a pizza/bread oven, should have been roughly $4,800 ($3,900 plus $900 for the optional bake oven).

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Water Pumping

I have a typical rural water system—a jet pump pulling water from a shallow well and pumping into a pressure tank. When we lose electrical power, we have no water—a situation that I would like to remedy with as much simplicity as possible.

I would like to install a DC-powered pump in the well and have it run whenever water is needed in the house, eliminating the need for a pressure tank, an elevated storage tank, or a storage tank with a pressure booster pump.

I've made the assumption that once the lines in the house have been filled by the pump, they would remain pressurized, and a flow sensor or pressure sensor could be used to turn on the pump. I would use batteries to power the pump with DC, and charge them from the grid. Our water usage is less than 100 gallons on most days. Even a worst-case draw of 500 gallons per day at 5 gallons per minute (which I think is more than we need) would require 100 minutes of actual pump run time. My well pump is 17 years old, and I want to be ready with an alternative when it fails.

Jim Yannaccone • Turbotville, Pennsylvania

Your project has several variables, so let's take them one at a time. First, the pump: A jet pump (like yours) works from above, "pushing" some of the water down one pipe to help push more water up a larger pipe. It is the *least* energy-efficient type of well pump. In your quest to protect your water supply from power failures, you are correct to seek a more appropriate pump.

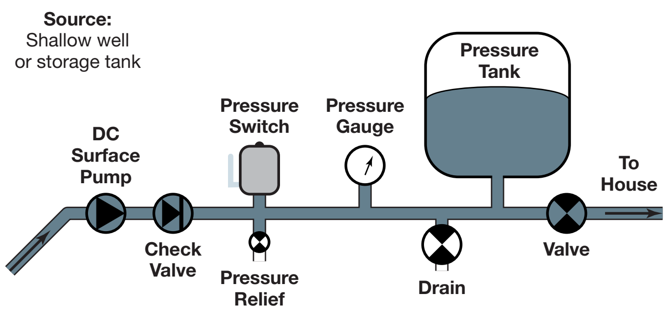
If your groundwater is no more than 20 feet below your wellhead (at pump level), a surface pump should work. A low-power, efficient DC surface pump to supply low water needs like yours would be the Flowlight Booster Pump, available from many off-grid RE suppliers.

However, if your groundwater level is (or may ever be) more than 20 feet down, a submersible pump is the best choice. Your well casing—the outer plastic or metal pipe that defines your well—will need to be no smaller than 4 inches (inside diameter). If you have only a 2-inch well casing (the minimum for jet pumps), you will need to have a new well drilled to use a submersible pump.

Specialized DC pressurizing pumps like this Flowlight Booster Pump use less than half the energy of conventional pumps.

Courtesy Solar Power & Pump Co.

DC Surface Pump System



A variety of submersible pumps are compatible with solar electricity. Contact an experienced designer and supplier of solar pumps, specifically for a battery-based system that can supply the lift plus the pressure that you require. If you don't have a local off-grid specialist, then check the Internet for an experienced solar pump supplier. If your water is not more than 200 feet down, you can install the pump by hand on flexible pipe, without heavy equipment.

You will need some form of storage and pressure delivery. If you use a solar pump without a battery (that is, PV-direct), you must have water storage and it will need to be elevated to deliver pressure. To deliver adequate pressure for a modern home (43 psi), though, your storage tank would need to be 100 vertical feet higher than your house. Most folks aren't able to meet that kind of tank height to create the pressure they want. So I'd advise keeping your pressure tank—the modern alternative to the elevated tank—since it imposes no significant energy loss. Using a pressure tank also helps modulate the pump's run time, so it can run for a few minutes, then stop. As water is drawn out and the pressure drops, the pressure switch will trip and re-activate the pump. I recommend using a pressure tank with at least 40 gallons of capacity to minimize the pump's on/off cycling.

Along with a pressure tank, running your pump on demand (when water is needed) using a battery system would be a great solution. (You could also run some lights and other devices from the same system.) If the battery is charged from the power grid, you have what is termed an "uninterruptible power supply." If you use a PV array for primary charging, you'll have more security when the grid goes down. When it's up, you can use it for backup charging.

Windy Dankoff • Founder (retired), Dankoff Solar Pumps

Average Wind Speed

It's common to read about "average wind speed" when deciding whether or not it is worth installing a wind generator at a given site. But it seems unrealistic to talk about average wind speeds, as such. Obviously, if you had winds of, say, 25 mph for half a given amount of time, and 5 mph the other half, the power output would not be the same as if the wind were a constant 15 mph—there would be 125 times as much (theoretical) power generated during the time the wind was at 25 mph than during the time it was blowing at only 5 mph. So shouldn't this be taken into account when analyzing a potential wind site?

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CGS1	1.883	0.369	16.1	3.157	16.1	3.157	5075.84	995.263	5.1	
CGS2	1.844	0.362	16.02	3.141	16.02	3.141	5073.55	994.814	5.1	
[illegible]	1.917	0.376	16.05	3.147	16.05	3.147	5085.58	997.173	5.1	
[illegible] Systems	11.333	1.476	96.34	12.593	96.34	12.594	30566.28	3983	30.6	

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Furthermore, does it make sense to you that a wind system at my home could *theoretically* generate as much power in one or two days of 40 to 50 mph winds than could be generated over the rest of the year's average winds of less than 5 mph? After all, a 50 mph wind would generate (again, theoretically) 1,000 times the power that a 5 mph wind would generate over the same time span.

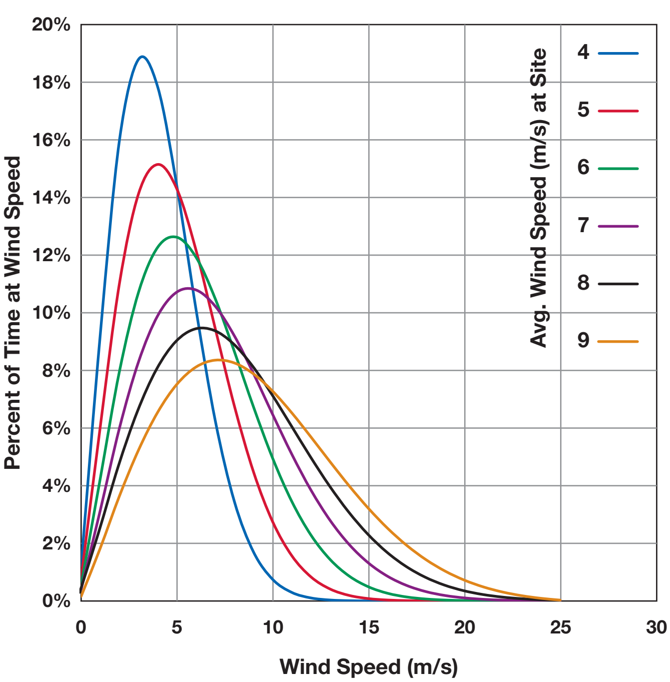
Malcom Drake • via email

You are absolutely correct that average wind speed alone does not provide enough information to determine energy potential. What is required is the distribution, which specifies the fraction of the time the wind speed spends in a particular range. Because it takes years of recorded data to provide an accurate distribution for a site, assumptions are often made. The typical assumption (based on much experience and measurement) is that the wind speed follows a predictable distribution—a common one that is fairly accurate for most sites is the Rayleigh distribution. For small wind turbines, a Rayleigh distribution is what the Small Wind Certification Council uses for the certified annual energy production curve based on the certified power curve. If an average wind speed is provided with no other context, the assumption is most likely a Rayleigh distribution.

As for building a turbine for rare, high winds—the economics are likely unworkable. The unit would have to be very stout—and hence prohibitively expensive—and it would sit idle most of the time, as the startup speed would be high due to its mass and inefficiency in light wind. When the winds did blow fast enough, it would indeed produce a lot of power, but then you'd have to find a way to store the energy. Energy is power multiplied by time: a large amount of power for a small period of time could be equal to small amounts of power for longer periods of time, and a wind turbine designed for the latter scenario would be much cheaper.

David Laino • Cofounder, Endurance Wind Power

Rayleigh Distribution of Avg. Wind Speeds



Wind speed distributions can be used to approximate real-world conditions (and therefore, wind system performance) at a site.

In the summer, attic insulation helps reduce heat gain through the ceiling to living spaces below. In the winter, it helps slow heat loss from the interior spaces.

Cooling & Insulation

I just read Claire Anderson's article "Design with PV in Mind" in *HP154*. We live in Massachusetts in a 60-year-old home, although the second story of the house was added 12 years ago. During this past heat wave, when temperatures were in the high 90s, our bedroom temperature reached 88°F. Will adding insulation to the attic to bring it up to modern standards keep upstairs rooms cooler during the summer?

Denise Sheppard • via email

Added insulation in the attic will make the upstairs rooms more comfortable in the summer. It will also reduce your cooling and heating loads, saving you money on your utility bills.

Just to give a rough idea of your savings, consider this: Let's assume your attic is 1,500 square feet and it is currently insulated with 6 inches of loose-fill fiberglass for R-13. On a hot summer day when the attic temperature is around 120°F, the heat gain into the living space through the ceiling is 5,800 Btu per hour. Nearly a half ton of air conditioning would be needed to take care of that heat gain.

Adding 16 inches of cellulose over the existing insulation will give you R-60, dropping the heat gain from 5,800 to about 1,250 Btu per hour—a reduction of nearly 0.4 tons of air conditioning, which will make it easier for your upstairs cooling system to keep the temperatures lower. (The winter savings for this insulation upgrade in Boston, if you are heating with electricity at $0.12 cents per kWh, would be about $430.)

Before adding new insulation, seal all of the air infiltration pathways between the living area and the attic—including around wiring, plumbing penetrations, ceiling light fixtures, vent fans, and the attic hatch. In many homes, these leaks are the single largest source of air infiltration, and plugging them will reduce your heating and cooling bills and reduce the chance of moisture problems in the attic. This sealing is a lot easier to do before the new insulation goes in. This is also a good time to seal and insulate any heating or cooling ducts in the attic.

Gary Reysa • builditsolar.com

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Courtesy Nunatak Alternative Energy Solutions

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Calculating Solar Capacity

What should be the power rating of a solar-electric array if I wish to use a 1 kW load all day?

Arvind Agarwal • via homepower.com

It's important to be realistic about the load. Unless this is a remote telecommunications site or something similar, it's doubtful that you have a 1-kilowatt load that's always running. Most loads vary by the time of day and other factors.

The first step in sizing a solar-electric system is to do a load analysis. In an on-grid situation, this can come from your utility bill. Look for the average kilowatt-hour (kWh) usage per billing period.

If you don't have a useful utility billing to work with, you either need to measure the loads, or do some estimating. For multiple loads in the system, I recommend a detailed spreadsheet or list showing each load with its watts and predicted hours of use. A watt meter can determine an appliance's true power consumption. With this information, you can calculate the watt-hour energy usage of each device, and add them up to get a daily kWh number.

Next, determine the solar energy available at your site. Find the "daily peak sun-hours" number for your area. It's generally easy to find this number via print and online resources (see homepower.com/121.14b). Peak sun-hours refers to the solar energy available. It's based on your local weather, but doesn't take into account the specifics of your individual site, such as shading from trees or buildings. If you intend to supply this load with an off-grid PV system year-round, you will need to choose the worst case for sun-hours, which is usually in the winter.

Once you have the sun-hours figure, you may need to modify it because of shading at the installation site. You can quantify the shading with a tool such as the Solar Pathfinder and then factor it into your calculations.

Next, you need to derate the solar-electric module's STC power rating to reflect what it will actually produce. PV module specifications are from unrealistic laboratory conditions (at 1,000 watts per square meter at a 25°C cell temperature). In the real world, they don't see these conditions very often—especially that low of a temperature. When modules get hot, their voltage drops and performance suffers. So it's necessary to apply a derate factor, which is in the general range of 0.60 for off-grid battery-based systems and 0.75 for grid-tied batteryless systems.

A 1 kW continuous load would require 24 kilowatt-hours per day (1 kW × 24 hours). If your location has 4 peak sun-hours, 15% shading, and you want a batteryless grid-tied system, the numbers might look something like this:

24 kWh per day ÷ 4 peak sun-hours per day ÷ 0.85 shading ÷ 0.75 derate = 9.4 kW PV array.

Or, if you want to start with a specific capacity of PV array, you can work the formula the other way. Working the calculations from PV capacity to load, you might see:

9.4 kW PV array × 4 peak sun-hours × 0.85 shading × 0.75 derate = 24 kWh per day

Taking into account all of the factors—and they will be different in each case—will help you get realistic information about what a solar-electric array will do at your site.

Ian Woofenden • *Home Power* senior editor

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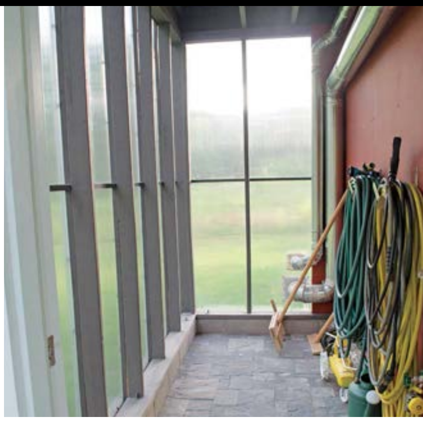
Courtesy William Sikora

The amount of thermal mass in a sunspace affects temperature extremes within the space and the heat available to the adjacent living space.

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Sunspace Thermal Mass

Would you please compare the advantages/disadvantages of a low versus high thermal mass sunspace? It seems to me that a sunspace with high thermal mass would have the advantage. It would heat up during absorption, and then more evenly and over a longer time release this heat back into the house.

Ken Kardong • via email

Deciding on whether it's more advantageous to incorporate a lot of thermal mass into your sunspace depends on what you want to use the sunspace for. If the sunspace is intended for growing plants year-round or if you want the sunspace to be comfortably warm into the evening, then having thermal mass in the sunspace is beneficial. The mass absorbs solar energy during the day, and releases it after sunset, keeping temperatures high enough for plants or people. The mass also reduces the need for backup heating in the sunspace to keep plants from freezing. In addition, a sunspace with mass requires less ventilation, used to prevent overheating during summer days.

If the sunspace is intended primarily for space heating for the house, a low-mass sunspace would be better. The solar energy needs to heat air—instead of mass—which is blown into the house to provide space heating. If you put in a lot of thermal mass, much of the solar radiation will heat the mass and significantly less will heat air for the house. The heat that goes into the sunspace mass is lost very quickly out the sunspace glazing after sunset, and is wasted. If the sunspace has dark-colored, well-insulated, but low-mass surfaces, the sun-heated surfaces quickly get warm, which circulating air then transfers into the house.

The disadvantage of a low-mass sunspace is that it loses heat quickly after sunset—it's not a place you'll want to spend your off-summer evenings, and won't provide much freeze protection for plants. In exchange for much more efficient space heating, you'll give up evening use and winter plant growing.

There are pros and cons to both approaches, and it depends on what you want to accomplish. You can also take a middle path and get some of the benefits of each approach.

Gary Reysa • builditsolar.com

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Light Clay-Straw & Solar

Pair Up for Sustainability & Efficiency

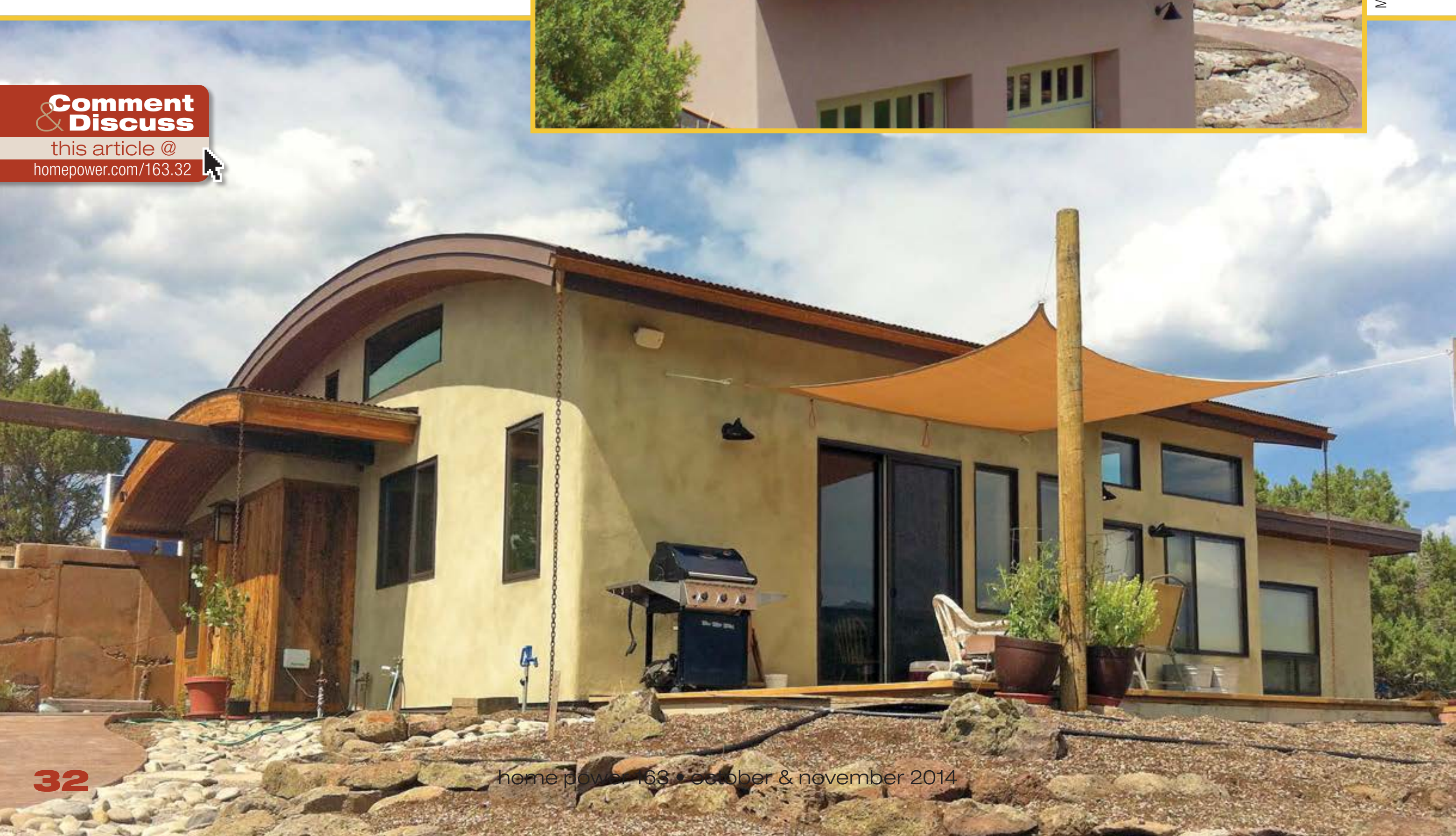
by Kelly Davidson

Hal Brill and Allison Elliot's light clay-straw home brings together passive solar design, active solar technologies, natural materials, and an efficient layout for an energy-saving, durable dwelling.

Right: Before the home was built, the garage was constructed and a grid-tied PV system was installed. The solar electricity that was generated (and credited to the utility account) offset electricity consumed during the home's construction.

Mike Pendy (2)

Comment & Discuss this article @ homepower.com/163.32



HOME POWER (HP): Besides incorporating solar technologies, your home has some unique features. What served as your initial inspiration?

ALLISON ELLIOT: The development process took several years. Key inspiration came from architect Michael Frerking's house that was featured in a 2005 issue of *Sunset* magazine. We fell in love with the curved roof, and that really landed the design for us.

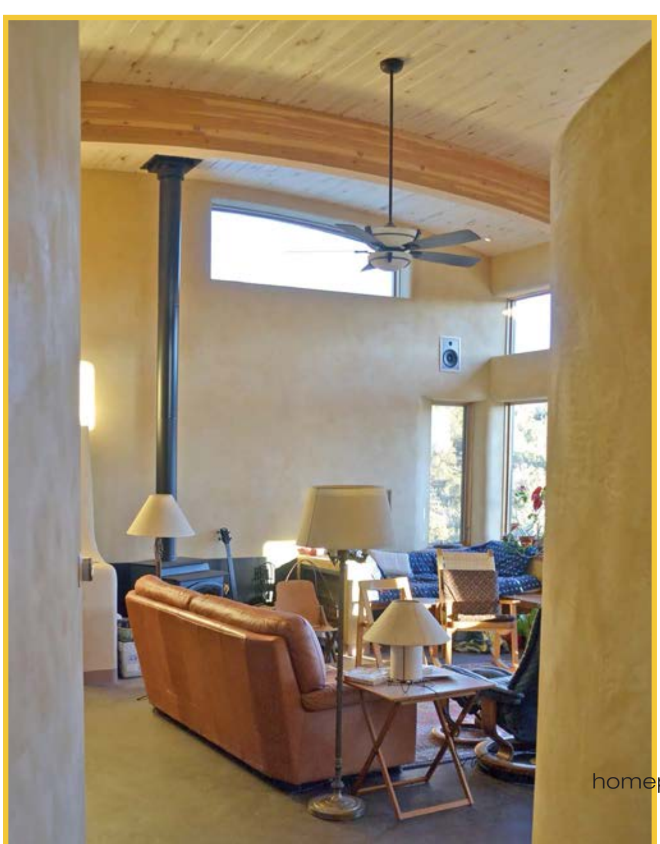
The overall design is dominated by this curve, which evokes Anasazi cliff dwellings and our experiences in the canyons of Utah on raft trips. Our front hall is like a slot canyon—narrow, curving, and emerging into the larger space of the living room. Like a slot canyon, the light you see ahead draws you forward. The walls of our guest and music room—what we call the "flex" room—are of red clay plaster called Bryce Canyon, as if it were the darker, deeper part of the cliff dwelling.

HP: Why did you decide to use clay-straw (or "light-clay") as the wall infill material?

ELLIOT: Through the years, we attended numerous sustainable building conferences, including the International Straw Builders Conference. We were drawn to the idea of straw bale, having had friends who went that route, but we were also intrigued by clay-straw.

HAL BRILL: We were fortunate to be able to tour two clay-straw homes in our area and to see how they performed in both summer and winter. Paonia has large temperature swings—climbing above 90°F in the summer and dipping below 0°F in the winter. We wanted something with enough thermal mass to handle those swings.

Natural materials—from the tongue-and-groove ceiling to the natural clay walls and floor—are cornerstones of this home's design.



Courtesy Dave Houghton

Mike Pendy

Solar collectors, which provide water and space heating, are ground-mounted on the north side of the house.

Clay-straw seemed to be the middle ground. It offers more thermal mass than straw bales but not as much as traditional adobe. There are no voids, and burrowing insects or rodents aren't an issue. Clay-straw walls are also thinner—12 inches versus 18 inches for straw bale—meaning that for smaller building envelopes, you gain more square footage. The thinner walls also enable using a narrower footing, saving on material and costs (see "Building with Clay-Straw Walls" sidebar).

HP: How did your design evolve?

BRILL: Over the years, we had conversations with a dozen or more engineers and architects at various presentations, workshops, and events. From each meeting, we took away input that we incorporated into our plans. The design kept morphing.

ELLIOT: Finally, we took the stack of accumulated plans to Taylor Talmage, the designer at Elemental Design + Build. A few weeks later, he called us back into the office. He had smoothed out all of our pieces, and made it a whole.

HP: What challenges did you face with determining the design?

TAYLOR TALMAGE, DESIGNER: One of the big challenges is trying to give the client everything they want for the price they want. There are always trade-offs that have to be made, and sometimes it is difficult to decide what stays and goes. Green design can add from 5% to 25% to a typical project. In this case, there were certain design elements (like the curved roof) that weren't necessarily "green," but added cost to the project.

HP: What design guidelines or requirements were given to you? How did you approach the project in terms of philosophy or style?

TALMAGE: First and foremost, Hal and Allison wanted their house to be as "green" as possible in materials and in energy efficiency. My job was to hone in on their priorities and refine their vision. They had already decided on the curved roof and clay-straw, but they were unsure if it would be appropriate for their design. After exploring a number of alternative building systems, including straw bale and adobe brick, we determined that clay-straw would work.

The infill clay-straw walls need ample time to dry before receiving exterior and interior finishes.

Courtesy Dave Houghton (2)

The foundation was built with Faswall blocks that consist of concrete-coated wood chips with rock-wool insulation inserts.

We felt it had the best combination of R-value, wall thickness, locally sourced materials, and "feel." From that point on, we explored all the materials in the house, from foundation to lighting, and evaluated them based on a number of criteria, including whether they were eco-friendly, cost-effective, site-appropriate, energy-efficient, durable, recycled/reused, and beautiful.

HP: **What are the key features of the home's passive solar design?**

TALMAGE: The site had perfect solar orientation, which also aligned with the views, which are mostly to the south and southeast. The long side of the building (and the outdoor spaces) faces 20° east of south, which works for passive solar design in colder climates and also maximized the views from the main parts of the house.

I usually use a concrete slab-on-grade for thermal mass and solar gain storage. However, because we were dealing with expansive (swelling) soil, we poured a concrete footer and used Faswall blocks (concrete-coated wood chips with rock-wool insulation inserts) for the stem walls. The wood subfloor was topped with 3 inches of adobe clay for thermal mass. To slow heat loss through the floor, the subfloor was insulated underneath with open-cell

Building with Clay-Straw Walls

Instead of using a conventional insulation, such as cellulose or fiberglass, to fill wall spaces, Brill and Elliot opted for clay-straw. Clay-straw construction combines loose straw with a thin coating of clay and water ("clay slip") to form a thick monolithic wall that offers both the insulating properties of straw and some of the mass-storage capacity of earth.

For the clay-straw infilled walls, the homeowners turned to Don Smith of SmithWorks Natural Homes in Crested Butte, Colorado. After touring one of his local projects, the couple, along with designer Taylor Talmage, was convinced that clay-straw was the way to go. They were natural materials that could be sourced regionally, and the walls would result in an envelope that would provide good thermal performance and comfort, and be aesthetically pleasing. The longevity of the materials also appealed to them.

Today's clay-straw wall building combines tradition with modern equipment and techniques. The process begins with wall forms—the Brill–Elliot house uses a Larsen truss matrix with 2-by-4 verticals inside and out. Plywood gussets connect the uprights, which are spaced at 48 inches on center. Straw bales are broken apart and tossed with a clay slip—a medium-thick mixture of clay and water. (Note: The clay is not pure, but rather loam with a high clay content.) The slip-coated straw is then poured into the forms and compacted by foot or with constructed wooden tampers. After being filled and the mixture tamped, the forms are removed immediately to avoid surface mildew growth and allow the wall to dry. Depending on the season and the climate, drying may take a couple of weeks—or several months.

Once dry, the surfaces of the walls can be finished—they have sufficient "tooth" to receive natural plaster without the need for lathe or chicken wire. In Elliot and Brill's home, lime stucco was used on the exterior. American Clay earthen plasters from New Mexico were used inside. The barley and wheat straw for Elliot and Brill's home came from Colorado's San Luis Valley and the clay was trucked in from about 20 miles away.

While clay-straw walls may be outside the norm in the United States, the practice has a long tradition in Europe, where 12th-century homes built with a mixture of clay and straw fibers still stand. As with any other home, the key to longevity, Smith says, is to properly care for the roof and foundation—the building needs to have a "good hat and boots" (properly sized overhangs and a good foundation) to protect its walls from the elements.

spray foam. The floor also has hydronic tubes embedded in the adobe—they were installed on top of the subfloor and the adobe poured over them.

HP: **What kind of glazing did you specify to optimize solar collection?**

Talmage: We specified low U-factors for all of the Marvin Integrity windows and doors, and a high solar heat gain coefficient (SHGC) for south-facing doors and windows.

The overhangs are 18 inches deep and shade the south-facing windows in the summer without obstructing the spectacular views. Hal and Allison plan to build a secondary shade structure—a pergola—and grow hops on it.

HP: **Did you use energy modeling to determine how the house might perform?**

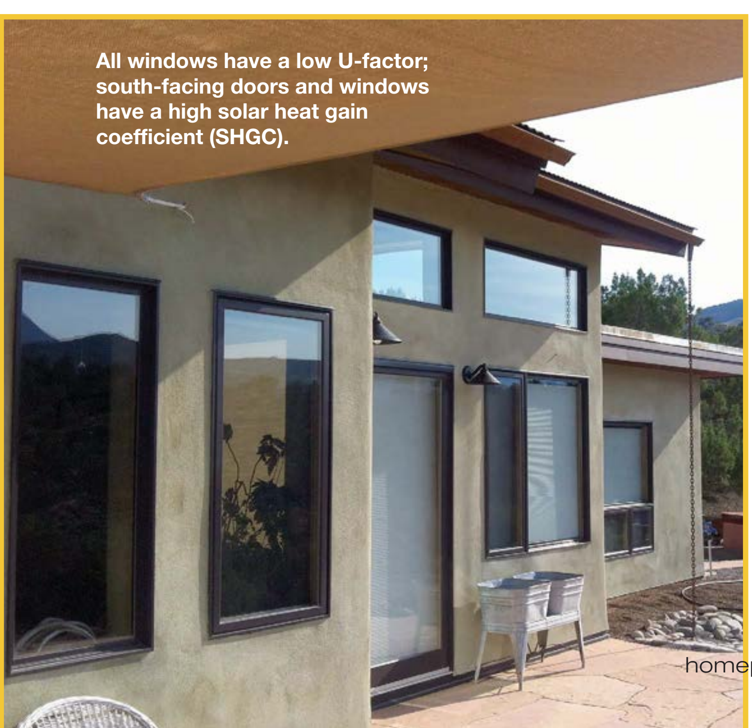
Talmage: Dave Houghton, project engineer for Resource Engineering Group (REG) in Crested Butte, performed an energy analysis, which showed that the home would perform well overall. The actual calculations for heating loads, which were used for system design, indicated a peak heat loss of 17.5 Btu per square foot, according to Zack Gustafson, project engineer at REG.

HP: What other strategies were used with the passive solar design?

Talmage: We took advantage of the sloping site and dug the north side of the building into the hillside. This helps moderate temperatures both in the winter and summer.

Window Specifications

			U-Factor	
Placement	**Glazing Type**	**SHGC**	**No Argon**	**With Argon**
North & East	Cardinal LoE^2-272	0.41	0.30	0.25
West	Cardinal LoE^3-366	0.27	0.29	0.24
South	Cardinal LoE-180	0.69	0.31	0.26



All windows have a low U-factor; south-facing doors and windows have a high solar heat gain coefficient (SHGC).

Mike Pendy

Hydronic tubing was laid over the insulated subfloor (below) and covered with three inches of adobe clay, which serves as the floor surface (right).

Courtesy Hal Brill (2)

HP: **How about insulation?**

Talmage: The walls have an estimated R-value between 18.1 and 19. Closed-cell spray foam was used to insulate the curved roof to R-32.5. Although spray foam is expensive, it results in a very tight building envelope. The Faswall block foundation with the rock-wool inserts has an estimated R-value of 21. We also insulated the exterior of the foundation.

HP: **Beyond an efficient envelope, what other energy-saving strategies did you incorporate into the home?**

Brill: A year before we were ready to start construction, a friend told us that the $3-per-watt PV rebate through the local utility was about to expire, which put us on a fast track to build a garage so we could install a grid-tied PV system. It was just too good of a deal to pass up.

Insulation or Mass?

Testing of clay-straw wall sections at the Forest Products Lab in 2004 showed an average per-inch R-value of 1.51. With 12-inch-thick walls being common for this type of construction, the resulting R-value is about R-18.1. A June 2005 research paper published by the Canadian Mortgage and Housing Corp. reports an R-value of about 19 for a 12-inch-thick wall (see bit.ly/StrawClayReport).

"While the R-value might not seem impressive," says Smith, "the walls work extraordinarily well as part of the whole-house system." Brill and Elliot testify to this after having lived in the home for a full year. On sunny winter days, the house remains a comfortable 68°F to 72°F without any supplemental heating. On cloudy days, small fires in the wood heater in the morning and/or evening keep the home comfortable. They burn about one cord of wood during the heating season.

The 2.94 kW grid-tied PV array provides all of the home's electrical energy needs.

Mike Pendy (2)

A single inverter (left) supplies a distribution panel (right) tied to the utility grid and to household loads.

HP: **How did you arrive at a 2.9 kW system size?**

Brill: Our previous house had a 1 kW system, so we knew what portion of our energy use could be offset with that system size. By looking at our bills, we estimated that tripling that size would come close to making our new home net-zero. We have Energy Star-rated appliances, of course, but probably the main energy-efficiency feature is the LED lights. We hired Read Hunker, a local lighting designer, who was knowledgeable about the newest technology.

HP: **How did you design the garage to accommodate the PV system?**

Brill: The garage was designed specifically for the rooftop PV system, so it's oriented and sloped for maximum energy harvest. We also allowed room for future system expansion.

HP: **What is your PV system's average monthly and lifetime energy production?**

Brill: We started producing energy from the PV system on December 15, 2010. The inverter's production display says 18.4 MWh (as of August 9, 2014). This means our system has produced an average of 418 kWh per month.

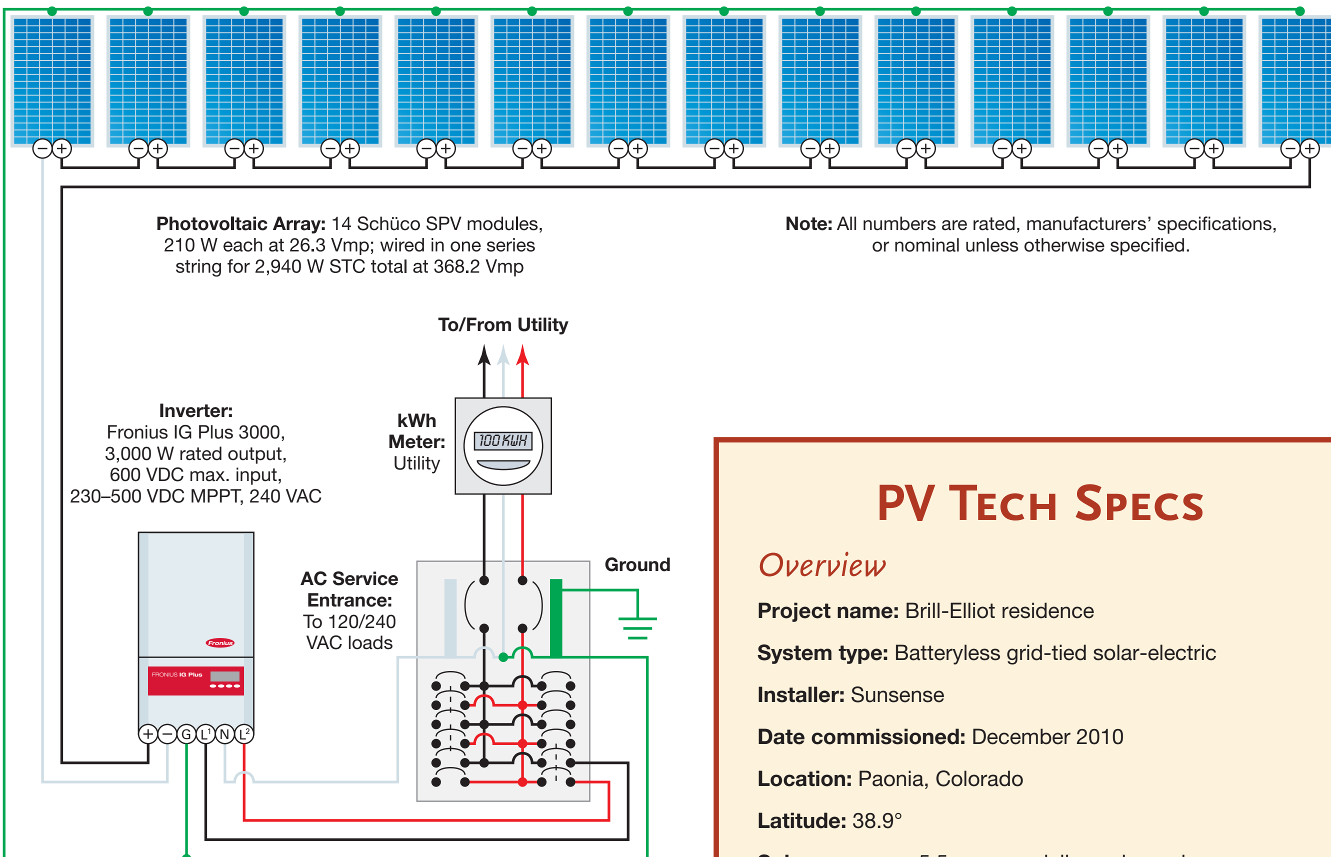
HP: **How much of the home's electricity does the PV system supply?**

Brill: In the first year of living in the house—from October 2012 to 2013—our meter shows that we consumed 1,300 kWh, so we didn't quite get to net-zero. But a certain amount of this electricity was used to heat our hot tub, which is now connected to a solar water heating (SWH) system, and for the electric baseboard heaters in my office above the garage. We

Courtesy Dave Houghton

Lots of glazing on the house's south face allows the low-angled winter sun to warm interior spaces.

Brill & Elliot Batteryless Grid-Tied PV System



installed a wood heater there this past summer, so electricity demand will also drop substantially.

Because we took advantage of the rebates and built our garage first, the cool thing was that the solar-electric system was spinning the meter backward before we started construction on the house. The utility commissioned the net metering on December 14, 2010. From then until November 28, 2011, the meter recorded -4,300 kWh. So that's a good indication of what our system produced without hardly any loads—we used only a few lights in the garage during that time.

HP: **Beyond the home's passive solar design and use of solar electricity, how else do you use the sun?**

Brill: We also collect the sun's heat with solar thermal collectors. Our SWH system serves three functions—domestic water heating; space heating (radiant tubes in the floor; we have three zones); and the hot tub.

We decided to ground-mount the collectors. Because of the sloping site, and since our house is bermed into the hill and has a low profile, we could place them 12 feet behind our north wall and not have them shaded by the house. We rely on electric backup (a boiler), rather than natural gas. If our existing PV system can't meet the backup loads, we can always expand it.

PV Tech Specs

Overview

Project name: Brill-Elliot residence

System type: Batteryless grid-tied solar-electric

Installer: Sunsense

Date commissioned: December 2010

Location: Paonia, Colorado

Latitude: 38.9°

Solar resource: 5.5 average daily peak sun-hours

ASHRAE lowest expected ambient temperature: -2.2°F

Average high summer temperature: 93.2°F

Average monthly production: 418 AC kWh

Utility electricity offset annually: 100%

PV System Components

Modules: 14 Schüco SPV 210 SMAU-1 210 W STC, 26.3 Vmp, 7.98 Imp, 33.68 Voc, 8.35 Isc

Array: One 14-module series string, 2,940 W STC total, 368.2 Vmp, 7.98 Imp, 471.5 Voc, 8.35 Isc

Array transition box: SolaDeck

Array installation: Direct Power & Water Power Rail mounts installed on south-facing roof, 24° tilt

Inverter: Fronius IG Plus 3000, 3.0 kW rated output, 600 VDC maximum input, 230–500 VDC MPPT operating range, 240 VAC output

System performance metering: Inverter faceplate meter

System Costs

Initial cost: $16,910

Less incentives: -$11,373

Final installed cost: $5,537

Four 4-by-8-foot collectors provide hot water, which is distributed for domestic use and space heating, and to a hot tub.

HP: **How was the system sized?**

Zachary Krapfl, SWH System Installer: We based the system size on anticipated loads (consumption data and heating loads), and the desired amount of backup. Each collector is the equivalent of 2 kW. Hal thought three collectors, or 6 kW, might suffice, but I recommended five collectors for 10 kW (170 kBtu/day). We settled on four collectors, leaving room for one more, and specified a 270-gallon storage tank.

In Colorado, domestic water-heating loads for two frugal water users can easily be met by one collector. Depending on its volume, a well-insulated hot tub can also be heated with one collector. For Hal and Allison's home, the real kicker was the space-heating load. Under normal circumstances, one thermal collector can provide enough heat for 300 to 400 square feet. This is a well-insulated house, but Hal and Allison wanted a bit of thermal storage to ride out a one- to two-day storm. Two more collectors can handle heating 600 to 800 square feet depending on the desired temperature, the amount of DHW consumed that day, and the hot tub's target temperature.

Ultimately, Hal and Allison decide how they want to consume the stored energy from the SWH system. If a long storm is coming, they can direct the heating to the DHW and hot tub, and then use some wood to heat the house, or put all of the energy into the radiant floors and skimp on the DHW and hot tub heating.

HP: **How much heat does each of the major hot water loads require?**

Krapfl: Daily averages for domestic water heating are based on 45 to 50 gallons of water use per day, or about 30 kBtu of heat needed. In the winter, hot tub loads average 31.5 to 35 kBtu per day, based on a temperature loss of 10°F to 12°F in a 24-hour period. Space-heating loads are based on my experience with Colorado-based passive solar-designed homes with active thermal for auxiliary heating. This house's internal footprint is about 1,500 square feet, so the theoretical heating capacity of the radiant thermal system is 50% of the load if DHW and hot tub loads are also met.

Solar Water Heating System Tech Specs

Overview

System type: "Steamback" closed-loop glycol-based system, atmospheric tank

Installer: Clean Slate Energy

Production: 3,240,000 Btu per month (average)

Climate: High clearness index, arid

Percentage of hot water produced annually: 96%

Equipment

Collectors: Four Schüco Performance, 4.1 ft. x 7 ft.

Collector installation: Ground mount, 55° tilt, true south

Heat-transfer fluid: Schüco glycol-based steamback fluid

Circulation pump: Schüco Solar Station (Wilo pump, 38 W)

Pump controller: DeltaSol, double relay

Storage

Tanks: American Solartechnics, 270 gal.

Heat exchangers: Four; site-manufactured, corrugated stainless steel

Backup DHW: Electric tank-style, 50 gal.

System Performance Metering

Thermometer: Web Energy Logger (WEL; available through ourcoolhouse.com)

Thoughtful Growth

Courtesy Dave Houghton (2)

Allison Elliot **Hal Brill**

After meeting Hal Brill at a Bioneers conference 13 years ago, Allison Elliot relocated from the San Francisco Bay Area to the western slope of Colorado, and fell in love with the small-town charm of Paonia. In the shadow of 11,400-foot Mount Lamborn, the town sits in a valley of orchards, cattle ranches, horse pastures, and a bevy of vineyards and wineries. But when building sprawl threatened the town's rural character and hillside views, Elliot and Brill decided to take matters in their own hands.

On one of their regular walks, they noticed that a large area of land on the outskirts of town—roughly 100 acres—had been marked with stakes and flags. "We were a bit surprised that it was private property. We had always just assumed the land was open space," Elliot says. The property was for sale and earmarked to be subdivided.

"We certainly are interested in supporting thoughtful growth, but this didn't seem like the best way to go about it," Elliot adds. "It didn't make sense to us to plan a tract-home style development at the edge of town while there were still many open lots in town. Part of what makes this area beautiful is how the edge of town falls away slowly—becoming less dense as you move up into the hills. This is one of the few places you can walk from town onto a dirt road and then onto public land." The development would have put 30 or more houses along the ridgelines, destroying views from town.

Elliot and Brill knew several families who were also looking for small acreages accessible to town by foot and bike. The group incorporated as Hawks Haven and pooled their personal funds to purchase the 100-acre property. Brill, who is a managing partner of Natural Investments—specializing in sustainable and impact investments—had the expertise to manage the financial side of the equation, while Elliot, who works with several nonprofits, handled the administrative details.

By working with the nonprofit Black Canyon Regional Land Trust, they set aside 60 acres as a conservation easement. In return for giving up development rights, the landowners received federal and state tax credits, which made the land purchase financially possible, Brill says. "The land was originally priced for development, with preliminary plans that could have resulted in as many as 90 homes covering the entire property. By using conservation easements, we were able to sell tax credits and recoup some of the purchase price. This enabled us to keep much of the property as open space."

The remaining 40 acres were subdivided into two neighborhoods. One of them—Creek Vista—lies within Paonia and consists of 12 single-family home sites, plus a senior apartment complex. So far, four homes, each using solar design principles, have been built. The other neighborhood—Hawks Haven—lies outside of town. Brill and Elliot describe it as an "intentional neighborhood"—everyone has their own lot and home, but share values and opportunities to work together. The members wrote covenants that encourage the use of solar energy, green construction, and permaculture practices, while providing open space for wildlife and recreation. Hawks Haven consists of seven home sites that are each two to three acres.

If the concentration is only on heating the home, you can toss out DHW and hot tub heating potential. The DHW system is passive, however, so if Hal and Allison turn on hot water, the cold water entering the home automatically gets preheated in the thermal storage tank first and then transferred to the electric backup DHW tank.

***HP:* Tell us about the unique function of the "steamback" collectors.**

Krapfl: The glycol-based, closed-loop system has "steamback"-based collectors that provide passive overheating protection. If there's a power outage or if the storage tank's setpoint temperature has been met, the circulator pump will shut down, but if the sun is still shining on the collectors, the temperature of the heat-transfer fluid in the collector will continue to increase. When the temperature of the glycol/water mixture in the collector rises above the boiling point of water, steam will be produced. The steam formed takes up much more volume than the equivalent amount of liquid, and pushes the remaining glycol mixture from the collectors into large expansion tanks, where it is protected from temperature degradation. The steamback collector is designed to evacuate the glycol from the collectors at temperatures well below those which would make the glycol acidic. This method of overheating mitigation also protects other components within the system.

***HP:* What are the considerations for having one SWH system serve multiple functions?**

Krapfl: For some, living in a home with active solar is an energy juggle and fun to play with. Do you direct the heating to one energy consumer, like a hot tub or radiant floors, and shut down the other functions during inclement weather? Or do you distribute the production equally? Or do you oversize the array and storage tank to allow for more winter gains and increase your solar fraction? These are all questions to ask yourself when getting into the solar heating side of things.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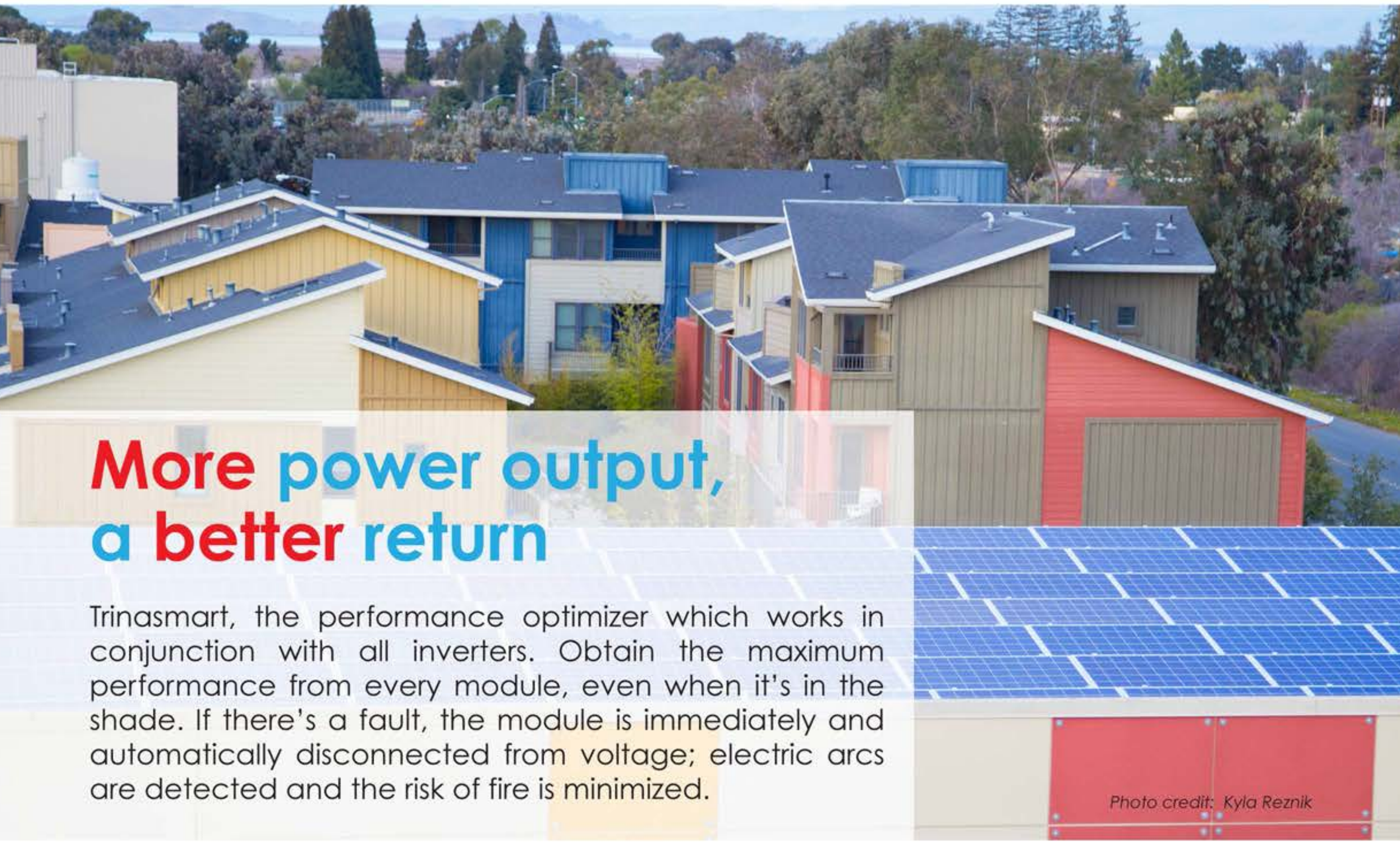

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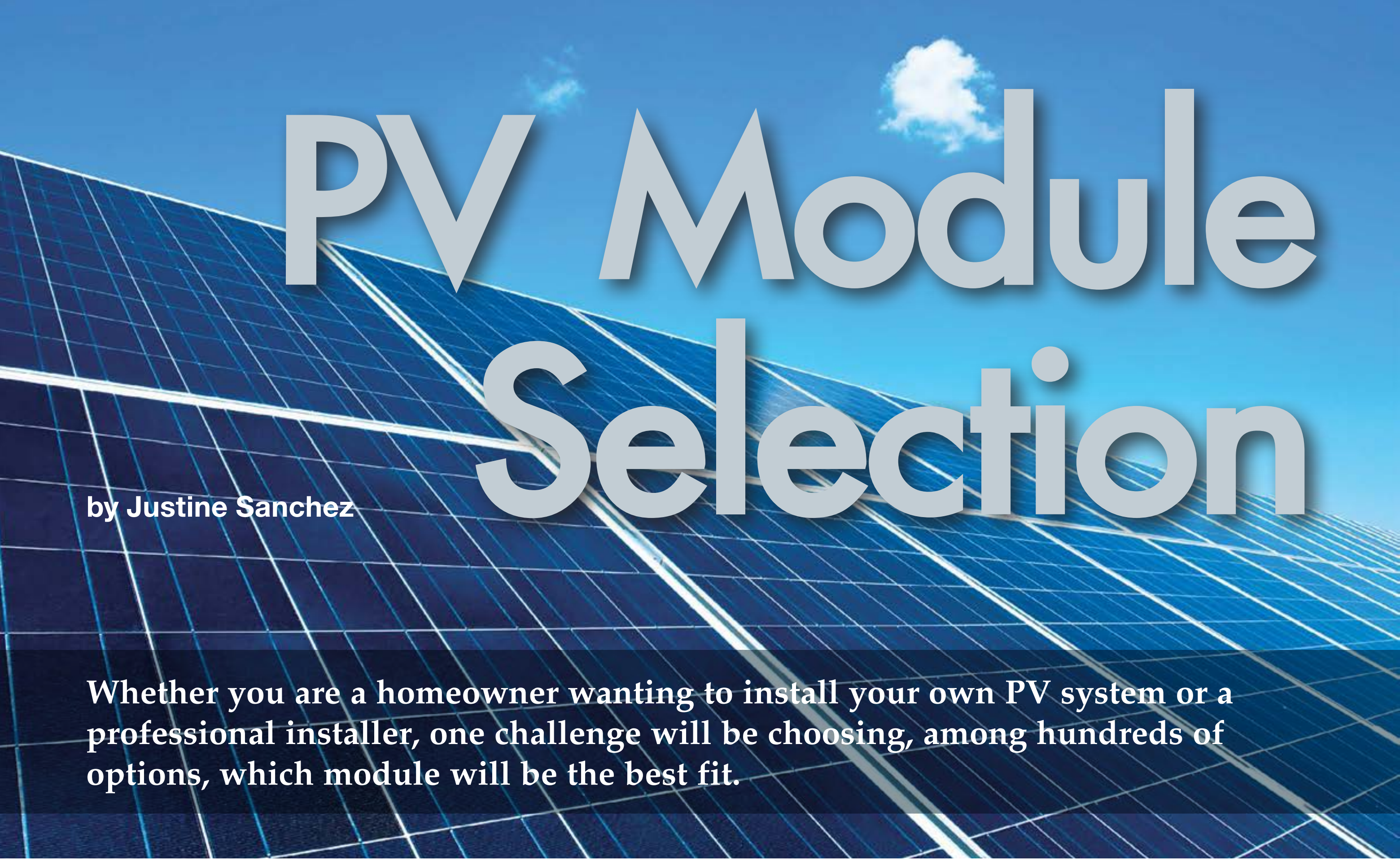

PV Module Selection

by Justine Sanchez

Whether you are a homeowner wanting to install your own PV system or a professional installer, one challenge will be choosing, among hundreds of options, which module will be the best fit.

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Selecting modules requires an understanding of module attributes and specifications. Once you are familiar with those, the job becomes ranking modules based on your criteria. You will find that the most important module characteristics depend on the site and your system goals.

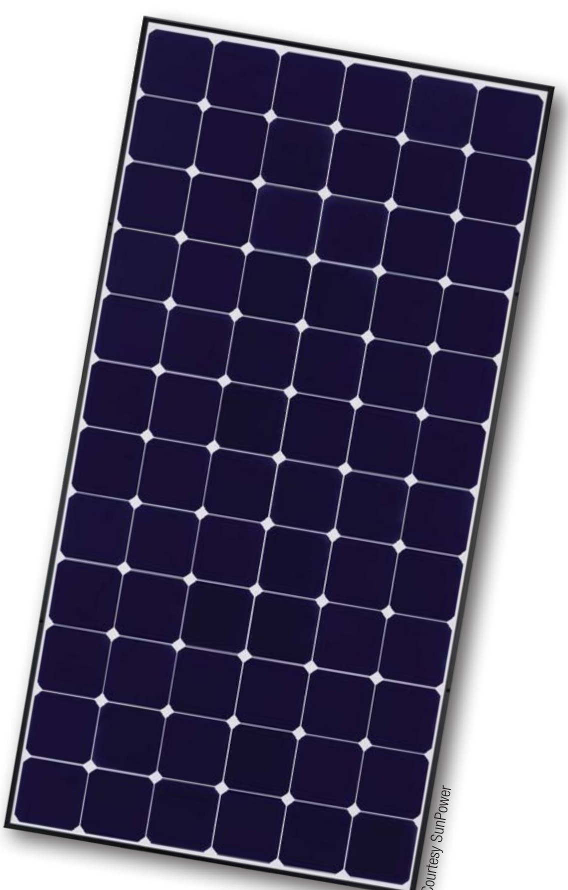
This article discusses the top module considerations: module efficiency, price, aesthetics, reliability, manufacturing location, and integrated features. Then, we consider some common scenarios and how module attributes fit them.

Module Characteristics

Efficiency

Module efficiency is a function of power output per square foot (W/ft.^{2}). The higher this value, the more energy a specific footprint can produce. Module outputs range from about 11 to 19 watts per square foot. For example, let's say the usable shade-free area on your rooftop measures 240 square feet (20 by 12 feet). Using modules that produce 15 W per square foot yields a 3.6 kW array.

Module dimensions also come into play when determining actual array wattage. Common 60-cell modules are about 65 by 39 inches wide. For our example, we could fit two rows of six modules in a portrait configuration. If the module wattage is 265 watts (with an efficiency of about 15 W/ft.^{2}), our array will be 3.18 kW.



Courtesy SunPower

Currently, SunPower offers PV modules with the highest efficiencies (W/ft.^{2}). But unless array space is tight, efficiency isn't always the most important criterion.

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Price

Module price is a factor for most folks. The good news is that module prices have dropped dramatically over the last few years. In 2008, modules were approximately $4 per watt; it is now common to find them for less than $1 per watt. Total system costs followed the same trend—in 2008, they hovered around $8 per watt; now, the average cost is less than $4 per watt (before incentives; assuming professional installation).

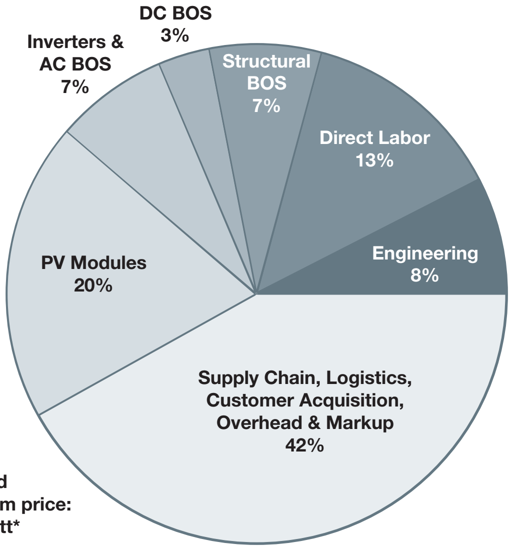
Once you factor in any local incentives and the 30% uncapped residential federal tax credit (currently set to expire at the end of 2016), it is no wonder we are seeing so much growth in the PV industry. In fact, in the first quarter of 2014, 74% of new electrical generation in the United States came from solar. Residential PV installations exceeded commercial installations for the first time since 2002, and more than one-third of the residential PV systems came online without any state incentives.

Style

Aesthetic considerations vary by the homeowner, but can be important to many. Options are available to help modules blend with roofing materials. While the standard look has been aluminum/silver frames with a white back-sheet, both frames and back-sheets can be specified in black, and module racks can be ordered to match.

Some specialty PV modules have clear back-sheets. Used in PV awnings, they provide some filtered light underneath the array. Additionally, there are frameless modules (some also with clear back-sheets) that provide a uniform, modern look to the array.

PV System Installed Costs



*Based on 6.5 kW (DC) residential system, standard multicrystalline silicon PV modules, 6 kW (AC) string inverter with integrated DC disconnect, standard rail-and-clamp racking system with flashed mounting, and rectangular array on composite shingle roof.

Data courtesy GTM Research/SEIA: U.S. Solar Market Insight

Reliability

Reliability reflects how a module will stand the test of time. Will it actually produce its rated power and be warranted for years to come? This is important, especially considering the rate in which module prices have fallen over the last few years. Have manufacturers been forced to cut corners in the manufacturing process to stay competitive? And will those cost-cutting measures haunt us in the future?

Frameless glass-on-glass PV modules, seen in this Lumos Solar array, can look almost seamless.

Courtesy Lumos Solar

Black frames and black back-sheets, like on these SolarWorld modules, can provide a more uniform appearance, but absorb more heat, which causes a slight decrease in efficiency due to increased temperature.

Courtesy SolarWorld

Clear glass backing in these Silicon Energy modules allows light to pass between the cells, making them desirable for shade structures.

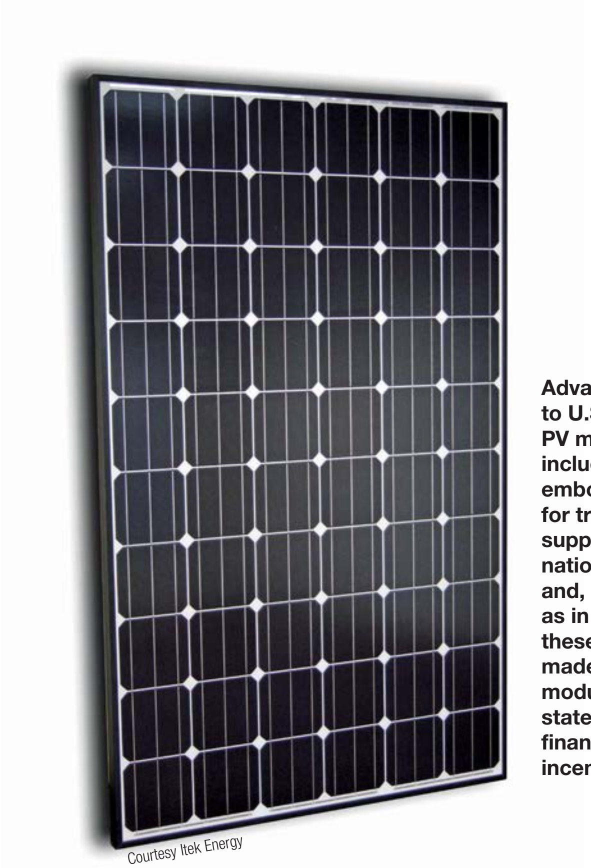
Courtesy Silicon Energy

Justine Sanchez

Buying modules from long-term manufacturers with a good track record can be a hedge against poor quality, but the only way to spot individual module performance issues is with module-level monitoring.

In a perfect world, there would be third-party-verified reliability—but such a certification system doesn't exist yet. However, various stakeholders in the PV industry are exerting some pressure, resulting in several PV testing labs now offering comparative accelerated testing programs and proposals for quality assurance in manufacturing.

In the meantime, we can buy modules from long-term manufacturers with a good track record. Ask your module manufacturer to share its warranty return rates. Some manufacturers will provide data from independent testing facilities that document field performance. Finally, ask other end users about their experiences with that particular manufacturer.



Courtesy Itek Energy

Advantages to U.S.-made PV modules include less embodied energy for transport; supporting the national economy; and, sometimes, as in the case of these Washington-made Itek Energy modules, additional state-sponsored financial incentives.

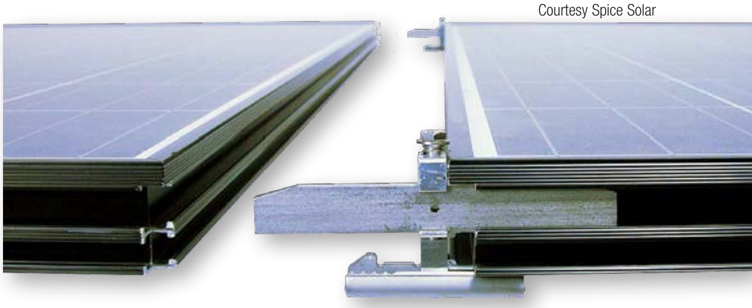
One way to keep tabs on your modules' performance is to use module-level monitoring through microinverters or DC optimizers. They can provide real-time side-by-side comparison, making module performance problems easier to identify. This can be useful should you need to file a warranty claim.

U.S.-Made

Manufacturing location is important if you prefer U.S.-made products, and it is critical for federal projects that must comply with the American Recovery & Reinvestment Act (ARRA) "Buy American" provisions. Location can also be important if you want to reduce the embedded energy from shipping.

However, PV module price drop has forced many U.S.-based module manufacturers to close their doors. Auxin Solar, Itek Energy, Mage Solar, SolarWorld, Stion Solar, Suniva, SunPower, and Silicon Energy offer modules produced in the United States (or at least assembled here, with components manufactured elsewhere).

Courtesy Spice Solar



Some PV modules offer a rail-free mounting option. These modules are compatible with Spice Solar's built-in racking system.

Features

Integrated module features are primarily aimed at decreasing system installation time and materials needed. For example, modules with grooved frames allow rail-free mounting—interlocking straps secure the modules together and leveling brackets/feet secure the array to the roof. Grooved module frames compatible with railless mounting systems are available from Andalay Solar, Silicon Energy, and systems installed by SolarCity (a large national solar integration company that recently acquired Zep Solar). Additionally, Spice Solar has recently launched its built-in racking system for use with Auxin Solar "Spice-certified" modules. And for standard module frames, there are railless mounting options from Dynoraxx, PMC Industries, Roof Tech, S-5!, and Zilla.

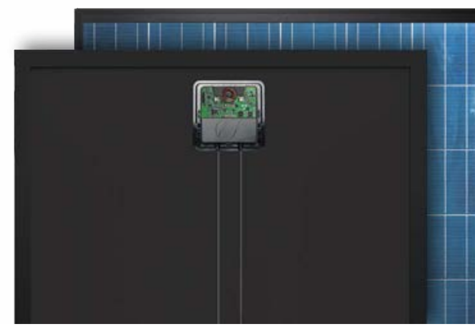
Integrated grounding is a common additional benefit with rail-free mounting. Since the interlocking module-to-module components can also bond the module frames together, there is often no need for additional grounding on each module—only one array-to-equipment grounding conductor (EGC) connector is used to bond the entire array to an outgoing EGC.

Integrated Electronics

Some PV manufacturers (such as Trina Solar and UpSolar) offer integrated DC optimizers to provide module-level monitoring and maximum power point tracking (MPPT). This integrated feature reduces the installation time required to mount and wire DC optimizers separately for each module. Additionally, the DC optimizers on these "smart modules" are field-replaceable, so you don't have to send the entire module back to the manufacturer to repair an electronics failure.

Courtesy UpSolar

UpSolar's "smart module" integrated SolarEdge DC optimizer reduces installation time compared to using separate MPPT optimizer units.



Trina Solar's TrinaSmart modules offer Tigo Energy's module-level MPPT optimization and individual module monitoring.

Courtesy Trina Solar

Solar Stereotypes: Prioritizing PV Criteria

There's no magic decision-tree for module selection, since the best module for your situation depends on the particularities of your site—and your personal design goals. But here are some "solar stereotypes" for a starting place toward choosing the right module.

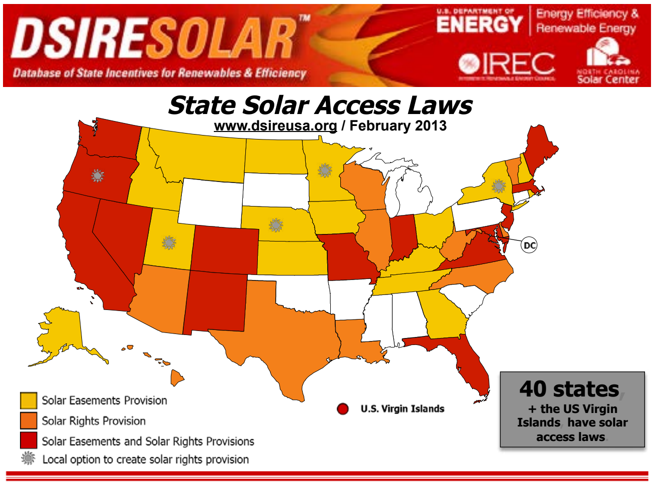
"Green, But Broke"

Some folks are on a tight budget, so module price trumps all other criteria—but this strategy also means DIY installation. The least-expensive modules come by the pallet, but you'll need to factor in shipping costs. Getting a few friends together for a bulk purchase (and shared shipping expense) can be a good approach. On the flipside, if you aren't up to DIY installation, it may be difficult to find an established installer willing to install products that are not purchased through their company.

If you're "green, but broke," consider financing or leasing a PV system, where little or no money down is required and the system can be paid off over time (years or decades). Or consider a power purchase agreement (PPA), in which you buy energy (kWh) from an onsite PV system installed and

Dave Strenski

If you have electrical and carpentry skills, you can potentially save a lot of money by installing a PV system yourself (see Dave Strenski's article on page 58 of this issue).



Courtesy dsireusa.org

Visit dsireusa.org to see which states and localities offer solar access protection.

owned by a third party. It is important to note that when the system is owned by a third party, they are the ones who receive any available tax credits and other solar incentives. (For more information, see bit.ly/SEIAfinancing.)

"Hands Tied by an HOA"

Some homeowners associations (HOAs) regulate or won't allow PV installations—usually due to perceived aesthetics. They may require the array be parallel-mounted flush to the roof (no angles opposing the roofline). Or the HOA may require that frames and back-sheets be dark-colored to better blend with roofs.

Many states (currently 41) have solar rights/access laws intended to ensure citizens can install solar systems on their properties. These laws vary widely; it is important to research and know your rights. For example, Colorado has a solar access law that doesn't allow covenants to prohibit or place unreasonable restrictions on solar systems. However, the law does allow "reasonable restrictions," so long as these limitations do not significantly reduce the PV system's efficiency or increase system cost. (For more info, see bit.ly/SolarAccessLaws and dsireusa.org).

"Small Rooftop—or Bad Rooftop"

Many homes have limited available roof space for PV arrays, making module efficiency the top priority. And some regions require setbacks around the array for firefighter access, further limiting the array mounting area. If you are trying to reach a certain output size, your only option may be to choose high-efficiency modules—which come at a premium (about 20% more per watt).

Another factor may be partial shade from obstructions such as nearby trees, vents, or chimneys. When some modules will be shaded some of the time, using integrated microinverters or DC optimizers is a good choice to avoid compromising the performance of rest of the array, while avoiding increasing installation time. This approach also includes the benefit of module-level monitoring, which is helpful in assessing module performance and problems should they arise in the future.

If using high-efficiency modules or module-level electronics still doesn't get you to your production goals, you may need to consider ground- or pole-mounts, or a PV awning or shade structure. At this point, module price will probably rise to the top of your criteria, since these mounting options are more expensive, requiring excavation, concrete, and a more expensive rack. Besides producing clean energy, a PV awning or shade structure can provide a covered outdoor space. In this case, you might want to purchase modules with a clear back-sheet, allowing some dappled light to shine through.

"Super-Green or Less-is-More Reductionist"

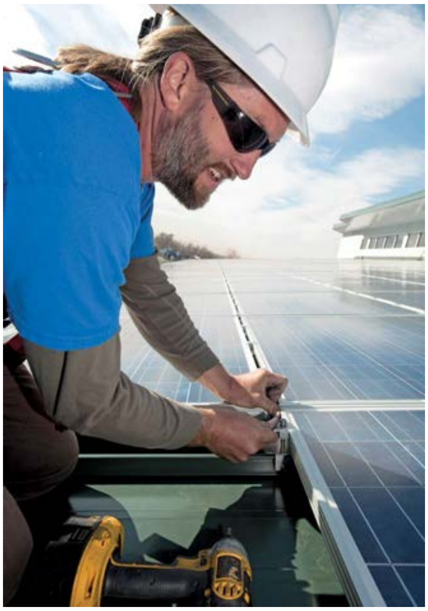
If you're "super-green" or an "LIMR," you'll be interested in the extremes of reducing your system's embodied energy and installation time. You'll likely focus on modules with specialty integrated features, such as those that can accommodate railless mounting and integrated grounding. You will also prioritize module efficiency, since higher efficiency can also translate into less rack and wire per watt. Module manufacturing location will also be high on your list of criteria—and you'll want to find made-in-the-USA products.

"Off-Gridder"

Battery-based PV systems have additional components that add to cost, so selecting lower-cost modules can help stay within the owner's budget. Off-grid systems not only require batteries, but also battery boxes, large battery cables, charge controllers, DC and AC disconnects and overcurrent protection, and more expensive inverters. Also figure in shipping of these components (batteries are heavy) and more required installation time.

Small rooftops may require using high-efficiency modules to meet your energy production goals. Poor rooftop orientation or convoluted shapes may necessitate a ground-, pole-, or awning-mounted system.

Courtesy Stion



Topher Donahue

Professional installers may put a product's reliability at the top of their module selection criteria in an effort to reduce warranty callbacks.

"Professional Installer"

When your job is to design, install, and maintain PV systems for the homes in your area, module reliability is crucial. You're on the front line for the PV industry and your reputation is at stake. Since you're responsible for determining which modules to use, you'll be the one who has to deal with underperforming or failed modules. The movement toward comparative accelerated testing programs and quality assurance in module manufacturing is much-appreciated industry progress. You'll likely be shopping for modules from reputable manufacturers, and with a sturdy warranty.

While it's fun to present these stereotypes, most real-world installations will be a combination of the above scenarios. For example, I just purchased modules for my next PV array, and found that several of the categories applied—a local HOA to appease, a small rooftop, super-green. But more accurately, I am a solar nerd—and that means I want it all.

web extras

"Module-Level Performance" by Dan Lepinski • **homepower.com/162.66**

"Solar Equipment Innovations" by Rebekah Hren • **homepower.com/157.38**

"Choosing PV Modules" by Justine Sanchez • **homepower.com/152.40**

"PV Array Siting & Mounting Considerations" by Justine Sanchez • **homepower.com/155.66**

"Pump Up the Power: Getting More From Your Grid-Tied PV System" by Jeremy Taylor • **homepower.com/127.72**

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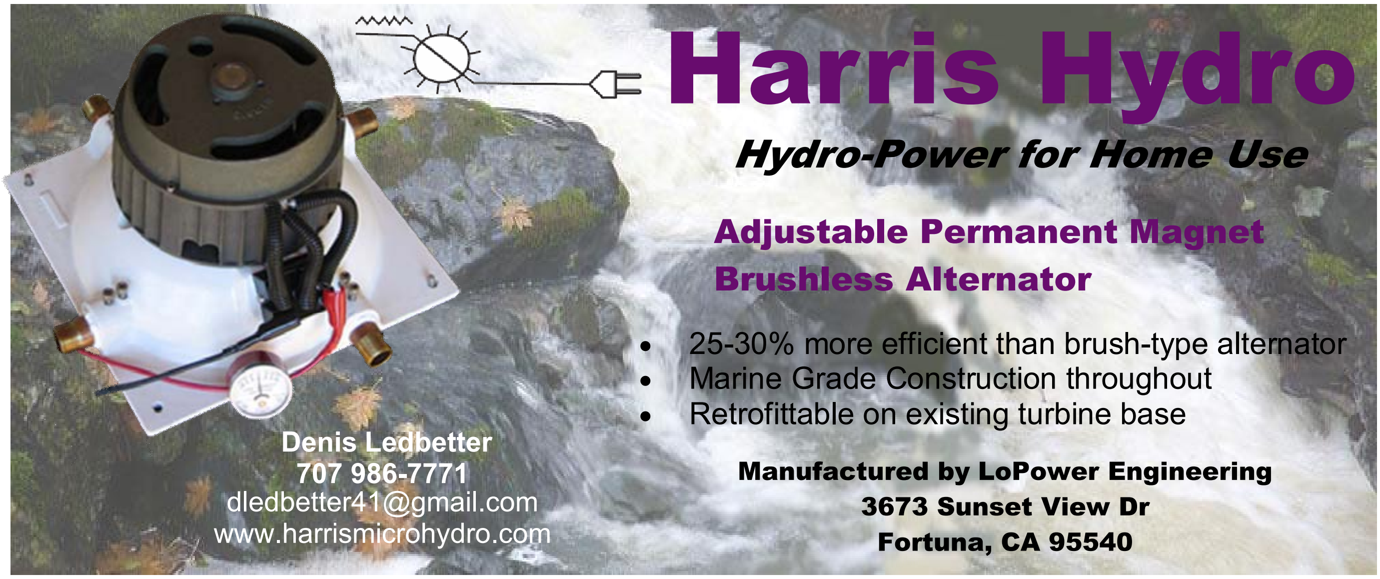
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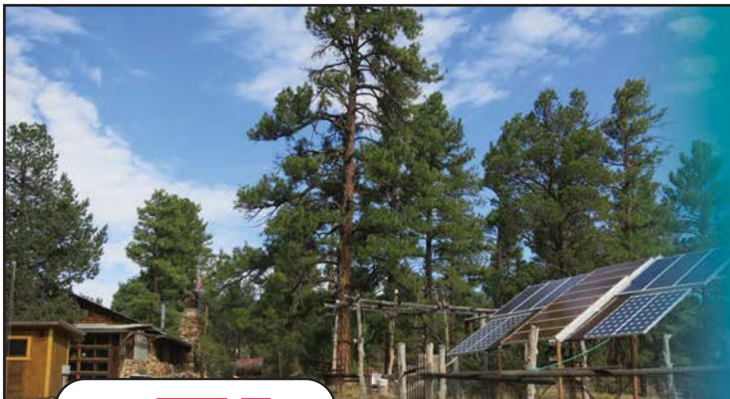

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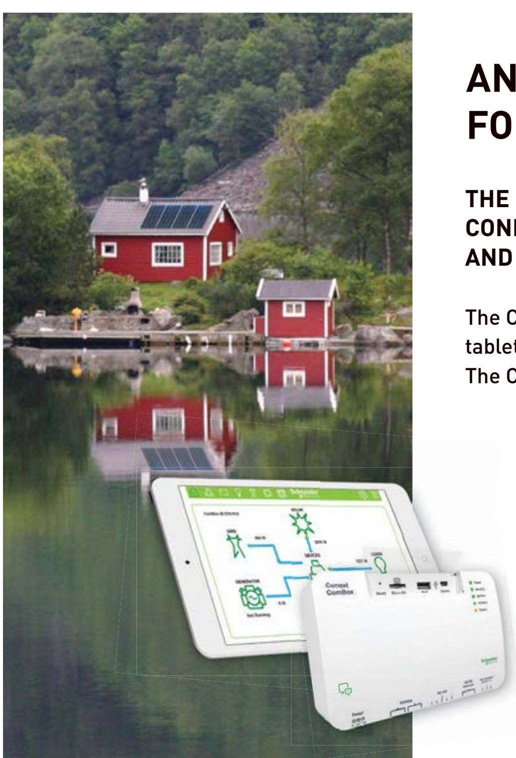

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Passive Solar Home Principles

by Scott Gibson

Courtesy David Dietrich

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Implementing solar design principles can slash heating and cooling bills, reducing the size of the renewable energy system you'd need. This article, the first of three, covers siting, orientation, building shape, and room placement.

Solar installer Bristol Stickney wistfully remembers passive solar conferences in the 1970s that drew hundreds of building tradespeople—all excited about building houses that derived a big part of their space heating from the sun. He had to look only as far as Mesa Verde, the spectacular Pueblo settlement in southern Colorado, to see how long passive solar has been in use. Those solar advocates of 40 years ago thought the ideas were finally making it into the building mainstream.

But passive solar design never reached its full potential—politics, cheap utility energy, and missteps by early passive solar practitioners helped cause the passive solar movement to lose its zip. Now, when people talk about "solar," says Stickney, an industry veteran based in Santa Fe, New Mexico, they usually mean rooftop PV modules that produce electricity, not the building practices that allow homeowners to reap free heating from the sun.

Time-tested passive solar design: The ancient Mesa Verde residents built cliff dwellings that took advantage of passive solar gain.

Courtesy NREL

Despite its second-class status, passive solar works—and well. The passive solar vanguards were correct—even in northern climates, a well-designed passive solar house will reduce a home's energy costs. And unlike technologies such as ground-source heat pumps or PV arrays, many passive-solar features add little or no construction cost.

Basic Building Blocks

Passive solar design includes practices that help keep buildings cool in summer as well as warm in winter—something that early solar designers struggled to master. "A good passive solar house provides comfort no matter what the weather," Stickney says. "In the past, a lot of passive solar houses had too much glass and would overheat when it was sunny and the weather was mild. It would get too hot in the spring and fall, but not hot enough in winter."

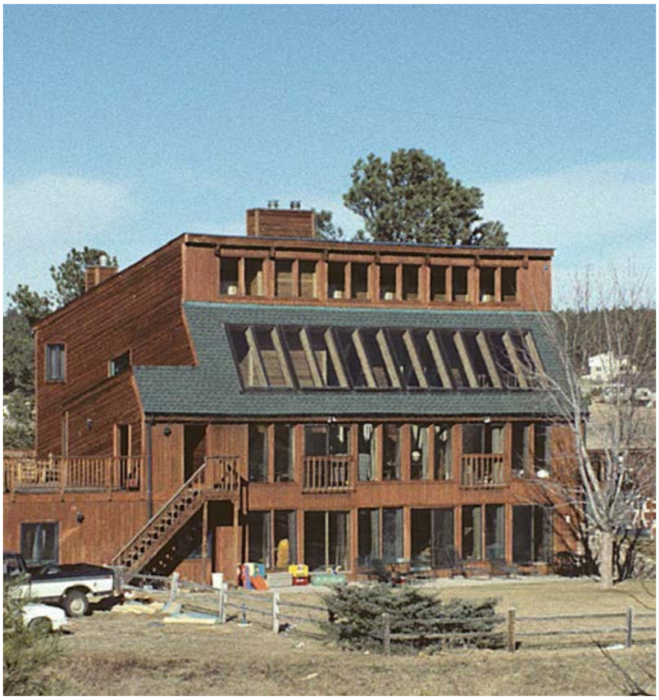
Designers have since learned how to deal more effectively with that challenge. But any good design is site-specific, since each building site has its own weather and temperature patterns, as well as a unique topography that affects heating and cooling. A passive solar house designed for the high deserts of New Mexico might be pretty uncomfortable if transferred to coastal Maine. The house design must match its site.

There needs to be a good understanding of regional approaches, says Mark Chalom, an architect in Santa Fe, and a long-time solar designer. "In New Mexico, we have 300 days of sun, and it is strong. We can design a home that can gain as much energy as it loses for the month of January. But winter in Maine is different—the cold climate is dominant and energy conservation is the main goal."

Courtesy David Dietrich

Balancing thermal mass and glazing is the key to moderating solar-gain temperature swings.

Early passive solar designs set the stage for the technology but also suffered from design errors, including excessive glazing area, lack of overhangs, and sloped glazing.



Dan Chiras

Despite regional differences, there are a handful of strategies at the heart of passive solar buildings anywhere. Key design issues and strategies are the:

- Building site and how the house is oriented on the site
- Shape of the building and its thermal envelope
- Size, type, and location of windows
- Use of thermal mass to moderate interior temperature swings
- Design of roof overhangs that shade glazing in windows and doors.

Although the principles of passive solar design aren't hard to understand, the details can be daunting. Computer modeling can help, although the software can be complicated to use. Hiring an energy modeler is another option—more expensive but also reliable in balancing the many factors that affect energy performance. Alternately, owner-builders can refer to a series of builder guidelines published by the National Renewable Energy Laboratory (NREL; see the "Solar Design by Region" sidebar), or the guidelines published by the New Mexico Solar Energy Association (NMSEA; see Web Extras).

Courtesy Wayne Appleyard

Courtesy Barley/Pfeiffer Architecture

Everyone knows a solar house needs south-facing windows. But a lesser-known important element is properly designed overhangs or exterior shade structures that shade those windows from the high-angled summer sun, while allowing low-angled winter sun to enter.

The Site

For the best solar gain in winter in the northern hemisphere, most homes should have their longest side facing true south. True south is not the same thing as magnetic south. This deviation, called the magnetic declination, varies by location—from 17°W in parts of Maine to 10°E in the Southwest. For help, consult the National Geophysical Data Center's website (bit.ly/NOAAdeclination).

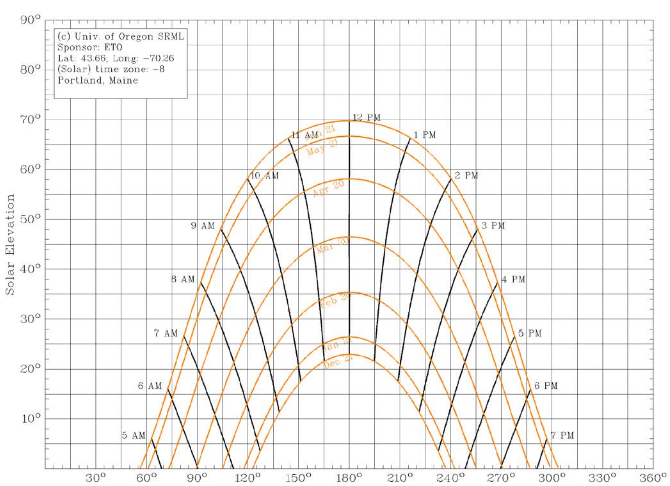
NMSEA guidelines say the south-facing side of the building can be as much as 15° from true south without a significant loss in solar gain. Other designers say the south-facing wall can be within 30° of true south. Generally, the closer to true south, the better for passive solar gain during the winter.

Every orientation has its trade-offs. When the principal glazed wall is more southwesterly than true south, for example, windows will contribute significantly to winter heat, but also increase summer cooling loads because of intense afternoon sunlight. In some locations, a southeasterly orientation may be more favorable, allowing a morning warm-up without afternoon overheating in the swing months.

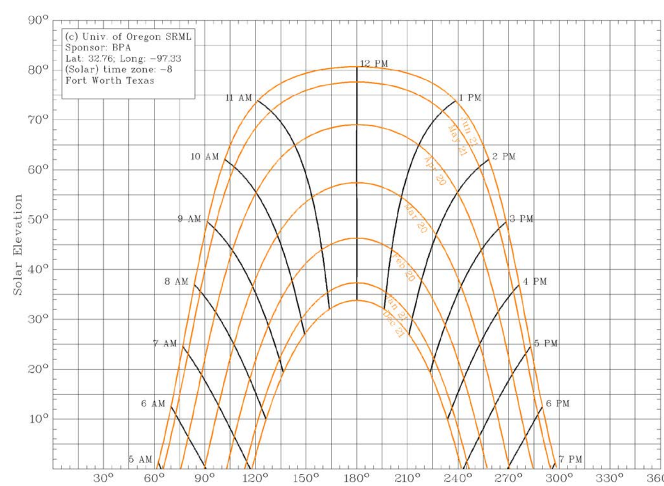
Make sure the home's "solar window" is clear—no vegetation or other obstructions, such as fences or outbuildings, should be within 10 feet of the home's south wall. Even deciduous trees, which drop their leaves in the winter, aren't a good idea—the leaves may be gone but tree trunks and branches will reduce available sunlight enough to decrease solar gain. In summer, the sun is so far overhead that leaves aren't effective in blocking sunlight anyway.

Time of year is an important consideration in calculating how vegetation affects both shading and solar gain. At the summer solstice, the sun rises at its most northeasterly point of the year, and sets at its most northwesterly point and reaches its highest point in the sky. Conversely, at the winter

Sun-Path Diagrams Help Define the Available Solar Resource at Your Site



Portland, Maine: 43°40' north latitude



Fort Worth, Texas: 32°45' north latitude

Sun-paths for your location will display the sun's altitude and azimuth for the entire year. This is valuable for determining your available solar exposure for any orientation; specific obstructions can be sketched in. Notice, for example, how the winter solstice noon sun in Portland, Maine (left), is only 22.5° above the horizon, while in Fort Worth, Texas, on the same day, the noon sun is at 34°. Generate a sun chart for your location using the University of Oregon calculator at bit.ly/UOsuncharts.

PASSIVE SOLAR MODELING...

Energy-modeling software can be used to calculate energy use, heating and cooling loads, and other characteristics of a particular house design. There are many to choose from—some of them free, some not.

EnergyPlus, BEopt, the Passive House Planning Package (PHPP), DOE-2, and REScheck are among the many offerings. Some programs have very specific purposes. The "Manual J" calculation, developed by the Air Conditioning Contractors of America, is used to size heating and cooling equipment. PHPP helps designers meet the stringent energy and air sealing requirements of the Passive House Institute U.S.'s building standard by comparing the effects of window sizing and insulation amounts on energy performance.

An older and somewhat simpler program is Energy-10, a Windows-based program developed at the NREL. It's no longer available as a download through NREL, but you'll still find it online, including this site at the University of Washington (bit.ly/UofWenergy10).

The DOE maintains an extensive list of energy software tools, with a brief explanation of what they do (bit.ly/DOEenergytools). Many, if not most, of the programs are complicated and require entering a lot of data to produce useful information about how the house is likely to perform. Also, many energy programs do not accurately account for added thermal mass, such as Trombe walls.

Some modeling programs are too complex for simple passive solar designs undertaken by an owner-builder, and even some architects don't use them routinely, but rely instead on experience.

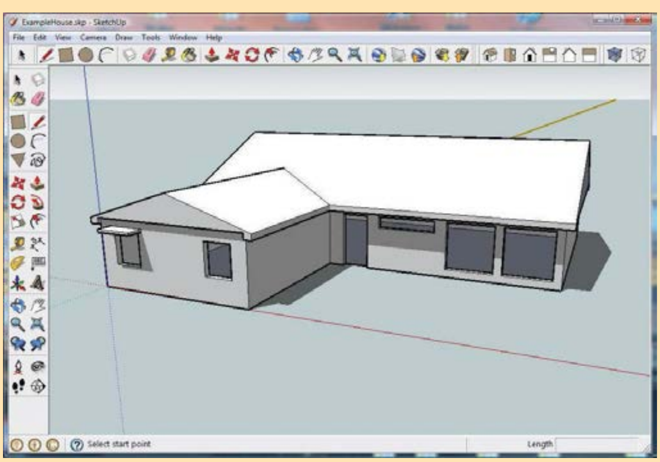
A Simpler Option

Google's free SketchUp modeling software (sketchup.com) can help you visualize how sunlight falls on a house. If you've never used the software before, it will take some time to learn how to create a model. Many books and websites are available to help you learn this software. But once you've made a simple building, it's easy to test how building components, such as walls, windows, and roof overhangs, receive sunlight at different times of the day and year.

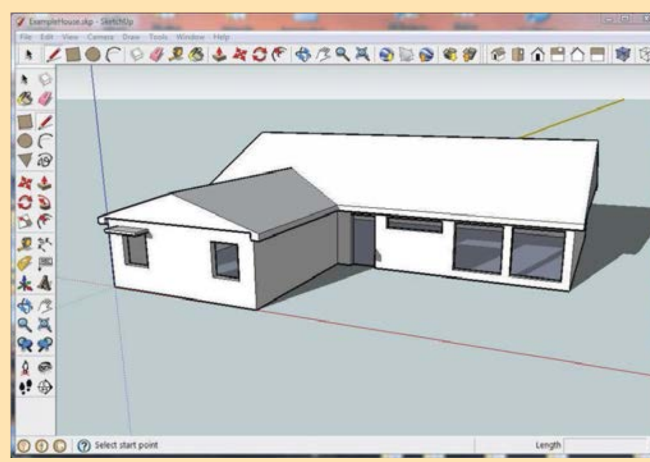
After creating a model, set the location of the building site and turn on the "shadows" function. Slider bars set the month and time of day, and shadows show on the house. This allows you to see where your home needs adjustment—extending a roof overhang, for example, to better shade the windows. (View a video of SketchUp's shading simulation at homepower.com/163.50a.)

SketchUp also can be used with other modeling programs and plug-ins. Legacy OpenStudio, for example, offers a free plug-in that integrates SketchUp with EnergyPlus, a whole-building energy simulation program that's also available on the DOE website. A variety of other plug-ins for SketchUp also are available online.

Computer modeling isn't for everyone, but if you have some computer proficiency and can take the time to experiment, there are lots of resources available.



Solar noon on June 21 at 47°30' north latitude



Solar noon on December 21 at 47°30' north latitude

Courtesy builditsolar.com (2)

solstice, the sun's path of travel is at its narrowest, and the sun is lower in the sky than at any other time of year.

Geographic location is key in determining how nearby buildings, trees, and other objects affect the amount of sunlight reaching the house. New Mexico solar guidelines, for example, say that a one-story building at least 17 feet from the house will not create winter shading, and a two-story building is fine as long as it's at least 39 feet away (assume one story is about 10 feet tall).

But a house at a higher or lower latitude would be affected differently by nearby objects because the sun angles are different. At more northerly locations, the winter sun is at a low angle, so even far-away objects could cause shading. At more southerly locations, sun angles are greater, and such objects could be closer to the house without causing substantial shading issues.

Eastern and western exposures are another story. Trees to the west of the building site can be helpful in blocking afternoon sun during the summer to decrease cooling loads. And, because limbs will be bare in the early spring and fall, trees will allow some solar gain in the cooler shoulder seasons. Deciduous trees on the east side of the building also can permit a little solar gain in the morning during spring and fall.

Traditional designs can accommodate passive solar strategies if the proper orientation and adequate south-facing glazing is maintained.

Courtesy sunplans.com (2)

As important as adequate south-facing glazing is minimizing glazing on the north side to reduce heat losses through the home's envelope.

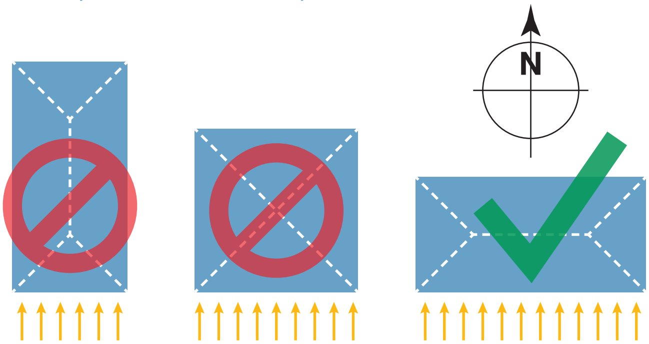
But even the most thoughtfully chosen building site can change over time. Neighbors move in and may add trees, new buildings are constructed, and existing trees get taller—these are factors to consider before you build. While solar access is protected by local regulations in some areas, that's not universal. With that in mind, the U.S. Department of Energy suggests looking for a lot that is deep from north to south and placing the house at the north end of the property.

Shaping the Future

Always provide enough room on south-facing walls for windows, says Debra Coleman, an author and architect who specializes in passive solar design. A standard 8-foot-high wall has to be long enough to accommodate the needed square footage of south-facing windows while leaving enough room for doors, interior wall space, and framing. This typically means a rectangular house with its long side facing south.

Windows take up a lot of wall space, which affects building design. NREL guidelines (bit.ly/NRELwindows) suggest south-facing glass area should equal 7% to 12%

House Dimension & Orientation for Optimal Solar Exposure



Long Axis North/South:
- Inadequate south-facing wall for solar glazing
- Excessive east & west exposure causes summer overheating
- Difficult to get natural light & heat to north side of house

Square Configuration:
- Having adequate south-facing glazing may be a challenge
- East & west exposure contributes to summer overheating
- Challenging to get natural light & heat to north side of house

Long Axis East/West:
- Maximizes south-facing wall for winter solar gain
- Reduces east & west exposure & summer overheating
- Easier to get heat & natural light to north side of house

Solar on Sloped Lots

South-facing sloped building sites allow a "walkout" ground floor. These south-facing rooms have solar gain, and additional solar gain can be captured through the second-floor windows. Because they're earth-bermed, rooms on the north side of the first floor (and other floors, if the berm is steep enough to allow it) lose views and natural light but have lower heating and cooling loads. Overall, a house built into a south-facing slope would have the same solar gain potential as a two-story house built on a flat lot but only part of the heat loss through the above-grade north walls.

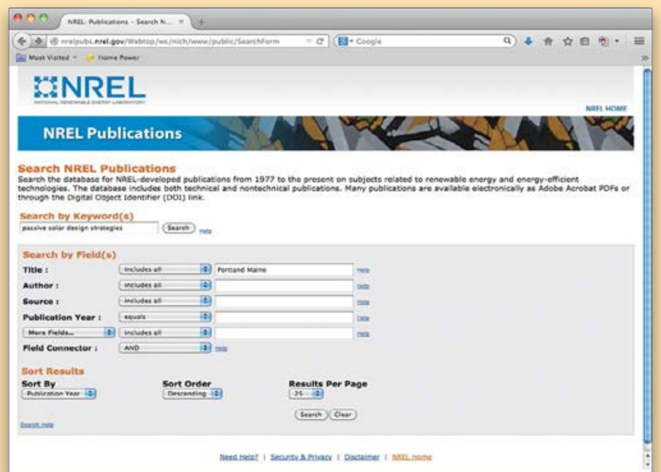
It can be challenging to design for lots that slope to the north because only the upper level has south-facing walls for glass. Designers have to be satisfied with a lower overall solar potential, or consider adding a second aboveground level to pick up more south-facing wall space.

Courtesy Wayne Appleyard

SOLAR DESIGN BY REGION…

Regional passive solar guidelines have been developed for roughly 150 cities across the United States by engineers and researchers at the National Renewable Energy Laboratory (NREL). The work has since been digitized and can be downloaded for free for individual cities at **bit.ly/NREL_SolarDesignCities**.

The reports help solve a fundamental challenge with passive solar design: how to adapt general principles to specific locales. The amount of south-facing glass, insulation levels, and thermal mass are among climate-specific variables covered by the guidelines. While energy modeling is helpful, the reports were intended to help people create reliable passive solar designs without it.



Courtesy NREL

Worksheets are specifically tailored to geographic location. For example, guidelines for Fort Worth, Texas, assume between 1,000 and 2,500 heating degree-days (HDDs) per year, while Portland, Maine, assumes more than 7,000 HDDs.

Examples in each set of guidelines show how energy consumption can be reduced by 20%, 40%, and 60% (compared to a "base-case house") by adding insulation, increasing south-facing glazing, and employing solar features, such as a sunspace or a thermal storage wall.

In Fort Worth, including 100 square feet of south-facing double-pane glass would reduce the amount of energy that has to be purchased for heating by 19.3%; the same amount of glass in the Portland, Maine, house would produce solar savings of 6.4%. Adding a masonry thermal storage wall behind single glazing yields 12.5% solar savings in Portland, but a whopping 30.3% in Fort Worth.

You'd need less insulation in Fort Worth to achieve a 60% reduction in heat energy consumption in a sun-tempered house (south-facing glazing equaling 7% of total floor area) than you would in Portland: R-25 in the walls versus R-38. And Fort Worth is more forgiving with air leaks. To reach the 60% goal, the Fort Worth house could have 0.51 air changes per hour (ACH) versus 0.75 ACH in the base-case house. In Portland, you'd have to get that number down to 0.28 ACH from the base case of 0.50.

Worksheets and accompanying tables at the end of each set of guidelines let you plug in different values for insulation, window type, and amount of direct solar gain, to see how it would affect heating and cooling loads.

of interior floor area. When a separate sunspace is added (a room with a south-facing wall and operable doors and windows into the rest of the house), the total of all passive solar collection area can be as much as 20% of the floor area.

This can add up to a lot of windows—and a lot of south-facing wall. For example, suppose a 1,500-square-foot house has window area equaling 12% of floor space. That's the equivalent of twelve 3-by-5-foot windows on the south wall alone. Stretching the east–west axis of the house provides more south-facing wall area for all of those windows, but that extra wall area also makes the house more difficult to heat than a cube-shaped building.

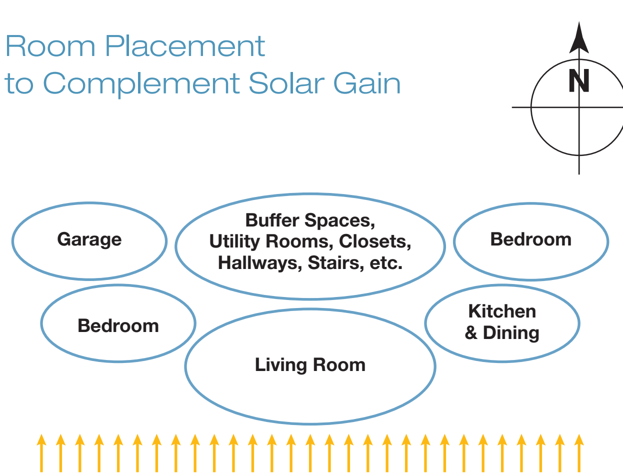
"The same things that keep heat inside in winter also keep heat out in the summer," says Coleman, "so minimize glass on the east and west, and have the house as compact as possible with the least amount of wall area versus floor area to minimize heat gain and loss."

Studies at NREL found that taking an average double-wide house trailer and orienting it so that the long side faced south cut fuel consumption for heating by 10% to 20%. On the right site, orienting a house with the long axis facing south shouldn't add to construction costs.

Room Placement

With rooms arranged to take advantage of the sun's heat and light, occupants will be more comfortable, and mechanical heating and lighting requirements will be lower. They key design question is, which rooms are occupied most frequently and at what times of day?

Room Placement to Complement Solar Gain



web extras

"Passive Solar Retrofit" by Dan Chiras in *HP138* • homepower.com/138.106

Passive Solar Architecture in "Media," reviewed by Andy Kerr in *HP150* • **homepower.com/150.21**

"Designing a Passive Solar Slab" by Robert Riversong in *HP136* • **homepower.com/136.60**

"Passive Solar Design Blunders" by Dan Chiras in *HP105* • **homepower.com/105.38**

Courtesy Debra Coleman, sunplans.com

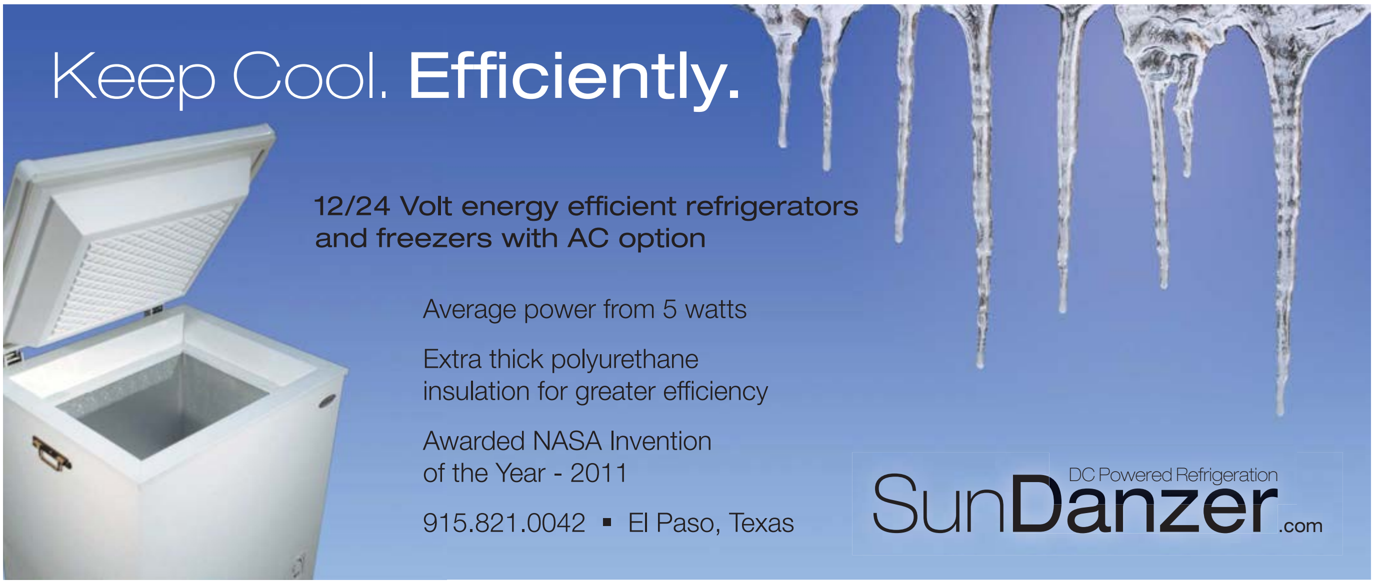
A west-end screened porch provides some protection from the afternoon sun, helping to prevent overheating and reduce summertime cooling loads.

The NMSEA guidelines offer a conceptual layout showing the living room facing directly south, with the kitchen/dining area on the southeast corner and a bedroom on the southwest corner of the building. The garage and buffer spaces such as closets, hallways, and stairs are located on the north or northwest side of the building, with another bedroom located on the east side.

In a house like this one, the bedroom on the east side would get morning sun, as would the kitchen/dining area for a sunny breakfast and cooler afternoon-evening cooking and eating. The main living area of the house reaps the biggest reward for solar gain, while the southwest-facing bedroom would be warmer in the afternoon and not as bright first thing in the morning. On the cooler north side of the house, which would ideally have fewer windows than other areas, rooms that aren't as heavily used by people become buffer zones.

Living rooms are often placed on south-facing walls so these frequently used areas have the best access to natural light and winter solar gain. But when the best views in the house are toward the east, some homeowners may prefer moving the living room there rather than picking up the solar gain from a southern exposure.

A south-facing master bedroom can be an attractive feature, but the room is unlikely to be used much during the day—a location with lower light levels might be much more practical for bedrooms. General rules for room locations are helpful as a starting point, but they can be broken under some circumstances.

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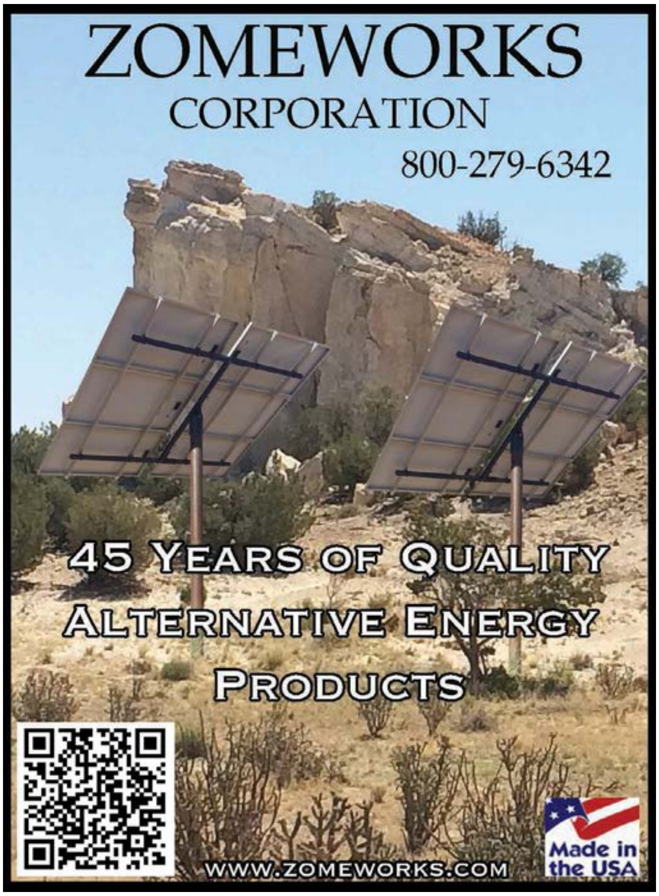
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Finally Walking My Solar Talk

Story & photos
by Dave Strenski

As a nine-year volunteer for SolarYpsi, a grassroots solar advocacy organization, I've helped design and install about a dozen grid-tied solar-electric systems in Ypsilanti, Michigan. Ironically, until recently, my own home's rooftop had remained without photovoltaic (PV) modules.

I often dreamed of solar power for our family's home, but the high initial system cost, the home's orientation, and its location in the historic district seemed like high hurdles. The front of our 122-year-old Victorian home's gable end faces south with three large maple trees shading it, and its roofs face east and west. The backyard is filled with trees and a garden, so a ground- or pole-mounted system was not an option.

Then there was the cost of the system itself. In SolarYpsi's early years, PV systems cost $7 to $11 per installed watt—and that was with using an all-volunteer labor force. My interest was renewed after I calculated the installation cost for our latest PV project at the Ypsilanti Food Cooperative. Using volunteer labor and $0.78-per-watt Evergreen PV modules from a bankruptcy sale, SolarYpsi was able to install the system for $3 per watt. This was the first time PV power seemed it might be affordable for non-ideal orientations or locations. More surprising was that the $0.78 per watt

Grassroots Solar

The mission of SolarYpsi (SY) is to educate the public about solar power and encourage them to put PV systems on their houses. SY gives community presentations about solar and provides free PV system design consultation. Its current goal is to help get 5 megawatts total—one thousand 5 kW PV installations—on residential rooftops by 2020.

Last fall, the City Council passed a resolution to help make the thousand solar roofs a reality. With the help of an Eastern Michigan University professor, SY is using geographic information systems to identify homes with good solar potential and contacting the owners of those homes. (For more information, see "Understanding Solar Power in Ypsilanti" at youtube.com/watch?v=Mx0pTz-Qc40.)

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Even with some reduction in efficiency, "non-optimal" array orientations, like on this west-facing roof, can pencil out financially.

was not an anomaly. Later that summer, closeout UniSolar modules were available for $0.50 per watt after the company's bankruptcy. That motivated me to start searching the Internet regularly, and I soon discovered that $1-per-watt PV modules were becoming common.

Three occurrences inspired me to revisit the idea of putting a PV system on our house. Our retired neighbor, Larry, was installing a PV system at his house, and he was able to self-install his system for less than $2 per watt (before incentives). He took a creative approach to the mount, purchasing aluminum channel for the rails at a scrapyard for a fraction of the cost of new rails. He also saved some money by fabricating his own top clamps and roof mounts. Note that creating custom racks can save some money upfront, but the responsibility of making sure all of the appropriate engineering calculations have been considered and implemented falls on the system owner (see Web Extras for an article on racking options for roof-mounted PV systems).

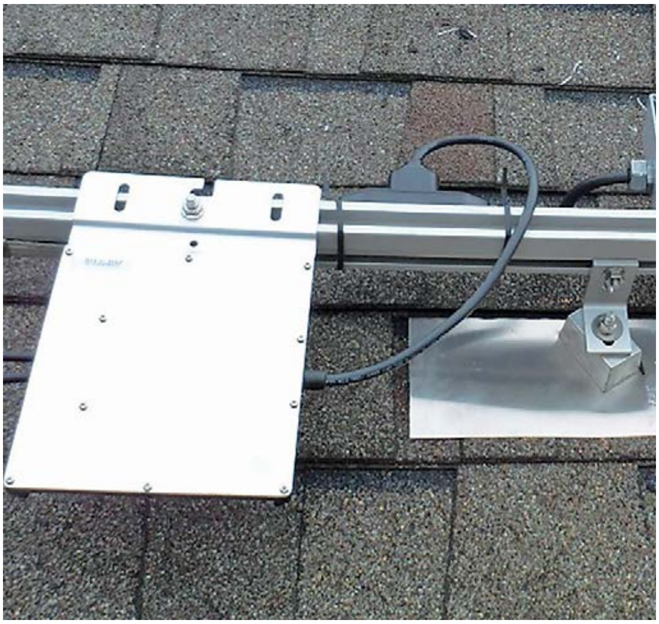
Then, a new PV installation company, Sade Power, established itself in southeast Michigan and was advertising batteryless grid-tied PV installations for $2.50 per watt. Another local solar contractor—AJ Leo—was also installing systems for about $3 per watt using Michigan-made PV modules and inverters.

I was aiming for a gross price of $2.50 per watt. This would be reduced 30%, since we could take advantage of the federal tax credit. Our local utility company, DTE Energy, also was sponsoring a solar incentive program, offering an upfront rebate of $0.20 per installed watt and a production-based incentive of $0.03 per kWh generated for the next 15 years. This would make the final installed cost less than $1.50 per watt.

The final motivation came from a *Home Power* article that discussed non-optimal array orientation and system performance (see Web Extras). I had assumed that east- and west-facing arrays would generate only about 50% of the energy of south-facing arrays and were not cost-effective. However, the article reported that these orientations could provide up to 80% of the energy generated by a south-facing array. I decided to take another look at our home's solar prospects.

Even though the PV system on the west-facing roof is visible from the street, the system was approved by the Historic District Commission.

Homeowner and volunteer labor helped reduce installation costs. After rebates and projected production incentives, the calculated cost was about $1.16 per installed watt.



Enphase M250 inverters were installed on SolarWorld rails attached to Quick Mount PV flashed feet.

Designing the System

My main goal was to maximize the power that the array could generate on the west-facing roof with Michigan-made Sonali Solar 250-watt modules. I sketched out both landscape and portrait layouts to determine what would yield the best use of space and highest production.

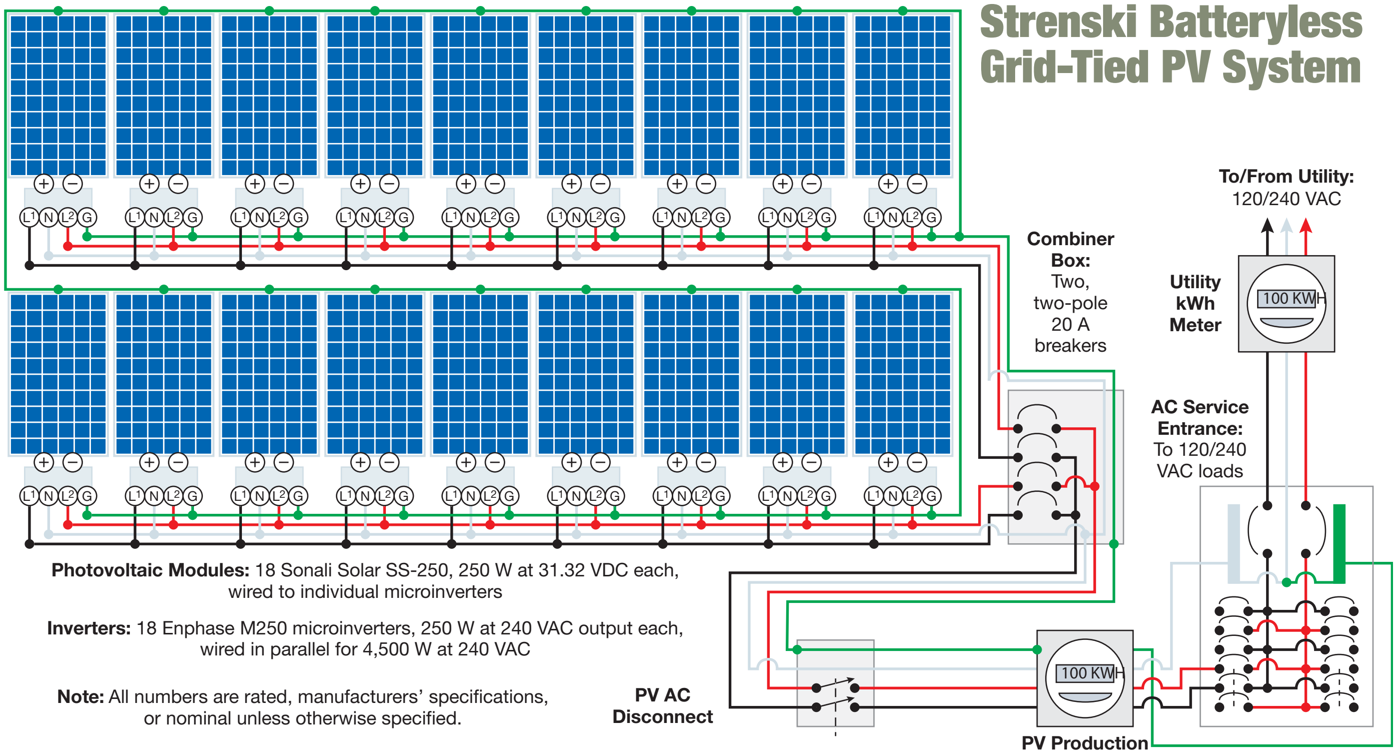
Our utility provides its customers with the past three years of their electricity use data, and I was able to download it for our home. Our average monthly use was 450 kWh, or about 5,400 kWh per year. Once I'd calculated this amount, I used PVWatts to find our site's average number of sun-hours. A west-facing PV array tilted to 45° would receive an average of 3.18 daily sun-hours. Applying an overall grid-tied system efficiency of 75% (to account for shading, inverter inefficiency, and wire losses) would mean we'd need a 6.6 kW PV system to zero out our electricity bill on an annual basis. However, the roof space limited the array size to 4.5 kW.

This west-facing array provides about 75% of the production of a similarly sized array that would be oriented to true south.

Once we'd decided on the system's size, we needed to convince the local Ypsilanti Historic District Commission that putting PV modules on our home would not destroy its historic aspects. The commission had already approved several municipal solar projects, but this was the first time a residence would have PV modules visible from the street. They mulled it over and finally ruled that historic preservation and renewable energy systems could coexist. Their biggest concern was making sure that the PV modules were "removable," and that the array wouldn't cover or damage any unique architectural features of the building. They liked the proposed design since it covered the entire roof face and not just part of the roof—they felt it blended into the roofline better. (In Ypsilanti, there are no fire setbacks required by local fire or building codes, so having an edge-to-edge PV array is permitted.)

The Sonali Solar 250 W modules were available for $0.95 per watt. I wanted to use a Renovo string inverter (also Michigan-made) with them, but a few trees and a power pole created some shade, making microinverters a better choice, since shade on one module won't sabotage the power output of the entire string in a microinverter-based system. After researching different microinverters and accounting for the costs of specialized cables, mounting hardware, terminators, and a communication gateway, I opted for Enphase M250 microinverters. Initially, I thought that all 18 inverters could be placed on the same cable, but this exceeded the limit for a 20-amp, 240 VAC circuit. Thus, an additional cable, terminator, and combiner box was required to protect

Strenski Batteryless Grid-Tied PV System



each string of nine inverters with a 20 A, two-pole circuit breaker. In fact, with all of the "hidden" costs, the inverters, communication, and AC power transmission constituted the largest part of the final installation costs.

With my full-time job as a computer applications analyst, I didn't have a lot of free time to design and build a rack. So I contacted a local solar contractor, SUR Energy, to order the balance-of-system components: an AC disconnect, combiner box, Quick Mount PV's Classic Comp mounts, SolarWorld Sunfix Plus rails, and the Enphase microinverters. It was the classic trade-off of available time versus money.

One interesting aspect of the installation was how quickly the parts could be delivered and installed. The final decision to do the installation was made in September 2013; by October I had all the parts. The installation was completed during two weekends in November with assistance from three of my neighbors who were excited to help and learn about solar-electric systems. The coming cold weather also motivated us

The Enphase Envoy production meter, which lives near the service panel, communicates to the Enlighten Web interface.

Tech Specs

Overview

Project name: Strenski house

System type: Batteryless grid-tied PV

Installer: Homeowner

Date commissioned: December 2013

Location: Ypsilanti, Michigan

Latitude: 42°

Solar resource: 3.18 average daily peak sun-hours (for 270° orientation / 45° tilt)

ASHRAE lowest expected ambient temperature: -4°F

Average summer high temperature: 89.6°F

Average monthly production (estimated): 222.1 AC kWh

Utility electricity offset annually (estimated): 50%

Photovoltaic System Components

Modules: 18 Sonali Solar SS-250, 250 W STC, 31.32 Vmp, 7.98 Imp, 37.2 Voc, 8.45 Isc

Array: 4,500 W STC total

Array installation: Parallel-to-roof array, with Quick Mount PV Classic Comp mounts; SolarWorld Sunfix Plus rails; installed on west-facing roof (45° tilt)

Inverter: 18 Enphase M250, 250 W rated output at 240 VAC, 48 VDC maximum input

System performance metering: Enphase Envoy with Enlighten website

The Enphase Enlighten Web interface allows real-time and cumulative tracking of individual module and whole-array performance.

to finish the installation quickly. Getting the system online before the end of the year also meant that I could collect the 30% federal tax credit for the 2013 tax year.

Since there were contractors installing PV systems for $2.50 per watt, I set that as my budget's upper limit. I hoped to come close to my neighbor's installation cost of just under $2 per watt, but the microinverters bumped up costs slightly. The final gross cost was $2.43 per watt, using volunteer labor. With the 30% federal tax credit and our local utility company's incentives (an upfront rebate and production-based incentives), the net cost was $1.16 per watt. Depending on its production, the system should pay for itself in eight to nine years—assuming a fixed price for electricity of $0.17 per kWh. Not a bad investment for something that has a 25-year warranty.

PVWatts Estimates vs. Actual Production

	Daily Solar Radiation (kWh per m^2)	Estimated Production (kWh)	Energy Value	Actual Production (kWh)
January	1.55	159	$27	45.3
February	1.48	130	22	96.8
March	2.95	315	54	305.0
April	4.04	403	68	375.0
May	4.85	484	82	449.0
June	4.87	455	77	450.0
July	5.42	517	88	275.0*
August	4.25	411	70	no data yet
September	3.89	360	61	no data yet
October	2.32	226	38	no data yet
November	1.33	115	20	21.1*
December	1.17	105	18	68.6
Average	3.18			
Year		3,680	$625	no data yet

*Partial month

System Costs

Item	Cost	% Total
18 Sonali Solar SS-250 PV modules, 250 W	$4,293	39.3%
18 Enphase M250 microinverters & cabling	4,146	37.9%
SolarWorld Sunfix plus rails, brackets, splice kits & clamps	726	6.6%
Enphase Envoy communication gateway	536	4.9%
24 Quick Mount PV Classic Comp mounts	525	4.8%
Conduit & wiring	289	2.6%
Historic, electrical, building & utility permits	307	2.8%
Disconnect & meter socket	112	1.0%
Total	$10,934	100.0%
DTE Energy SolarCurrents rebate	-900	
DTE SolarCurrents ongoing production-based payments (15 yrs.)	-1,528	
30% Federal tax credit	-3,280	
Grand Total	$5,226	

Unexpected Lessons

There are some advantages to DIY installation, but it can also come with some caveats—especially if you're working on a second-story, steep roof. You need to feel comfortable climbing on high roofs and being roped in. For me, this was the fun part of the project. On the 12:12 roof, a good ladder with a stabilizer bar was a must. For safety, we also used a fall-protection system (see Web Extras for a roof safety sidebar in "PV Rack Strategies"). Having extra parts like nuts and bolts while up on the roof was a must, saving trips down and up the ladder when they slip from your hands and roll off the roof.

The stressful parts of the project were making sure I had dotted my i's and crossed my t's when it came to understanding all of the electrical and structural codes that applied. A big pitfall would have been to have the system fully installed and then find out from the electrical inspector that I had not grounded everything properly—and have to redo the whole project to fix the error. But worse would have been to have unknowingly used wire that was undersized for the project and then have to rewire the whole system. For my installation, the building inspector insisted on having structural drawings to prove the roof could handle the system's weight. The roof had only one layer of existing shingles and 2-by-12 rafters on 16-inch centers. The PV modules' combined weight was similar to another course of asphalt shingles, and he agreed that the roof could accommodate the system.

web extras

"PV Array Output at Various Tilts & Orientation" by Justine Sanchez in *HP155* • **homepower.com/155.32**

"The Right Fit" by Jeff Tobe in *HP161* • **homepower.com/161.44**

"PV Rack Strategies" by Greg McPheeters & Tim Vaughan in *HP142* • **homepower.com/142.80**

Strenski PV array time-lapse video • **youtube.com/watch?v=Daz52wZbVd0**

The author and his family in front of the PV production meter.

One design aspect we wrestled with was how to space the module rows. Although the gap between the modules in a single row is fixed by the top clamps (about 3/4 of an inch), the gap between the rows can be whatever you want. For shedding snow, a small gap (less than 1 inch) helps the rows act as one continuous slippery surface, letting snow slide off in one sheet. While a larger gap (several inches) might aid in summer cooling, in the winter, snow on the upper module can slide into the gap, creating a small snow dam. In the end, practicality won out—a gap of 12 inches was chosen because it gave us more room to stand on the steep roof while we installed the modules and microinverters.

Component Manufacturers

Microinverters: Enphase • enphase.com

Flashed mounting feet: Quick Mount PV • quickmountpv.com

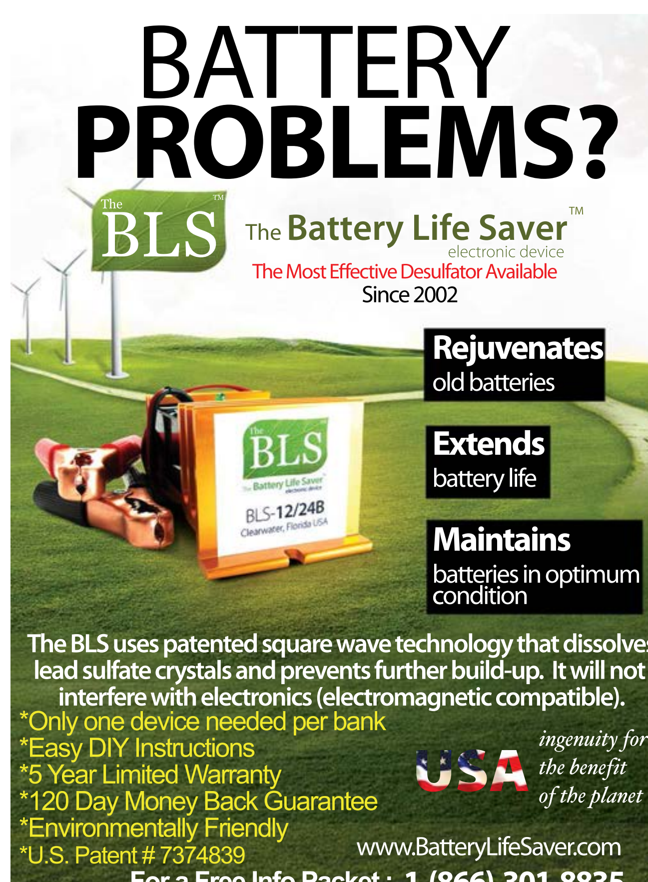
Rack rails: SolarWorld • solarworld.com • Sunfix Plus

PV modules: Sonali Solar • sonalisolar.com (sourced through cbssolar.com)

PV Power

The M250 microinverters' monitoring software shows how much power each module is producing. This winter, it was interesting to see which modules shed their snow the quickest to start producing power. The system is performing close to my expectations, although the array receives more shade than I anticipated, which results in lower production in some months compared to the original PVWatts estimates (see "PVWatts Estimates vs. Actual Production" table).

Besides the system's clean energy and lower utility bills, the next-best part of the installation has been people visiting our house who don't even notice the modules on the roof. It's amazing how quickly the solar modules have blended into the neighborhood's landscape.



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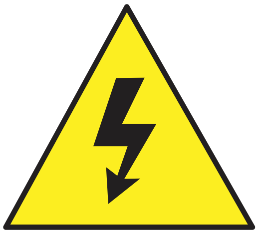

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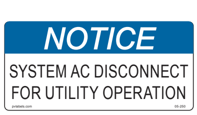

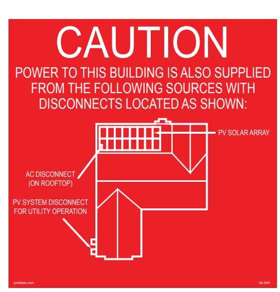

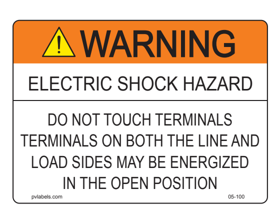

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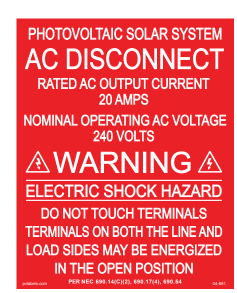

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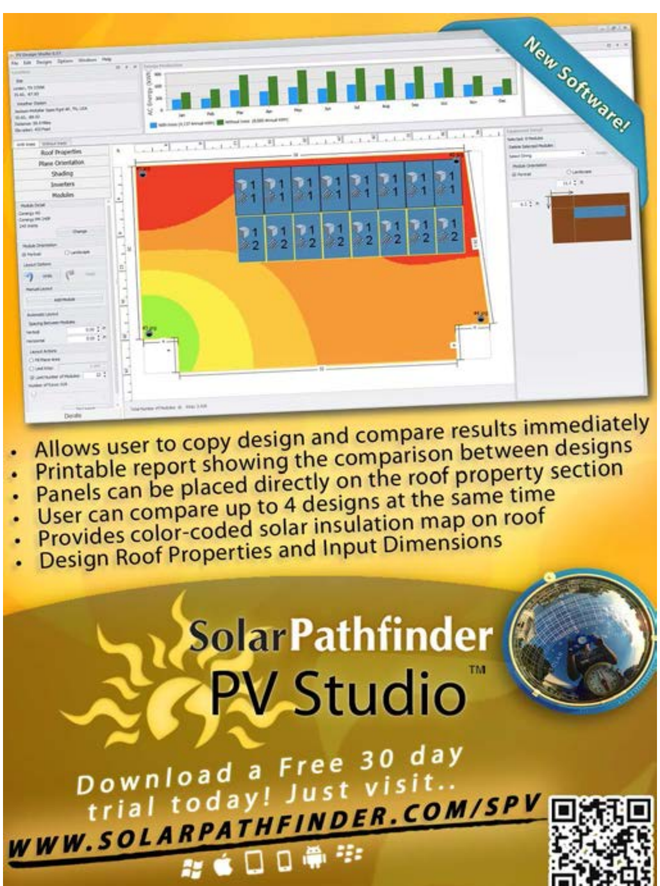
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ROOF-MOUNTED RACKS

for Solar Water Heating Collectors


Courtesy SunEarth

by Vaughan Woodruff

The installation of solar water heating (SWH) collectors is an investment in one's energy security. Proper installation protects that investment.

A roof-mounted array has the economic benefit of utilizing an existing structure—your home or garage's roof—rather than having to build a separate structure to support the collector array, which can be costly (see "Ground-Mounted SWH Systems" sidebar).

Even so, a roof-mounted SWH system should not affect the building's structural integrity. Examine the roof structure and be certain that the rack can be attached to the roof framing—not the sheathing! If the roof already looks like it is having a difficult time doing its job—i.e., it is sagging or bounces when you walk on it—you may need to reinforce it. If you plan to use a tilt rack (see "Tilt or Parallel?" sidebar), be sure to understand collector loads on the roof. It may be necessary to consult a professional for advice or have the system engineered.

Design Loads

This article provides a glimpse into the mind of a structural engineer and discusses the impact of a collector array on a structure. This insight should help you determine the various forces that can affect a project, and to appreciate the expertise that an engineer can lend to your project.

Build-Your-Own Rack

SWH racks can be DIY. But commercially available mounts are engineered and use materials that are compatible with one another and resist corrosion. The structural strength of the collector itself is considered, along with lateral bracing as necessary to ensure that collector stress is minimized. When building a DIY rack, these responsibilities become the owner's.

The forces upon a collector and roof are the major consideration when designing a rack or selecting mounting hardware. These forces are categorized as dead loads, live loads, and environmental loads.

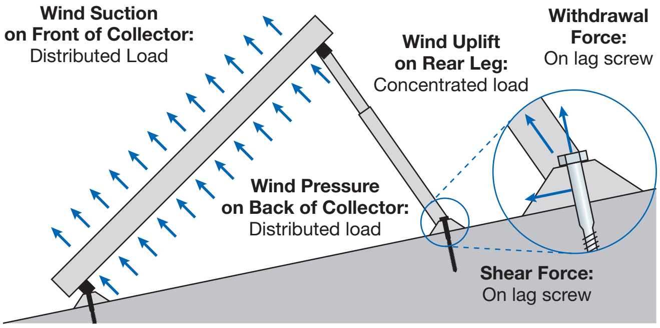
Dead loads result from the weight of the collector, the mounting hardware, and the collector fluid—and remain constant. For SWH systems that use glazed flat-plate or evacuated-tube collectors, the collector dead load is approximately 3 to 5 pounds per square foot (psf). For comparison, a layer of shingles has a dead load of 2 to 3 psf. The exact empty and filled weights of a particular collector can be obtained from the manufacturer's specification sheets. Integral collector storage (ICS) units and thermosyphon systems contain tanks and may have dead loads that range from 25 to 70 psf.

Live loads are intermittent, resulting from movable objects. The weights of the staged equipment and of solar installers working on a roof would be considered live loads. These loads typically don't affect rack design, but the roof itself must be able to support live loads.

Environmental loads come from rain, snow, earthquakes, and wind. Rain is rarely considered when designing the mounting for a solar array unless the design causes pooling on the roof. It is best practice to avoid such a situation by orienting the attachments to the roof in a manner that permits normal drainage of the roof surface.

Typical snow loads in the United States range from zero in areas such as Florida and Southern California to 100 psf in northern Maine to up to 400 psf in some locations in Alaska. Drifting and sliding snow can increase these loads

Wind Loads on Rack



significantly. Snow loads for collector racks are affected by local siting—whether they are in an exposed area where wind will readily blow snow off, or they are in a sheltered area where the snow is unlikely to be blown away.

Due to their filled weight, ICS and thermosyphon systems may be subjected to significant earthquake loads. Consideration of earthquakes is specific to portions of California, as well as Hawaii, Puerto Rico, and the U.S. Virgin Islands. Evaluating the effects of these loads is complex and should involve professional engineering.

Wind loads are a critical consideration for tilted racks. The greater angle a collector is from the plane it is mounted on, the more impact wind loads will have. The magnitude of wind loads depends upon:

- Wind speeds at the particular location.
- The height at which the collector is mounted. A collector mounted on a 30-foot-high roof, for example, will experience greater wind loads than one mounted on a lower roof.
- The collector exposure. Coastal homes that are unsheltered, for example, will have much greater wind loads than homes sheltered by large buildings or trees.
- Wind-loading effects are exponentially related to the wind speed. A site with twice the wind speed of another will be subject to four times the wind force. Maps are available to assist designers with determining wind speed. In some cases, local authorities having jurisdiction will specify the "design" wind speed.

Distributed versus concentrated loads. Many roof loads are considered distributed loads, which means they are spread out evenly over an area—like the roof sheathing, underlayment, and roofing material. Wind and snow loads on the roof surface are also distributed loads. But when the wind or snow load is on the collector, it is exerted on the feet, becoming a concentrated load, which is applied to points on the roof structure.

Concentrated loads for flush-mounted collectors tend to have minimal impact on the stresses in the roof structure. When collectors are installed on tilt racks, the geometry of a tilt rack amplifies the impacts of the wind. The design of the mounting rack will have a significant effect on how large the concentrated loads will be on the roof structure.

Ground-Mounted SWH Systems

Likely, the best solar window at your site will determine whether your solar water heating (SWH) system is roof-mounted or ground-mounted. Both have their advantages—and disadvantages.

Since the ground-mount is independent of the roof, any concerns associated with the strength of the roof for supporting solar collectors are eliminated. Using a ground-mounted array also minimizes the safety risks associated with installing equipment on an elevated surface. Tilt racks are commonly used in ground-mounted systems and provide the owner with an opportunity to install the collectors at an angle that best suits the application.

However, ground-mounted systems require their own foundation and are usually more expensive than roof-mounted SWH systems. Besides cost, there are other challenges associated with ground-mounted arrays. The type of soil in an area can have a huge impact on the stability of a new foundation. The presence of rock ledge may require drilling and pins to secure the foundation and clay may cause settling that could affect the integrity of the collector array. Additionally, ground-mounted arrays typically require burying pipe and can significantly increase the amount of piping needed between the collector array and the storage tank. This not only adds costs but also can affect performance by increasing heat loss in the system and potentially requiring more pumping power.

Vaughan Woodruff

Foundations for ground-mounted systems must be installed below the frost line in areas subjected to freezing soil.

Tilt or Parallel?

For aesthetics, it is often preferable to mount collectors at the same slope as the roof. Parallel-mounted arrays are less conspicuous and also minimize the effects of wind on the collector array. But in systems where parallel mounting will dramatically impact system performance—for example, when the roof pitch is too shallow, placing the collector at risk of summertime overheating and wintertime underperformance—tilt racks may be used. A tilt rack elevates the upper portion of the collector to increase the array's mounting angle. For further discussion about the impact of the collector tilt on system performance, see "Site Assessment for Solar Water Heating Systems" in *HP159* (homepower.com/159.64).

Flush-mounted collectors blend aesthetically with the roof and have less wind-loading, but are dependent on having a favorable roof pitch.

Rack Design

Racks are designed to transfer dead and environmental loads from the collectors to the roof structure. Hardware secures the collectors to the rack, the rack is attached to the building surface (usually the roof), and the structure then carries the loads to the ground. SWH mounting kits are usually available from the collector manufacturer to match the collectors' frame. Most mounting kits use clamps that are inserted into frame extrusions, and proprietary mounting hardware. This is in contrast to most PV racks, which can be used with most modules.

Two types of tilt racks are common—strut-type aluminum racks for flat-plate collectors and stainless-steel racks for evacuated-tube collectors. ICS units may also be installed on tilt racks, but these collectors are less prevalent in the U.S. than flat-plate and evacuated-tube collectors.

Aluminum for flat-plate collectors. Several manufacturers offer a tilt rack that uses two struts—one supports the upper portion of the collector, while the other supports the bottom portion. The upper strut is connected to legs attached to feet that are secured to the roof structure. The lower rail is attached directly to mounting feet without legs.

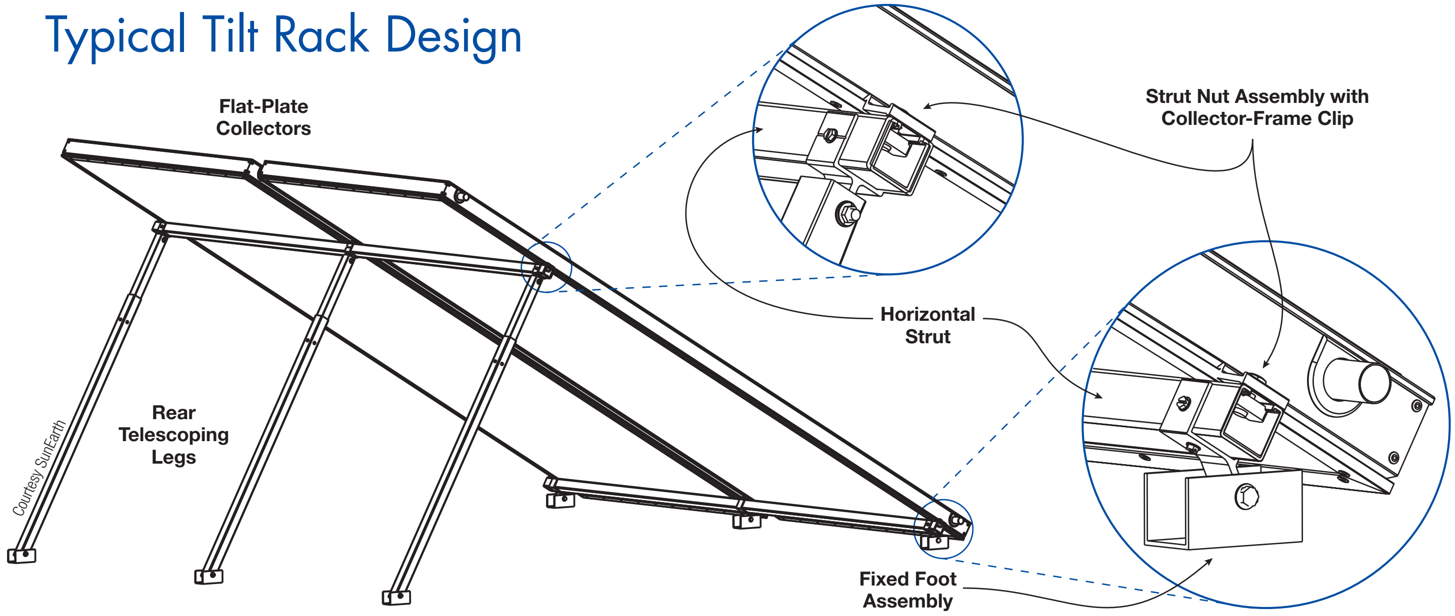
The distance between the rails depends upon the environmental loads and the strength of the collector frame. Loads can cause bending stresses, which also are affected by beefiness of the collector frame. Lighter, shallower frames will have more deflection (i.e., will bend more) and require more support than deeper frames. Longer cantilevers will increase the stresses in the collector frame, as will a large spacing between the rails. The allowable cantilever collector is less than the allowable span between the rails. For example, SunEarth specifies a maximum cantilevered length that is 20%

Installing collectors in a landscape position can improve the aesthetics of the installation and reduce the wind loads on the roof.

Vaughan Woodruff (3)

When the roof orientation is less than ideal, tilt racks can often be rotated 90° to allow for a wall-mounted array.

Typical Tilt Rack Design



This aluminum tilt-up rack for flat-plate collectors (by SunEarth) makes the most of a shallow roof pitch.

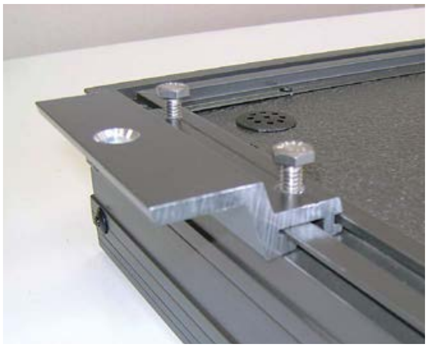
of the length of the collector while allowing the rails to be spaced at roughly 75% of the collector length.

Stainless steel for evacuated-tube collectors In contrast to flat-plate collectors, which can use the structure of the collector frame for bracing and support, evacuated-tube collectors rely strictly on the rack for structural support. Since stainless steel is stronger than aluminum, the thickness and size of an evacuated-tube rack tend to be thinner and smaller than those for a flat-plate collector. Racks for evacuated tubes require significantly more bracing—the manifold could easily be pushed sideways since the collector itself lacks the rigidity of a flat-plate collector. Diagonal bracing is required for evacuated-tube tilt racks.

An evacuated-tube collector is secured to the rack by clamping the manifold and the tube's mounting rail to a frame, which has two or three rails that run parallel to the tubes. The collector is tilted by using legs bolted to the mounting rails and attached to the roof via a foot or to another stainless steel section that connects to the bottom end of the mounting rail to form a triangle.

Evacuated-tube collectors often need cross-bracing, seen here through and behind the tubes.

A close-up of the clamps that hold Apricus tubes to the rack.



Courtesy Solar Skies

This rack attachment clip is designed to work specifically with the frames of Solar Skies collectors.

Vaughan Woodruff

Seam clamps are often used when mounting collectors on standing-seam metal roofs. It is important to determine how the metal roof is attached to the roof structure to ensure that it can transfer the collector loads.

Sealing Roof Attachments

With the recent explosion of residential grid-tied PV systems, numerous flashing products have been introduced to help waterproof roof attachment points. Many of these products are easy to integrate with parallel-mounted solar collectors.

However, using these products with tilt racks proves to be a greater challenge. Most mounting feet on tilt racks require two lag screws to resist the withdrawal forces that can occur at the rear foot. Though there are a number of mechanical flashing products on the market that utilize two lag screws, only a few integrate with selected tilt racks in the SWH industry. Heliodyne, for instance, utilizes the same flashing used on standard plumbing vents to mechanically flash the feet of its tilt racks. EcoFasten Solar's GF2 flashing and brackets provide another option for connecting the rear mounting feet of standard racks directly to the roof. There are a number of collector manufacturers that suggest waterproofing lag screw penetrations by applying a quality sealant to the threads and between the mounting foot and the roofing.

Though some industry representatives claim that using sealant alone is a building code violation, there is a lot of ambiguity surrounding what is required for sealing penetrations. In many jurisdictions, if the roofing manufacturer specifies a method for sealing such penetrations, then the lag screw installation must conform to these specifications. In cases where the manufacturer doesn't specify these details or the roofing manufacturer is unknown, the building code specifies that the penetration must be flashed in a waterproof manner. This often means consulting with the original roofer, researching roofing best practices, and/or referring to the rack manufacturer's installation instructions.

Courtesy EcoFasten Solar

Flashed, two-lag mounting feet, like these by EcoFasten Solar, are preferred over just using lags and sealant.

Attachment Points

Lag screws are the most common method for attaching a collector rack to the roof. Other methods include using J-bolts that hook the underside of a rafter or roof truss. SWH racks may also be wall-mounted and attach to the wall similarly.

The lag-screw size required is determined by the load they must transfer from the rack to the roof structure. The same loads also determine whether the roof is strong enough to support the array.

The most critical loads on the roof attachments often occur at the rear leg when the wind is creating uplift on the collector—the lag screws hold down the rack as the rack tries to pull away from the roof. There is also a shear force that pushes perpendicular to the length of the lag screw.

When installing a collector rack, it is critical to follow the manufacturer's instructions. Changing the geometry of a tilt rack, for example, can have a significant impact on the magnitude of the loads that are transferred through the lag screws. For example, if the manufacturer requires the mounting leg to be installed perpendicular to the collector and the installer instead mounts it perpendicular to the roof, the withdrawal force on the lag screws could be significantly increased.

Some tilt racks are more versatile than others. Often versatility is determined by how stringent the spacing is between mounting feet. A rack that requires a specific spacing may not permit the use of lag screws or J-bolts if the spacing between the rafters or trusses is not compatible with the spacing of the tilt rack's mounting feet—in which case spanners between roof joists or trusses may be necessary.

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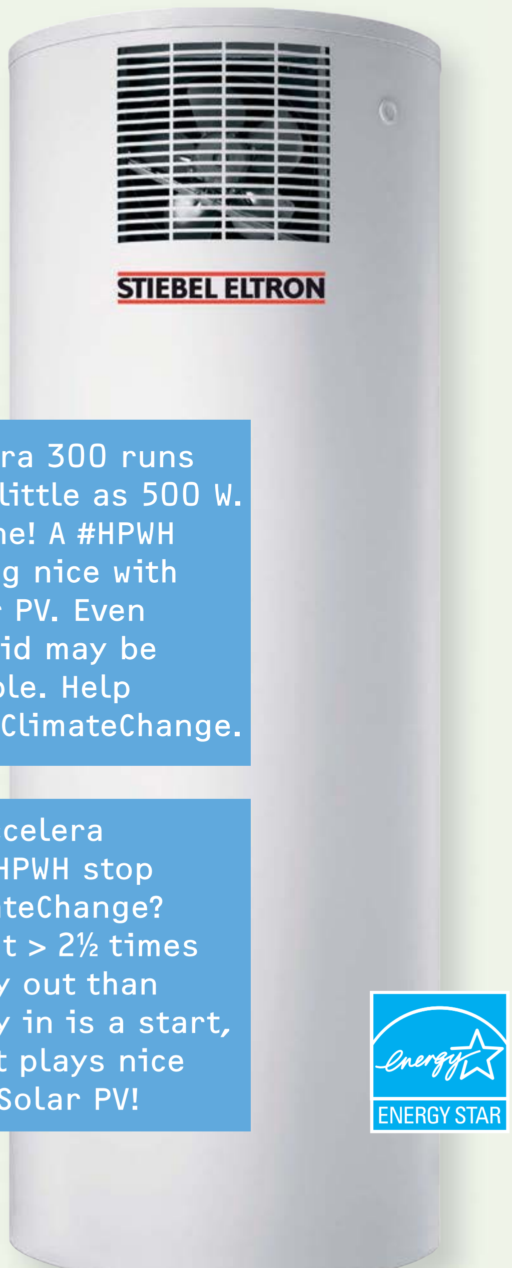

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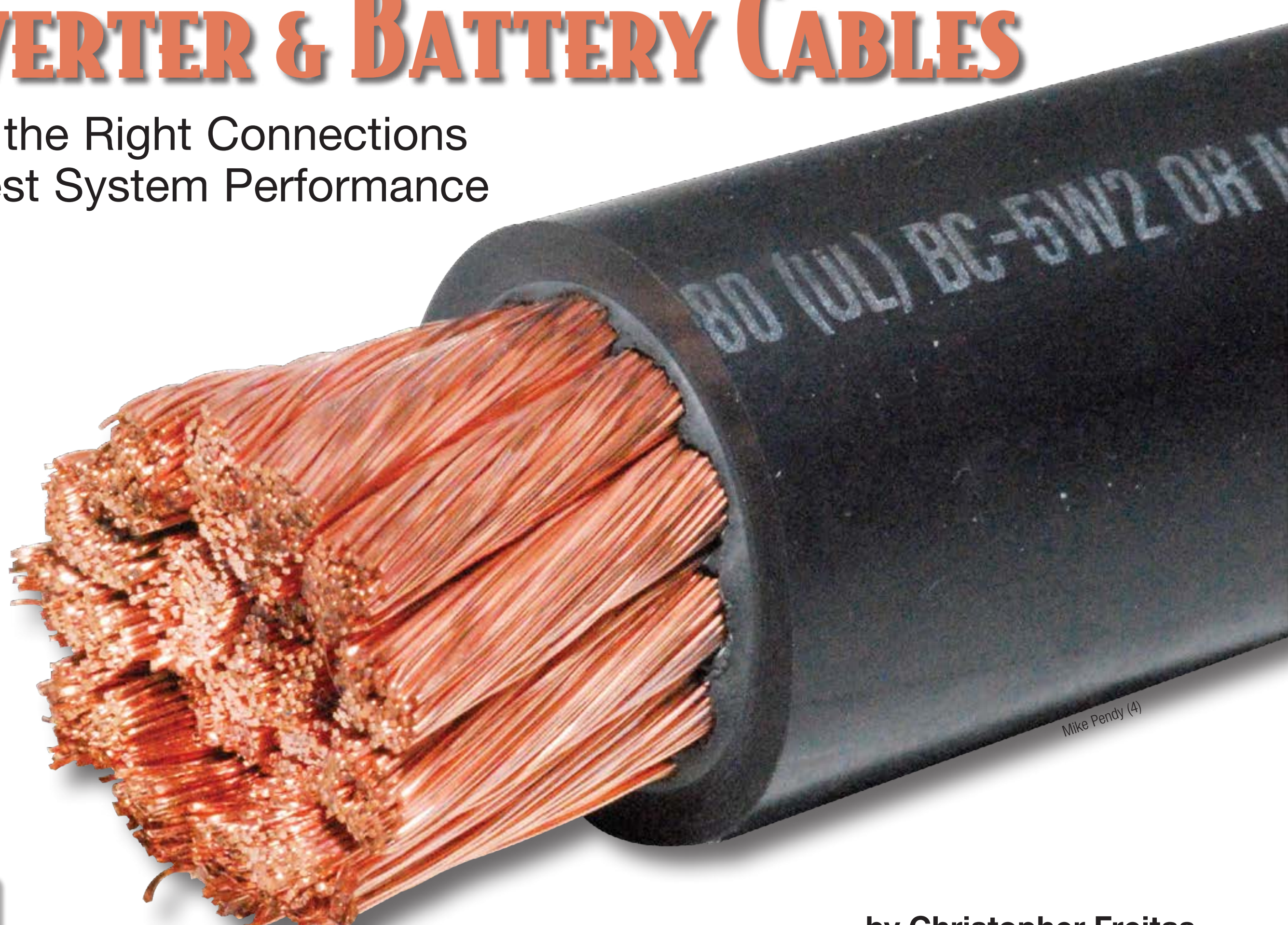

Mike Pendy (4)

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by Christopher Freitas & Carol Weis

Poor-quality and improperly installed battery and inverter cables can cause problems in the function and safety of a battery-based system. Here's how to select the right cables and install them correctly, for optimal system performance.

There is a perception that battery and inverter cables are expensive—and it is a tempting place to cut costs—but buying cheap cables can result in significantly reduced performance of the battery bank and inverter(s). It's a lot like putting cheap tires on a high-performance car—you save some money, but you don't get the performance and safety you might need. The common problems seen with cabling in battery-based renewable energy (RE) systems are typically due to low-quality cables and hardware, in combination with poorly made crimps and connections.

You can purchase preassembled cables or have them made to order, but you can also build them yourself. The details are important—battery cables and their ring terminal connectors (also called "lugs") carry high current and are used in harsh environments where they can be exposed to sulfuric acid, hydrogen gas, high temperatures, and dissimilar metals.

Cable Ampacity

For battery/inverter RE systems, the largest conductors in the system are usually the ones connecting all of the batteries together and then exiting the battery box to connect to the inverter. Since nearly all battery-based inverters operate at 48 VDC or lower, the cables need be large to handle high currents without significant losses. Sizing of these cables is based on the battery voltage, the inverter's continuous amperage rating, and the length of the cable. Commonly, these cables are either 2/0 AWG (acceptable for use with a maximum of 175 A breaker or fuse) or 4/0 AWG (acceptable for use with a maximum of 250 amp breaker or fuse), but will need to be individually calculated. For example, the installation manual for OutBack Power Systems' VFX3524 (3,500 watts; 24 VDC) inverter recommends 4/0 AWG for a battery-to-inverter cable length of 10 feet or less. This size

This fine-stranded 4/0 AWG, UL-listed cable is designated as THW, making it appropriate for battery–inverter cabling.

cable would result in a voltage drop of less than 1% at full rated output of the inverter, resulting in 34 watts of losses in the 10-foot-long positive and negative conductors. Shorter cables would reduce the losses proportionally.

Cable Types

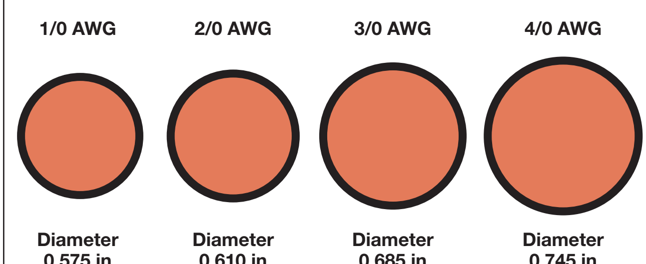
High-quality battery/inverter cables are made of fine-strand copper conductors with a flexible insulation covering and are available from manufacturers such as Polar Wire Products or Cobra Wire & Cable. Although finely stranded cables are not required, they make installing and servicing the system easier and reduce stress on the battery and inverter terminals. All high-quality battery cables are made with UL-listed wire and include a *National Electrical Code (NEC)*-required designation, such as RHW, THW, or THHW.

Lower-quality battery cables are often made from automotive or welding conductor cable. This type of cable is cheaper and easier to obtain—but is not acceptable by the *NEC* since it is not UL-listed or marked with the *NEC* wire type. While some types of welding cable have a UL listing, they have been approved using a different set of UL standards and tests, and are not marked with the required *NEC* wire-type designation.

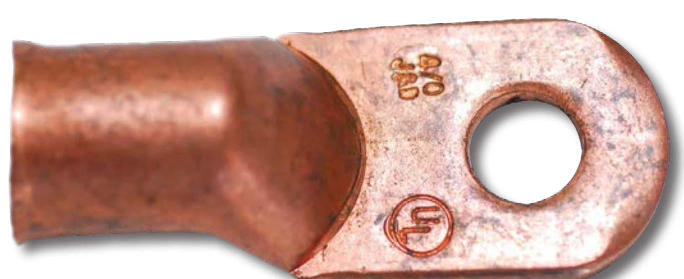
Battery Cable Size*

Size (AWG)	Diameter (in.)	Area (mm^2)	Ampacity[1] (Amps)
1/0	0.575	167.5	150
2/0	0.610	188.5	175
3/0	0.685	237.7	200
4/0	0.745	281.2	230

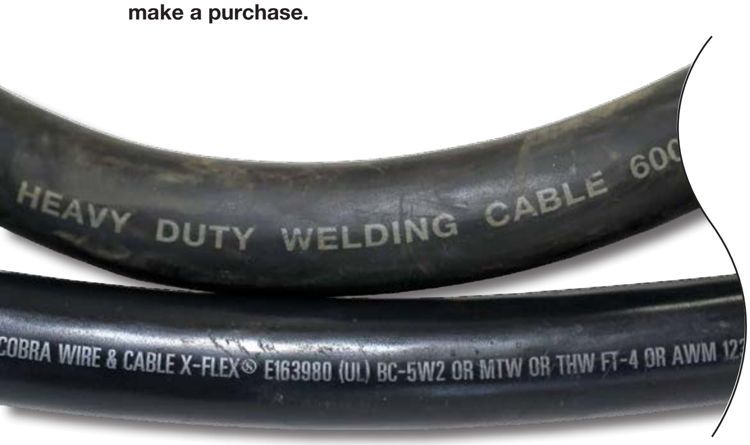
*For fine-stranded conductors from Cobra Wire & Cable
1. Copper THW, in conduit, 75°C



A bare copper closed-end-type lug made for 4/0 cable.



Welding cable (top) and UL cable (bottom) look very similar, but welding cable is not ***NEC***-approved. Be sure to carefully inspect the markings before you make a purchase.



Lugs

There are many different types of battery cable lugs to choose from if you're making your own cables. The following are things to consider:

Material. Lugs can be made from many different materials, including copper, steel, or aluminum. To establish high-quality, long-lasting connections, only copper lugs are recommended. Steel or aluminum lugs will corrode over time from environmental conditions or from galvanic corrosion that occurs when dissimilar metals come into contact.

Mike Pendy (2)

A tin-plated copper lug is crimped onto its cable, protected with heat-shrink tubing, and marked for polarity.

Bare or tin-plated. Copper lugs come in two varieties: bare or tin-plated. The tin-plated copper lugs are usually a dull gray color, and are preferred, especially for use at battery connections, since the plating reduces corrosion that can occur between the copper lug and the battery's lead terminals, especially when there is battery acid involved.

Open- or closed-ended. To prevent corrosion from entering the conductor strands, use closed-ended lugs at the battery. Open-ended lugs are less expensive and more commonly available, and can be used when making inverter and breaker connections, but should not be used for the battery connections.

A crimped, open-ended lug.

Listing. A lug needs to be tested and approved to UL standards, and rated for the system's maximum voltage, current, temperature, and conditions of use. When using a fine-strand cable, you'll also need to select lugs that are listed for the wire type (for example, fine strand wire is typically Class K). This can be difficult to determine or verify from the information available from the lug markings and manufacturer's datasheets.

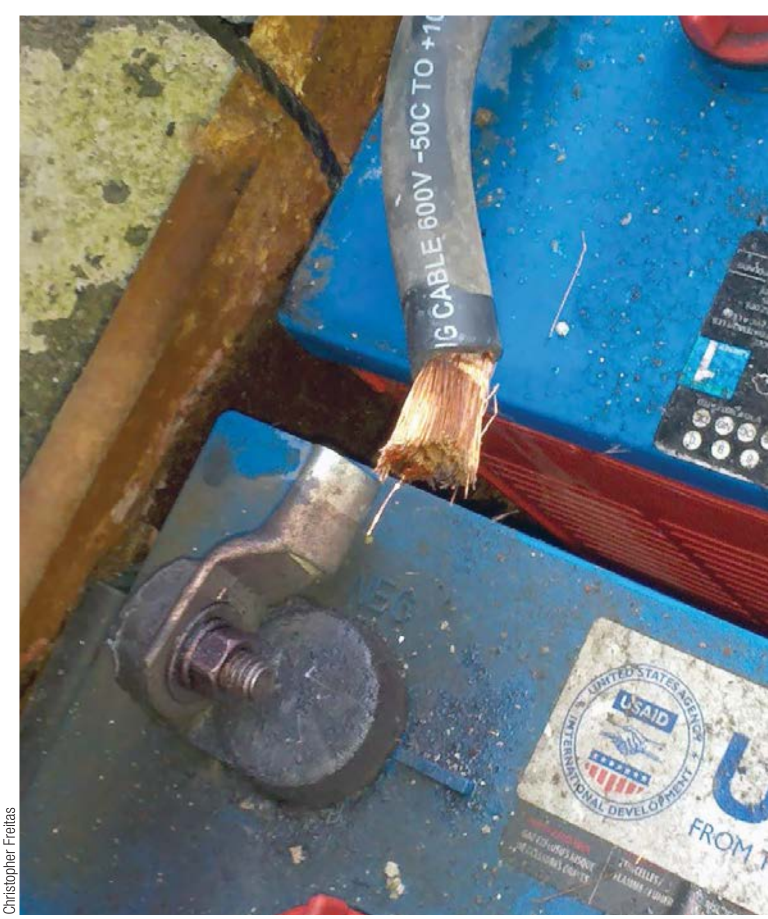
Sizing. All crimp-type lugs are rated to fit a specific conductor size, so matching the lug to the conductor is required by the *NEC* to ensure a good connection.

Bolt-hole diameter. It is also important to choose the correct bolt-hole diameter for the lug and terminal hardware combination. Drilling out the lug's hole to accommodate a larger bolt is not acceptable as it may reduce the lug's current rating; it also can result in higher resistance and excessive heat buildup that could potentially result in melted battery terminals or a fire.

Ring terminal size & shape. The "flag" or "ring" of the lug that attaches to a terminal comes in a variety of shapes and sizes. Lugs that provide a large surface area reduce resistance and the possibility of digging into soft lead battery terminals. Some breakers and inverters may need a smaller-size ring to fit on their terminals.

Avoid using set-screw-type compression lugs with finely stranded cable. Under pressure, the fine strands can twist and break off. The high number of strands makes the flexible cable's connection "soft," resulting in a connection that will be difficult to get tight and could potentially become loose over time.

A tug on this poorly crimped cable pulled it out of its lug. Good crimps are necessary for safety and low-resistance connections.



Christopher Freitas

Tight Lug & Cable Connections

Crimping. When lugs are not securely crimped on a cable, the loose connection causes higher resistance to the flow of electrons during charging and discharging. This can devastate the performance of a battery string or entire bank and could possibly result in melted battery terminals and even fire—but those aren't the only problems. Additionally, this is a hazard to someone maintaining the battery bank. During a routine inspection—for example, when the electrolyte level is being checked—a cable could accidentally be bumped loose from a lug and touch something else, causing a short-circuit or shock. If there is hydrogen gas present, a resulting spark could be very dangerous. Safety concerns, as well as possible performance degradation, can be eliminated by well-made cable crimp connections.

A low-quality crimping tool used to compress the lug onto the cable can result in a loose connection, with only a portion of the cable's strands of wire making electrical contact. These cheap crimpers often use a single "pin" to press on the lug's barrel and press the other side into a V-shaped groove, leaving voids inside of the lug. Over time, this poorly crimped lug will become loose, often overheating and failing. The lug may even come off the cable entirely if pulled.

High-quality crimpers use specific jaws to accommodate different-sized cables and compress the lug's barrel from multiple angles, either into a square or even a hexagonal shape. This produces a much tighter connection without any voids—making sure all of the cable's outer wire strands make contact with the lug. These types of tools are more expensive but necessary for making proper connections.

Soldering is an additional means of sealing the connection, so even if you're using solder-type lugs they first must be crimped on properly and then soldered. Few installers have the equipment to properly solder a cable connection without damaging the insulation; therefore, it is rarely done. Soldered connections are acceptable under the *NEC*, but may require additional scrutiny by an inspector to verify what lugs and processes were used.

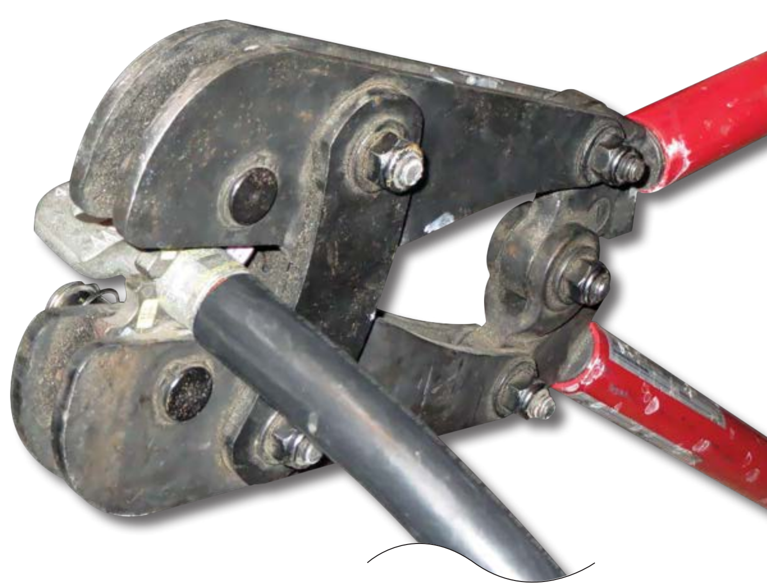
Protecting the cable. To further protect the battery cable strands from corrosion, seal the crimped connection with adhesive-filled heat-shrink tubing. This is available in a variety of sizes and colors from battery suppliers. It usually is made from a thick-walled plastic material and gives additional support to the delicate, fine-stranded wire where it connects to the cable lug. Don't be tempted to use electrical tape—it is not as effective.

Terminal Connections

Making a secure, low-resistance connection to the battery or the inverter terminal is just as important as properly securing the cable to the lug. Use the right type and size of stainless steel hardware when attaching to the lead post which is quite soft and can be easily damaged. The correct washer, lock washer, and nut placement is critical to the

Nunatak Alternative Energy Solutions (2)

When heated, heat-shrink tubing with sealing glue inside will keep out corrosive fumes and support the fine wire strands.



Using the right crimping tool for the cable size and lug type is crucial for making a good mechanical connection between the wire and lug.

Nunatak Alternative Energy Solutions (2)

The cable components before (top) and after (bottom) assembly, crimping, heating the shrink-tubing, and labeling with colored tape.

Cable Checklist

Cables

- ☐ Properly sized for ampacity limits and temperatures
- ☐ Insulation is the correct type, with *NEC* wire-type designation
- ☐ Cables or cable ends are color-coded to assist with proper connection
- ☐ Routed across the battery tops to avoid blocking access to vent caps during maintenance
- ☐ Connections are properly torqued to the recommended values on all of the terminals
- ☐ Locate battery-to-inverter cable connections on opposite corners of the battery bank to ensure equal current flow

Lugs

- ☐ Properly listed and rated for the size and type of conductor used
- ☐ Closed-end to prevent corrosion (especially at the battery connections)
- ☐ Cable lugs well-crimped to the conductor
- ☐ Heat-shrink to seal the lug crimp to the cable insulation
- ☐ Cable lugs placed in direct contact with the battery terminal (without washers between)

Hardware

- ☐ Stainless steel hardware used
- ☐ Flat washers and lock-washers used in the correct order on all bolts
- ☐ Anticorrosion material fully covers each battery terminal/hardware connection

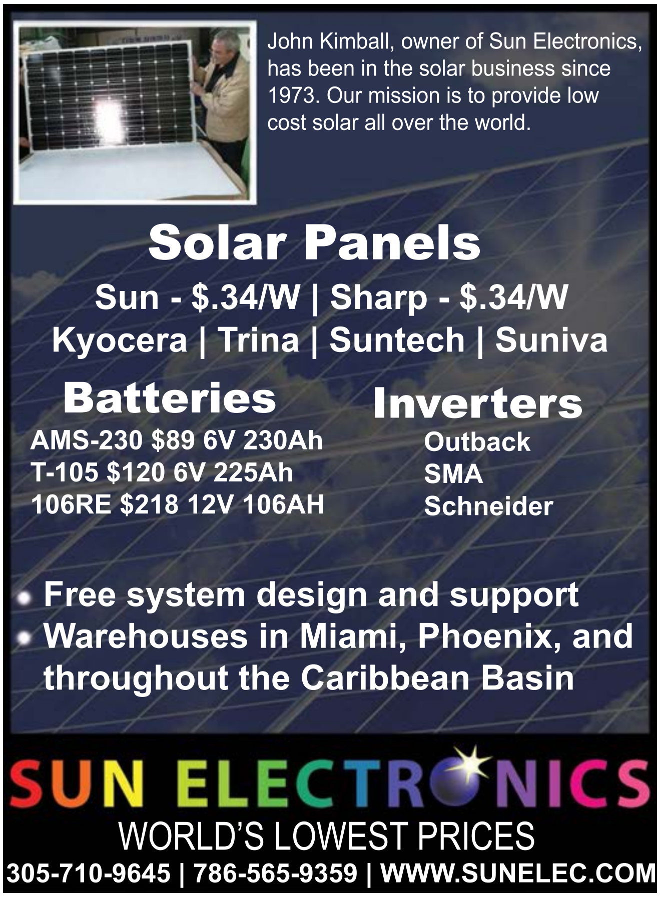
connection staying tight. Thoroughly clean the lead battery terminal with a wire brush before attaching the lug to achieve a good connection. Then tighten the terminal's hardware to the battery manufacturer's specifications and add an anticorrosion coating. Do not put any anticorrosion coating between the terminal and the cable lug.

Be diligent about placing the hardware in the correct order. A hazardous condition can be created if a washer is placed between a cable lug and the inverter or battery terminal. In this scenario, the high current that is drawn by the inverter would have to pass through the washer, causing the connection to overheat—which can damage the battery or inverter terminal and even cause a fire.

Cable Protection

In most battery–inverter systems, the battery cables are routed from the battery enclosure into a DC disconnect enclosure, through a breaker, and then to the inverter. The *NEC* requires that exposed conductors be protected. A common solution is to route the cables through conduit, which comes in many different sizes and types, including flexible or rigid, and metallic or nonmetallic.

The cables leaving the battery bank are usually not protected from overcurrent until they are connected to the DC disconnect enclosure, making them a substantial hazard if they are not well-protected. It is recommended to use nonmetallic conduit for these circuits to eliminate the potential for ground faults. The conduit should be attached to the battery and DC disconnect enclosures using a threaded male adapter; use plastic bushings on these sharp threads to protect the cable insulation. The conduit also needs to be well-supported and attached to walls or supports to prevent it from breaking and pulling on the conductors.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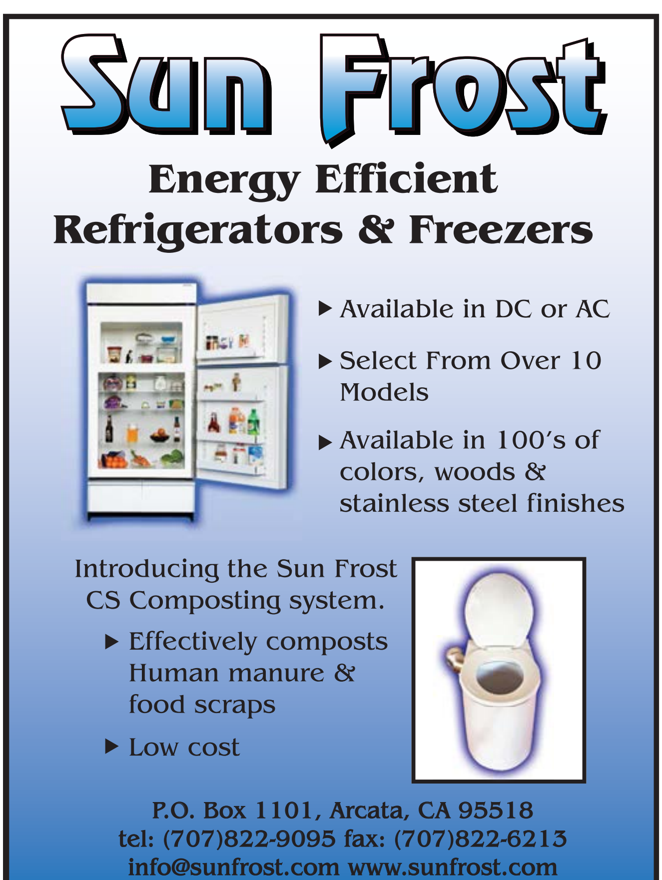
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NEC Calculations

by Ryan Mayfield

"Code Corner" in *HP159* and *HP161* detailed the requirements for circuit sizing and overcurrent protection under the 2014 *National Electrical Code (NEC)*. Here are some example calculations to bring that *Code* language to life. For those who use the 2011 *NEC*, don't worry—the calculations are the same.

If you're rusty on the "whys" behind the calculations, consider reviewing those previous "Code Corner" articles to understand the background information. The calculation examples use:

- 72-cell, 310 W module; 45.4 Voc, 9.28 A Isc, and 15 A maximum series fuse rating
- Four PV source circuits connected to a single string inverter
- The location is Sacramento, California, with an ASHRAE 2% average high temperature of 38°C
- Exposed rooftop conduit is 2 inches above the roof surface

  The effective temperature inside raceway [from Table 310.15(B)(3)(c)] = 38°C + 22°C = 60°C

  The 90°C conductor insulation correction factor for 60°C from Table 310.15(B)(2)(a) is 0.71
- The temperature of conductors that run through the attic space is estimated at 55°C

  The 90°C conductor insulation correction factor for 55°C from Table 310.15(B)(2)(a) is 0.76
- All terminals located in junction and combiner boxes are rated for 75°C
- All exposed conductors are PV wire and rated at 90°C; all conductors within raceways are THWN-2 and rated at 90°C
- With four source circuits, there are eight current-carrying conductors in the raceway, and the correction factor is 70% from Table 310.15(B)(3)(a).

Independent Source Circuits

For our first example, all PV source circuits run independently from the modules to a rooftop junction box (no combining on the roof) and then continue down to the inverter. The raceway is on the rooftop and exposed to sunlight, and runs through the attic before terminating at an inverter inside the building that contains an integrated combiner and DC disconnect. This scenario—keeping the source circuits independent from the array to the inverter—is common in residential applications.

We can jump straight into the circuit-sizing section of the *NEC*. First, find the maximum circuit current:

- From Section 690.8(A): Imax = Isc × 1.25 = 9.28 A x 1.25 = 11.6 A

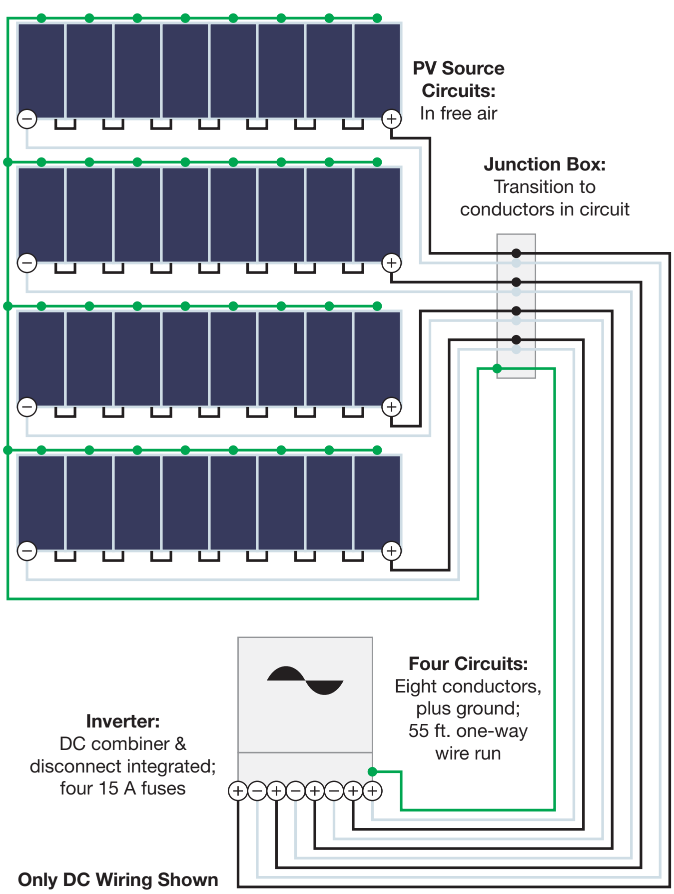
Next, determine the minimum conductor size required:

- Under 690.8(B)(1): Icont. = 11.6 A Imax x 1.25 = 14.5 A

  From Table 310.15(B)(16): Under the 75°C column, 14 AWG copper is the smallest conductor that exceeds the 14.5 A requirement (see "Code Corner" in *HP159* for discussion of the terminal limitations and 75°C lookup).

The second half of 690.8(B) is required to confirm the conductor chosen in (B)(1) has enough ampacity when exposed to the conditions of use for that circuit. The conditions of use will be the temperature the conductors are exposed to, as well as the number of conductors in the raceway. There are

Independent Source Circuits



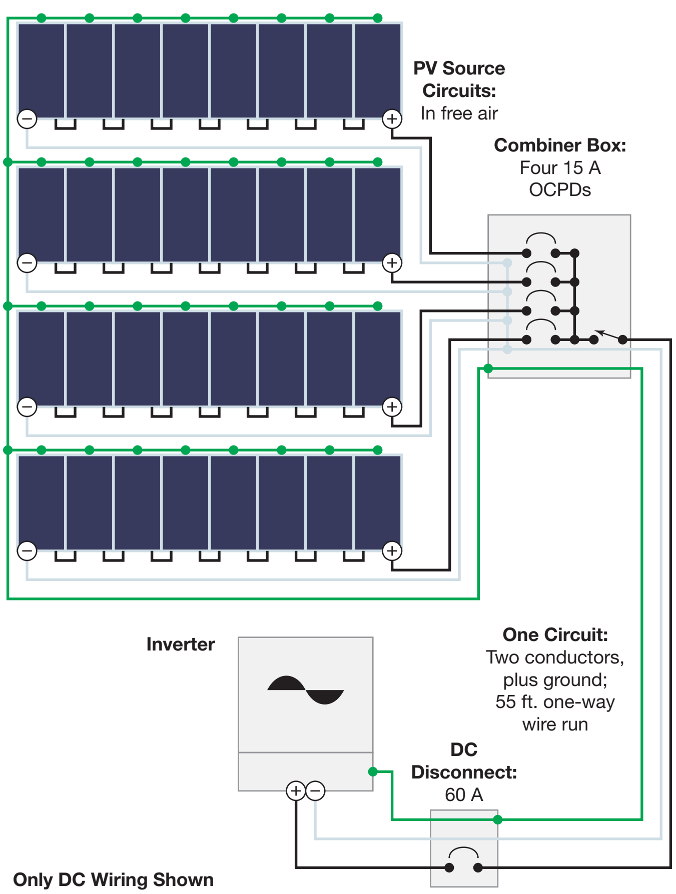
three different temperature conditions the circuit is exposed to: rooftop, attic, and building interior. Section 310.15(A)(2) requires that "where more than one ampacity applies for a given circuit length, the lowest value shall be used." This means, based on the general rule, we are required to use the circuit section exposed to the highest temperature to determine the proper conductor sizing.

Reading 310.15(A)(2) in its entirety reveals an interesting exception when two different ampacities apply to adjacent portions of a circuit. If the condition that results in the conductor's lowest ampacity is no greater than 10 feet and not more than 10% of the total circuit length, we are allowed to use the higher ampacity (lower temperature) calculation. This is due to the ability of the circuit to dissipate the heat for the relative short run through the higher-temperature location.

This exception affects the example if the rooftop raceway is run for a length less than 10 feet and that distance is also less than 10% of the total circuit. Our example total circuit length is 55 feet, and the exposed rooftop raceway is 9 feet, so we cannot apply the exception. Our lowest ampacity condition will be in the rooftop raceway section.

To confirm that the conductor has the appropriate ampacity under conditions of use per 690.8(B)(2), apply the correction factors (listed above) to the conductor's actual ampacity from the 90°C column:

Rooftop Combiner



- 25 A 90°C ampacity × 0.71 Table 310.15(B)(2)(A) correction factor × 0.7 Table 310.15(B)(3)(a) factor = 12.4 A

Using 14 AWG is permitted because the ampacity with conditions of use applied is greater than the Imax value. The final step is to consider the overcurrent protection devices (OCPDs) and verify that the conductors will be properly protected. Since there are more than two source circuits, the exception in 690.9(A) won't apply; OCPDs will be required. The minimum size will be calculated as:

- 690.9(B): Imax × 1.25 = 14.5 A; so the OCPD size will be 15 A.

But will the 14 AWG conductors be properly protected by a 15 A fuse? Article 240, as referenced by 690.9, provides allowances for an OCPD rating greater than the conductor's ampacity. In this case, the conditions of 240.4 are met, so a 15 A OCPD is allowed. Even with relatively strict applications of correction factors, a 14 AWG conductor would still be considered *Code*-compliant for this installation.

Rooftop Combiner

For this example, a rooftop combiner box is installed in place of the junction box. *NEC* requirements such as fuse servicing and disconnecting requirements make this less common in residential applications; but it's more common in commercial installations. We size the two current-carrying conductors leaving the rooftop combiner and running into the inverter's DC disconnect.

- 690.8(A)(2): Imax = 4 x 9.28 x 1.25 = 46.4 A
- 690.8(B)(1): Icont. = 46.4 A x 1.25 = 58 A; means 6 AWG copper
- 690.8(B)(2): 75 A x 0.71 x 1.00 = 53.25 A; which is greater than 46.4 so 6 AWG works.

Finally, if an OCPD is used in the output circuit, confirm the required size and verify the conductor's ability to carry the current:

- 690.9: 46.4 A x 1.25 = 58 A; so a 60 A OCPD required
- Per 240.4, a conductor with 53.25 A of ampacity is properly protected by a 60 A OCPD; again, 6 AWG is OK.

With practice and patience, understanding the rationale behind the calculations and the calculations themselves will become easier.

web extras

See "PV Circuit Sizing" in *HP159* for a discussion of the terminal limitations and 75°C lookup • **homepower.com/159.88**.

See "PV Overcurrent Protection" in *HP161* for discussion of sizing overcurrent protection • **homepower.com/161.76**.

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Evie: A Retired Golf Pro's New Country Life

by Kathleen Jarschke-Schultze

Our homestead's remoteness—and the need for all-wheel-drive to get here—has kept us from pursuing an electric vehicle (EV) for to-town transportation. But for years, I've wanted, craved, and sought an electric golf cart—not for golf, but for light hauling from one end of our barony to the other.

In the Rough

We live in the mountains, so our property is not level in most places. The parts that are flat are used for our gardens. We have three—the upper, main, and lower—and there is a fair amount of light hauling that takes place between the three, especially when we're preparing the beds for spring and during harvest in the fall. We have several contractors' wheelbarrows—you know, the deep metal ones—and a large garden cart that was my birthday present 29 years ago. As I have gotten older, though, it has become more of a chore to haul heavy loads in the 'barrows and cart. The uphill push is strenuous and the descent is downright scary.

A small electric golf cart, I surmised, would be just the ticket, since we could fuel it with excess electricity generated by our off-grid solar, wind, and microhydro system. I kept my eyes open for electric opportunities, and finally found one online for

Harry Martin

$350. I showed the ad to my husband, Bob-O, but he popped my balloon pretty fast, pointing out that the cart was a three-wheeled version that wouldn't work well on our sloped property.

I returned to my search. The cart had to be cheap, electric, and have *four* wheels. My possibilities were narrowing. Imagine my surprise when Bob-O came home from work one day and told me that a client had given his apprentice, Mike, a derelict electric golf cart.

They had been at a golf course to do a solar site survey and evaluation. As they were walking around, Mike spotted the golf cart, which was sitting off to the side of a building, with two flat tires. Obviously, it had not been used or running in awhile. When he asked about it, the client told him to take it if he wanted it. Eight months later, after the cart project still hadn't gotten traction at his house, Mike offered it to us.

Bob-O had been thinking about the cart and had a plan pretty well formulated for refurbishing it by the time he picked it up from Mike. He also named the cart—Evie, short for a "Little Electric Vehicle"—and wanted her name in script on her front panel.

Evie Playing Through

Years ago, Bob-O set up a racked 570-watt PV system on the southeast side of the shop specifically for keeping used deep-cycle batteries charged. So the first thing he did was to hook up Evie's motor to three old 12-volt batteries, which had been hanging out in the charging bay. The motor spun easily—both forward and in reverse. Now we knew we could get serious.

The two front tires were totally shot, so Bob-O moved the old, but still good, back tires to the front steering axle. Two new beefy, tractor-type tires went on the back drive axle. We also had to buy a new key for the cart as the original one was missing.

The cart was a very faded yellow with peeling daisy decals on the sides. Bob-O took the cart completely apart, cleaned it, did a little body work on the fiberglass body, and then sanded and painted the body Oregon Ducks green, a promise that had been made to the golf course owner. The final touch was a vinyl sticker of her name applied to the hood.

There was a wire basket next to where the golf clubs usually ride. I cleaned it and painted it white. Bob-O mounted it between the roof posts and behind the seat. It's handy for stowing gloves, bungee cords, a whisk broom, a hand towel, and whatever small tool we may need that day.

The old batteries just weren't up to snuff, so Bob-O bit the bullet and bought a matched set of six deep-cycle 6 V batteries. While he was still gnawing on that slug, he bought a small steel cargo bed made specifically for golf cart conversions. Turns out, converting golf carts into homestead workhorses is a popular idea. You can find just about anything you could think of for a cart conversion. He lined the bed with hard foam mats that lock together like puzzle pieces.

Par for the Greens

We have used Evie almost daily since Bob-O got it running—hauling hoses from one garden to another, and scooting seedlings from the greenhouse to gardens. We also use Evie to climb the hill to the main water tanks to check on them. It is quite a steep hill, and Evie slows to a crawl but keeps on climbing. We taught our Airedale dog to ride in Evie, but she prefers to run alongside.

I recently drove Evie down the 1.8 miles to the campground at the end of our road and sold free-range eggs from my chickens, honey from my bees, and whatever produce was ripe from the garden. All it cost me was a little prep time to make cardboard signs and get the produce arranged in ice chests in Evie's bed, and away I went.

The battery's state of charge was still high when I returned home. Evie could have easily made the trip twice and probably more—without recharging. Bob-O has set up Evie's recharging station under the shop-side array.

One fair spring evening we drove Evie out our pasture gate, beyond the fence, onto open range. We had seen one of the horse herds there earlier in the day. Horses can be very cooperative in supporting gardening efforts, since they tend to poop in the same place as other horses. We drove around and were able to fill Evie's bed with horse manure in no time.

Bob-O made my electric vehicle dream come true. We are always finding ways that Evie can work for us, making our homestead run a little smoother and safer. What did I do without one?

Kathleen Jarschke-Schultze

Evie the utilicart, at the charging station.

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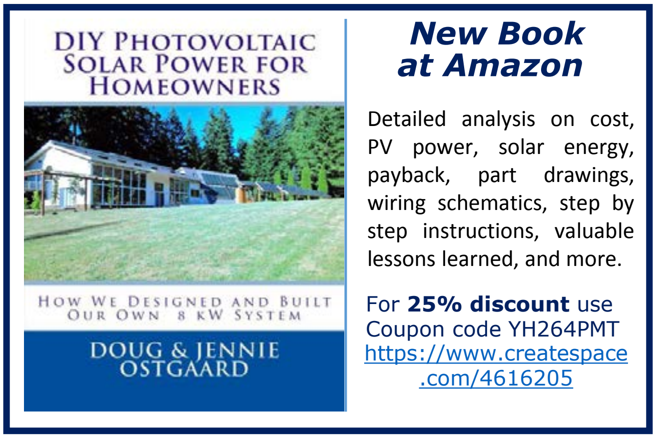

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Is Your Home Leaking Energy & Money?

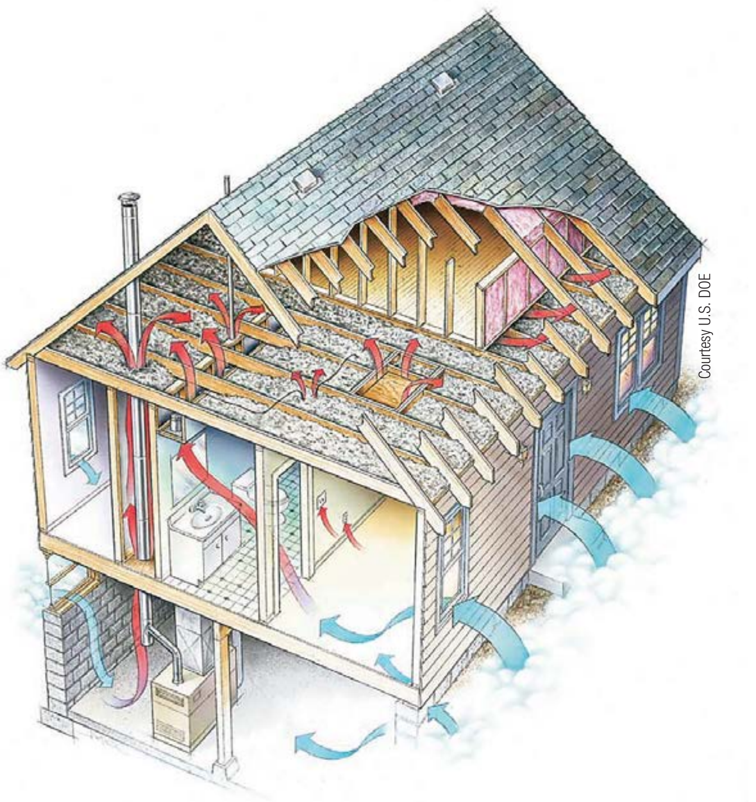
The U.S. Environmental Protection Agency estimates that homeowners can typically save 10% to 20% of heating and cooling costs (or up to 10% of a home's total energy costs) by sealing their homes. The benefits of sealing to prevent air leakage are not only about energy and money, they include quality of life—the comfort and livability of your home.

It's more than just the cracks around your windows and doors that let drafts swirl through your home. Attic hatches, wiring holes, recessed lighting, and furnace flues allow your indoor and outdoor air to exchange more than it should. Additionally, patching gaps in insulation helps keep your energy and money, along with your climate-controlled air, from slipping through the cracks.

The Benefits of Sealing

Imagine leaving one window wide open in your house all year long. What effect would this have on your comfort? Failing to properly seal (and insulate) can be the equivalent of doing just that, or worse.

For individuals with sensitivity to dust, pollen, or other allergens, air quality might also be a big selling point for air sealing, since this strategy can be a more effective and longer-term fix than using air purifiers to improve indoor air quality. It is important, however, to make sure a well-sealed home is also well-ventilated so that off-gassing of chemicals from furniture, wood products, and cleaning agents doesn't pose a threat to indoor environmental quality.



Courtesy U.S. DOE

Air leaks let both cold air in and warm air out. Either way, it's energy and money out.

Ben Root

A blower-door test determines the amount of air infiltration a home has, expressed in air changes per hour (ACH).

Air sealing can also protect structural elements from damage—especially in high humidity areas, where outside moisture can cause rot by penetrating the home through openings like plumbing vents and wiring holes.

A certified professional home energy auditor (look for HERS or BPI certification) can help identify energy improvements, and is the best bet for getting a thorough home energy audit. These professionals will use a blower door test to measure the airtightness of the building. To test this on one's own, the do-it-yourselfer can place a candle near a window and watch for a flicker, or walk the perimeter of the home with lit incense, paying attention to vents, doors, and windows, to see if the smoke gets siphoned through any cracks. If a leak is detected, air-sealing is the answer. Whether for energy savings, money savings, property value, indoor air quality, or comfort, air sealing is an important part of the home improvement and maintenance process.

—Martin Smith

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